Wages and job vacancy durations: Evidence from a spatial discontinuity

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Abstract

We estimate the causal effect of advertised wages on vacancy durations using online job vacancy data for the UK’s National Health Service, one of the world’s largest employers. We exploit a sharp border discontinuity resulting from the fact that jobs within inner London receive a fixed 4% wage premium compared to jobs in outer London. We find a significant negative effect of offered wages on the length of time a position is advertised. This is consistent with the predictions of a directed search model with heterogeneous job seekers and exogenous wage setting.

I Introduction

The effect of advertised wage on how long a job vacancy takes to fill has significant implications for managers. If a firm can fill a vacancy faster by offering a slightly higher wage, it may be optimal to do so. However, heterogeneity in the characteristics of firms, workers and labour market conditions means that wages and vacancy length are endogenous. For example, a firm might both pay more and leave ads open for longer in order to attract more productive applicants or because it operates in a tighter labour market. Online job ads provide an ideal setting to test this relationship for three reasons. First, they provide information on how long a firm announces that a vacancy will remain open, as well as whether it closes the vacancy earlier than announced. Second, the adverts contain the offered wage, not the actual wage earned by a given worker, and therefore provide an ex ante measure of what the firm expects to pay a new hire, which is unaffected by the ability of the specific worker that is hired. Third, the data provide rich data on the vacancies posted by specific organisations in specific locations and for specific roles, meaning that we can compare the effects of wage on vacancy duration within a single organisation, holding constant skill level and geographic area.
In this paper, we use data on vacancies at the UK’s National Health Service (NHS), taken from the job vacancy website findajob.gov.uk between April 2022 and April 2023. Due to the higher cost of living in and around London, the NHS pays a 15% wage premium for all jobs in outer London and a 20% wage premium for all jobs in inner London. We use a sharp regression discontinuity specification and estimate the causal effect of wage offers on vacancy duration by comparing vacancies in a narrow geographic band on either side of the inner/outer London border. The NHS is the world’s seventh largest employer (Statista 2022), meaning that we are able to assemble a large sample of vacancies. We find that vacancy durations are 7.1% lower in inner London than in outer London, controlling for job characteristics, location and distance to the border, implying an elasticity of vacancy duration with respect to wages that is greater than one in magnitude.

We contribute to the literature by providing a test of the competing predictions from theoretical models regarding the direction of the relationship between wages and vacancy durations. However, we also provide a policy prescription for the NHS. It is regularly claimed that the NHS is understaffed (The Health Foundation 2019, Rivett, Morgan 2022, Health and Social Care Committee 2022). As of September 2021, the NHS had 99,460 vacant positions and a job vacancy rate of 12% for nurses and 8% for doctors (Health and Social Care Committee 2022). Labour shortages in the NHS contribute to poorer health outcomes and a less effective health service, reflected by fact that the NHS in England, at the time of writing, has a waiting list of almost 7 million people (Health and Social Care Committee 2022). Moreover, evidence suggests that labour shortages may increase physical and psychological pressures on the existing workforce (NHS Pay Review Body 2022) which could further reduce the ability of the NHS to retain staff and exacerbate the aforementioned challenges over time1. This issue is not unique to the United Kingdom. Across western countries, employment in health services has not kept up with the growth in demand resulting from aging populations and increasing expectations for healthcare from wealthy and more educated populations (Shields 2004). Search theory predicts that higher wages should attract more job applications and lead to shorter vacancy durations. This suggests that raising wages could alleviate labour shortages, at least in the short run (May et al. 2006). The quasi-governmental body responsible for setting NHS pay has acknowledged that raising wages could help retain workers and improve the mental well-being of staff (NHS Pay Review Body 2022). However, it has not mentioned the fact that higher wages could make it easier to fill existing vacancies and this contention has not been tested empirically.

The paper is structured as follows. In Section II we outline the current literature exploring the relationship between wages, the job filling rate and vacancy

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rates. In section III we discuss the institutional background, namely the structure of the NHS "band" system and the geographical borders of the High Cost Payment areas in London. In section IV we discuss the predictions from theory and present a framework that introduces homogeneous firms and exogenous wage setting into Shimer's (2005) directed search model with heterogeneous job seekers, to fit the structure of the NHS. In sections V and VI we describe the dataset and the methodology, respectively, before outlining the empirical results in section VII. We conclude in section VIII.

II Literature Review

Our work relates to studies which have examined the relationship between wages and the number of applications a job receives, the vacancy duration and aggregated vacancy rates. Labour market search models have been employed extensively in the literature for the purpose of examining the relationship between wages and vacancy duration’s. In models of both directed (Moen, 1997) as well as random (Burdett & Mortensen, 1998) search, firms face a trade-off between wage and search costs. In directed search, firms post wages where higher wages attract more applicants, mitigating the cost of the firms search. In random search models such as McCall (1970), a higher wage increases the likelihood that the offered wage, which is drawn according to some probability distribution, exceeds the reservation wage. Therefore under both random and directed search, traditional theory would predict a negative relationship between starting wages and the duration of a vacancy.

Multiple studies have tested whether the negative relationship between wages and vacancy durations, implied by search theory, is observed empirically. Faberman & Menzio (2018) use data from the 1980 and 1982 waves of the Earnings and Opportunity Pilot Project Survey (EOPP) to examine the relationship between the starting wage, applications and interviews per week and the vacancy duration. They find that the starting wage is negatively related to the number of applications a vacancy receives and positively related to the duration of a vacancy. They recognise that this result contradicts traditional search theory and adapt a model of heterogeneous firms and jobs, first derived by Shimer (2005), to explain why, when firm heterogeneity is not adequately controlled for, this counter intuitive relationship can exist. Faberman and Menzio (2018) also concede that if they could control for heterogeneity to a greater extent then they would observe the negative relationship between wages and vacancy durations, as predicted by labour search theory.

Marinescu & Wolthoff (2020) assess the importance of wages posted on job posting websites in attracting applicants using data from CareerBuilder.com, an online job board, posting jobs across the US. The data set included information on the job title, wage, and the number of applications for each vacancy.
Controlling for a Jobs SOC code but not the job title, they found a negative relationship between a job’s wage and the number of applicants it attracts. However, after controlling for the much more detailed job title, they find that higher wages attract more applicants which would translate into lower vacancy durations. Kettemann, Mueiller, Zweimuller (2020) explore the relationship between wages and vacancy durations and applicant numbers using data from Austrian public labor market administration (AMS). They include a more sophisticated set of controls for worker heterogeneity than the studies mentioned previously. They also include establishment fixed effects to mitigate potential endogeneity resulting from the relationship between posted wages and establishment characteristics. They find a positive relationship between starting wages and vacancy durations in the raw data however, similarly to Marinescu and Wolthoff (2020), with sufficient controls for worker and firm heterogeneity, this relationship switches from positive to negative. Other studies that use online job vacancy data, such as Banfi and Villena-Roldán (2015) also find a negative relationship between vacancy durations and posted wages.

The finding of a negative relationship between wages and vacancy durations is also consistent with that of Belot, Kircher and Muller (2018). They employ an experimental ‘audit study’, in which unemployed job seekers were asked to search for jobs under laboratory conditions. The researchers created their own job searching website using vacancies from Universal Job match. They then presented job seekers with pairs of similar vacancies with different, randomly assigned wages. Each job seeker was free to ‘save’ jobs if they were interested in applying. They find that high wage vacancies attract a higher number of saves, suggesting that a 1% increase in the wage results in 0.7% to 0.9% increase in the number of saves. However, they also find that 42% of those that save for low-wage vacancy also do not save the high-wage vacancy. This is consistent with the trade-off between higher wages and higher perceived competition for a job which can explain the positive relationship between wages and job vacancy duration’s observed in the studies mentioned. Belot, Kircher and Muller (2018) produce a directed search model with multiple applications and on-the-job search, calibrated with UK data, which reproduces the negative relationship they observe in their empirical results. These findings are also consistent with the findings of Holzer (1990) who, using the EOPP 1982 data, find that firms that pay the minimum wage receive more applicants than firms that pay a markup against the minimum wage.

The methodology in this article varies from those referenced above. The literature we mention focuses on establishing the relationship between wages and hiring outcomes in the context of heterogeneous agents and firms. We mitigate the effect of heterogeneous jobs by exclusively using data from the NHS, which has strict conditions for pay progression. Therefore the menu of jobs available to job seekers are essentially homogeneous. This proposes a different way to mitigate endogeneity without the use of sophisticated industry and job
specific heterogeneity controls which are often difficult to attain. The result also has implications for labour shortages in the NHS which effect aggregate health outcomes in the United Kingdom.

### III Institutional Background

It is government policy that those that work for the NHS, in and around London, are entitled to an additional High-Cost Area Payment (HCAP) as a percentage of their base salary. This is to account for the higher cost of living in and around the Greater London Area. NHS staff working in fringe, outer or inner London are paid an additional 5%, 15% and 20% on top of their base salary respectively. The geographical boundaries of London HCAP areas are defined by the 2005 Primary Care Centre (PCT) zones, included in the NHS Terms and Conditions (NHS, 2023). The areas included in each zone are are listed in Table 1. The hospitals in each area are plotted on a map of Greater London. All independent, private and specialist hospitals in the London area are excluded. The map is shown in figure 1. The hospitals are colour coded according to the PCT Zone in which they are located. Notably, we label each hospital as red, blue, green.

<table>
<thead>
<tr>
<th>Inner London</th>
<th>Hammersmith &amp; Fulham, Kensington &amp; Chelsea, Westminster, Camden, Islington, City &amp; Hackney, Tower Hamlets, Lambeth, Lewisham, Southwark</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCAP = 20%</td>
<td>Brent, Ealing, Harrow, Hillingdon, Hounslow, Barnet, Enfield, Haringey, Barking &amp; Dagenham, Havering, Newham, Redbridge, Waltham Forest, Bexley, Bromley, Greenwich, Croydon, Kingston, Richmond &amp; Twickenham, Sutton &amp; Merton</td>
</tr>
<tr>
<td>Outer London</td>
<td>Basildon, Dartford, Gravesham &amp; Swanley, Billericay, Brentwood &amp; Wickford, Epping Forest, Harlow, Thurrock, Dacorum, Hertsmere, Royston, Buntingford &amp; Bishop Stortford, Southeast Hertfordshire, St Albans &amp; Harpenden, Watford &amp; Three Rivers, Welwyn &amp; Hatfield, Bracknell Forest, Slough, Windsor &amp; Maidenhead, Wokingham, East Elmbridge &amp; Mid Surrey, East Surrey, Guilford &amp; Waverly, North Surrey, Surrey Heath &amp; Woking</td>
</tr>
<tr>
<td>HCAP = 15%</td>
<td>Brent, Ealing, Harrow, Hillingdon, Hounslow, Barnet, Enfield, Haringey, Barking &amp; Dagenham, Havering, Newham, Redbridge, Waltham Forest, Bexley, Bromley, Greenwich, Croydon, Kingston, Richmond &amp; Twickenham, Sutton &amp; Merton</td>
</tr>
<tr>
<td>Fringe London</td>
<td>Basildon, Dartford, Gravesham &amp; Swanley, Billericay, Brentwood &amp; Wickford, Epping Forest, Harlow, Thurrock, Dacorum, Hertsmere, Royston, Buntingford &amp; Bishop Stortford, Southeast Hertfordshire, St Albans &amp; Harpenden, Watford &amp; Three Rivers, Welwyn &amp; Hatfield, Bracknell Forest, Slough, Windsor &amp; Maidenhead, Wokingham, East Elmbridge &amp; Mid Surrey, East Surrey, Guilford &amp; Waverly, North Surrey, Surrey Heath &amp; Woking</td>
</tr>
<tr>
<td>HCAP = 5%</td>
<td>Brent, Ealing, Harrow, Hillingdon, Hounslow, Barnet, Enfield, Haringey, Barking &amp; Dagenham, Havering, Newham, Redbridge, Waltham Forest, Bexley, Bromley, Greenwich, Croydon, Kingston, Richmond &amp; Twickenham, Sutton &amp; Merton</td>
</tr>
</tbody>
</table>

Table 1: London Boroughs included in High Cost Payment Areas (NHS Terms and Conditions of Service Handbook, 2023)
Figure 1: Hospitals in London. Red, Blue, Green and Magenta dots denote hospitals in inner, outer, fringe and non London respectively.
and purple for the inner, outer, fringe and non-London zones respectively.  

In pursuing this analysis, it is also important to understand the structure that defines wages for workers in the NHS. To ensure fairness and non-discriminatory practice, workers in the NHS are paid according to a band system. The system has eight bands, from Band 2 to Band 9, with Band 2 being the lowest and Band 9 being the highest. Band 1 was closed to new applicants on the 1st of December 2018. Each job in the NHS falls into a particular band which is bounded by a minimum and maximum salary range. These bounds are defined in the NHS Handbook (2023). Within this range, workers have a set period of time before they can be considered for a pay rise in their band. Therefore, there is some variance within pay bands, resulting from individual differences in experience. The band is determined by the responsibilities, skills, and experience required for the job. Band 2 jobs are typically entry-level positions that require little or no experience or qualifications as a domestic support worker, housekeeping assistant, driver, and nursery assistant. Band 3 jobs typically require some experience or qualifications, such as emergency care assistant, trainee clinical coder, estates officer and occupational therapy support worker. Band 4 jobs require more experience and qualifications, such as assistant practitioner, audio visual technician, pharmacy technician, dental nurse, and theatre support worker. Band 5 jobs are often roles that require a degree or equivalent qualification, such as nurses or paramedics. Band 6 jobs require a higher level of responsibility and expertise, such as specialist nurses or physiotherapists. Band 7 jobs are managerial or advanced practice roles, such as specialist nurses or physiotherapists. Band 8 is decomposed into 4 separate bands; 8a,8b,8c,8d. The included jobs are senior managerial roles, such as director of nursing or consultant physiotherapist. Band 9 jobs are the highest level of responsibility and expertise, such as medical director or consultant in a specialised field.

### IV Theoretical Motivation

As outlined in section II, the current literature suggests that, when econometric specifications can not adequately control for job heterogeneity, a positive relationship exists between wages and vacancy durations. We summarise Faberman and Menzio’s (2018) explanation for the positive relationship they observe. Their model uses a framework first derived by Shimer (2005). Consider a sample of heterogeneous firms, each with a single job vacancy, where some firms are ‘sensitive’ and other firms are ‘regular’.  

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2We describe areas not included in inner, outer, fringe zones as described by the 2005 NHS PCT zones as “non”. Workers employed at these hospitals in this area are not entitled to the HCAP.

3Note that because each firm in the model has only one job, we use the term ”job” and ”firm” interchangeably.

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comprised of high or low productivity workers. Such heterogeneity may result from differences in work ethic, innate ability, interpersonal skills and other personality characteristics (Cubel et al., 2016). Sensitive firms benefit more from hiring a high-productivity worker, relative to hiring a low-productivity worker than regular firms. Therefore, the sensitive firms post higher wages to attract a better pool of applicants. This also has the effect of reducing the probability that low-productivity applicants will apply to sensitive firms since they are less likely to be hired given the large pool of high-productivity applicants. If low productivity workers produce less output at sensitive firms than they do at regular firms, Faberman and Menzio (2018) show that this manifests in an equilibrium where sensitive jobs, that pay a higher wages, have fewer applications and longer vacancy duration’s. Empirical work using vacancy data from heterogeneous firms and not control for firm heterogeneity will therefore observe this relationship. However Faberman and Menzio recognise that if they could control for ‘sensitive’ or ‘regular’ jobs then the empirical relationship between wages and vacancy durations would be negative.

However we argue that, by analysing data from a single establishment with strict pay progression requirements, one should observe a negative relationship between wages and vacancy durations, even in the absence of sophisticated job title controls. We adapt the model described above to fit the structure of the NHS. Firstly we introduce exogenous wage setting by firms to replicate the band system which is centrally defined by the UK government. This differs from Faberman and Menzio who consider firms that set wages endogenously to maximise the probability of attaining a high productivity worker. Similarly we simplify Faberman and Menzio’s model by considering jobs to be homogenous. This means that we remove job seekers choice between ‘regular’ and ‘sensitive’ jobs. This is because the NHS band system ensures that job vacancies available to workers is strictly defined according to an individual’s qualifications and experience. For example, a band 5 nurse can only apply to positions in band 5 if they don’t have the qualifications or experience to move to band 6. Each band only includes ‘regular’ or ‘sensitive’ firms, but not both. This naturally negates the heterogeneity of jobs available to workers in other professions. Therefore, while there exists some heterogeneity between band 5 nurses, the heterogeneity in the jobs available to them is negated. In the context of Faberman and Menzio’s argument above, this means that individuals within a particular band do not have the option to apply to either a sensitive or regular job. The choice they make is strictly defined by their band.

First consider a number \( v_j \) of firms \( j \) who can be either type \( j = \{1, 2\} \). These types are identical in nature in terms of their level of relative productivity. Each firm offers a single job, within a given band \( b \), which is identical for firm 1 and 2. Firm \( j \) produces \( y_{ij} \) output when it employs job seeker \( i \). There exists \( \mu_i \) number of risk-neutral job seekers who are unemployed and can apply to one job each. Each job seeker \( i \) is of type \( h \) or \( l \) such that \( i = \{h, l\} \). We assume
that workers of type \( h \) are more productive than type \( l \) when working for firm \( j \), \( y_{jh} > y_{jl} \). Job seekers of type \( i \) derive utility from their wage \( w_i \). Meanwhile a of firm type \( j \)'s payoff is equal to their output \( y_{ij} \) less the wage they pay \( w_i \) to the worker. We simplify the analysis by presuming the existence of a single firm of each type such that \( v_j = 1 \) \( \forall j \in \{ l, h \} \).

The structure of the directed search is as follows. Both firms wages are set exogenously \( \bar{w}_j \) by some, non utility maximising, social planner. We assume that \( \bar{w}_1 > \bar{w}_2 \). For this purpose think of firms 1 and 2 to be analogues of hospitals in inner and outer London respectively. Workers observe the posted wages by firms and choose the probability that they apply to firm 1 or firm 2 respectively. Once applicants apply, firms select their preferred applicant. If the firm receives multiple applicants of type \( h \) then they select one from random while simultaneously, discarding all applicants of type \( l \). If either firm only receives applicants from job seekers of type \( l \) then it selects one randomly. If the firm receives no applicants then they hire no workers.

A job seeker of type \( i \) applies to the job \( j \) with a probability \( p_{ji} \). Therefore the number of applications a firm \( j \) receives from seeker \( i \) follows a Poisson distribution with an average:

\[
q_{ji} = p_{ji} \mu_i
\]  

Using Bayes’ rule we therefore express the expected utility of seekers of type \( h \), \( u_h \) and type \( l \), \( u_l \) as:

\[
u_h = p_{1h} \left( \frac{1 - e^{-q_{1h}}}{q_{1h}} \right) \bar{w}_1 + p_{2h} \left( \frac{1 - e^{-q_{2h}}}{q_{2h}} \right) \bar{w}_2
\]

\[
u_l = p_{1l} \left( \frac{e^{-q_{1l}}(1 - e^{-q_{1l}})}{q_{1l}} \right) \bar{w}_1 + p_{2l} \left( \frac{e^{-q_{2l}}(1 - e^{-q_{2l}})}{q_{2l}} \right) \bar{w}_2
\]  

The job seeker \( i \) aims to maximise their expected utility subject to:
A job seeker of type \( i \)'s expected utility is increasing in \( p_{ij} \) such that their preferences are monotonic. Therefore finding the first order conditions with respect to the respective probabilities is sufficient for optimality. Solving the first order conditions with respect to \( p_{ij} \) it can be shown that:

\[
\ln(\bar{w}_1) - \ln(\bar{w}_2) = p_{1h}\mu_h - p_{2h}\mu_h
\]

As the wages \((\bar{w}_1, \bar{w}_2)\) are exogenously defined, such that \( \bar{w}_1 > \bar{w}_2 \), one can deduce that for \( \bar{w}_j > 0 \), \( p_{1h} > p_{2h} \) and \( p_{1l} = p_{2l} \). Therefore given that the average number of applications for firm \( j \) is given by (1) it follows that:

\[
q_{1h} + q_{1l} > q_{2l} + q_{2h}
\]

This implies that the average number of applications for firm 1 is greater than it is for firm 2. While this model is static, it is intuitive that a higher number of job applications implies a lower vacancy duration. Notably this result occurs because the high wage firm attracts higher volumes of high productivity workers than the low wage firm, while attracting the same number of low productivity workers as firm 2.

Therefore a directed search model with homogenous jobs and heterogeneous agents with exogenous wage setting suggests that there exists a negative relationship between the starting wages of a job and vacancy duration. The implications of the model above are consistent with the heterogeneous directed search literature which suggests that higher wages can be used by firms as a mechanism to attract higher skilled workers Faberman and Menzio (2018). Therefore offering higher wages may be a convenient tool for firms to reduce vacancy duration’s and attract applicants of a higher calibre. This may provide evidence to suggest that the NHS could use wages as a means to increase the number of applicants to vacant positions and reduce labour shortages in the short run.

\[\sum_{j \in \{1,2\}} p_{ji} = 1 \] (4)

V Data

This research draws on weekly data, we collected, from the online job vacancy service findajob.gov.uk. The job posting website is managed by the Department for Work and Pensions (DWP) and allows firms of any UK company to advertise their vacant positions, while simultaneously providing job seekers with a free access medium to search for jobs. The service allows firms to detail to their job advertisement by including a job title, job description, location and salary. This

\footnote{A proof in included in the appendix}
helps job seekers find work quickly and easily, mitigating some costs associated with the search process for both firms and job seekers. An example advert is included in the appendix. This data set provides utility for the primary reason that it includes a wide range of variables that would prove useful to the analysis that is unavailable in conventional survey data. In addition to standard variables such as the wage rate and the job role, the vacancy data includes the exact job description, the number of hours worked, the precise geographic location of the job and the date of posting. As such this novel set of data provides a higher level of insight into the impacts of wages on the labour market than other data sets such as the Labour Force Survey, Annual Survey of Hours and Earnings or the Apprentice Pay Survey. This data is increasingly relevant in a world where more workers than ever are using the Internet as a means to search for jobs. (Kuhn & Mansour, 2013).

The data set includes data from 2020. However we narrow this time period to April 2022 to April 2023, as this sample period corresponds to the NHS financial year, during which the pay assigned to each band in the NHS remained fixed. This time period was also selected to mitigate the distortionary effects of Covid-19 lockdowns and the resulting social distancing measures during the preceding financial years 20-21 and 21-22. During these years there were regional lockdowns imposed which may have effected the results in ways that could not be controlled for.

The data collected from findajob.gov.uk includes all job vacancies posted during the sample period on the website in the UK. Therefore the data set is not exclusively comprised of NHS jobs. However the NHS makes up a significant proportion of job vacancies on the website. To aid in the robustness of this analysis we only consider hospitals in inner and outer London, as hospitals are poorly distributed along the outer-fringe and fringe-non borders. The location of each job posting was derived using the postcode variable included in the data set. The postcode of each hospital in the sample area was collected and cross referenced with the job vacancies postcode. All of the included hospitals are included in appendix C. From the collected data, we use the job title, posted wage, date the vacancy was posted and closed, name and postcode of the employer, and job description. In all NHS job postings the salary is given as a range. For example a job posting could have a posted wage range £32000 - £36000. We take the midpoint of the salary range and report it as the posted wage.

The posted vacancy duration, measured in days, $\tau_i$ was calculated using the opening date of a vacancy $\tau_o$, the date it was scraped $\tau_s$ and its closing date $\tau_c$. $\tau_c$ is predefined by the employer and is specified the job advert. Therefore

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5 The pay range assigned to each band changes each financial year to account for changes in the cost of living. Therefore using other weeks of data would reduce the robustness of the analysis.
using $\tau_c - \tau_c$ is not sufficient to calculate $\tau_i$. For this reason we adjust the dependent to account for vacancies that are removed from the website before the predefined closing date, presumably because the vacancy was filled. Job adverts were collected weekly and the latest version of the vacancy was kept. For example if the same vacancy was collected on on the 1st, the 8th and 15th of January, only the vacancy on the 15th is kept. Therefore if $\tau_c - \tau_s > 7$ then it can be deduced that the vacancy was closed early. For this reason we define $\tau_i$ as follows:

$$
\tau_i = \begin{cases} 
\tau_s + 7 - \tau_o & \text{if } \tau_c - \tau_s > 7 \\
\tau_c - \tau_o, & \text{otherwise}
\end{cases}
$$

We identify the band of a particular job vacancy by cross referencing the exogenous minimum and maximum wages associated with each band with the posted wage. While we would have preferred to procure this information from the job description, the inclusion of the band of a vacancy was too infrequently included in the data. The construction of this variable should pose no problem to the analysis however since it is legally mandated that workers are paid according to a centrally determined pay scale.

In table (2) we outline the summary statistics, including the sample mean and standard deviation of the starting wage and job posting durations.
<table>
<thead>
<tr>
<th>Sample Mean</th>
<th>Standard Deviation</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacancy Duration (Days)</td>
<td>11.49</td>
<td>8.74</td>
</tr>
<tr>
<td>Starting Wage (£)</td>
<td>42333.53</td>
<td>11218.26</td>
</tr>
<tr>
<td>Band 2</td>
<td>0.056</td>
<td>0.234</td>
</tr>
<tr>
<td>Band 3</td>
<td>0.048</td>
<td>0.241</td>
</tr>
<tr>
<td>Band 4</td>
<td>0.066</td>
<td>0.249</td>
</tr>
<tr>
<td>Band 5</td>
<td>0.227</td>
<td>0.419</td>
</tr>
<tr>
<td>Band 6</td>
<td>0.255</td>
<td>0.436</td>
</tr>
<tr>
<td>Band 7</td>
<td>0.225</td>
<td>0.417</td>
</tr>
<tr>
<td>Band 8a</td>
<td>0.077</td>
<td>0.266</td>
</tr>
<tr>
<td>Band 8b</td>
<td>0.025</td>
<td>0.158</td>
</tr>
<tr>
<td>Band 8c</td>
<td>0.011</td>
<td>0.103</td>
</tr>
<tr>
<td>Band 8d</td>
<td>0.005</td>
<td>0.073</td>
</tr>
</tbody>
</table>

Table 2: Summary Statistics (n=35922)

The average duration of a vacancy posting was approximately 11.49 days with a standard deviation of 8.74. Furthermore the average annual salary posted in the job advert was £42333.53. In figure (2) we show the proportion of job vacancies in each band for both inner and outer London. The proportions of each band in both inner and outer London are similar. Band 5, 6 and 7 make up the vast majority of job postings, at approximately 20% to 25% of all postings for each band in inner and outer London. We exclude vacancies for band 9 positions as the data set only includes vacancies for this band in inner and not outer London during the sample period.
VI Methodology

We utilise the data scraped from findajob.gov.uk between April 2022 and 2023, and the sharp border discontinuity resulting from London HCAP areas to estimate the causal effect of posted wages on vacancy durations. Consider two hospitals either side of the inner-outer border that are geographically close. The two hospitals should operate under similar socioeconomic conditions. Notably one would assume that factors such as the cost of living, labour market tightness, geographical mobility and demand for NHS services are similar. If it is the case that the average vacancy duration is different on for hospitals either side of the border, controlling for other factors, then one can deduce that the exogenous increase in the posted wage resulting in the difference in the HCAP in inner and outer London could act as a mechanism to influence vacancy duration’s. This analysis is particularly pertinent given the excellent transport links in London which mitigates geographical immobility’s that could otherwise invalidate the result. Therefore this acts as a natural experiment which can be used to mitigate potential endogeneity resulting from the relationship between job posting lengths and local labour market conditions.

This methodology is closely aligned with Greaves, Sibieta (2014) who use the existence of London HCAP zones to estimate the causal effect of teacher pay
on pupils’ educational outcomes as measured by KS2 Maths and English scores. They find that differences in centralised pay scales do translate to differences in actual teacher pay. This gives credence to the use of a sharp border discontinuity design. We consider each of these issues in our analysis of NHS staff and vacancy durations.

For this analysis to be valid it must be the case that the difference in centrally determined pay scales translate into differences in actual wages for NHS workers. We create a continuous variable \( \text{Distance}_i \), which tracks the distance in meters from each identified hospital to the inner-outer London border.\(^6\) The variable takes a value of zero at the border, is negative for inner London and positive for outer London. We plot the posted wages against the distance from the border in figure (4). Figure (4) demonstrates the sharp discontinuity relating to High Cost Payment Areas in London for bands 2 to 8b. In figure (5) we plot the duration of job vacancies against the distance from the inner-outer border in figure (5) for each band. Note that in figure (4) posted wages drop sharply from those advertised at hospitals in inner London to hospitals in outer London, as represented by the orange and blue dots respectively. This shows that the difference in the HCAP in both inner and outer London do translate into actual wages for NHS staff in each specified band. This gives credibility to the sharp border discontinuity approach we utilise in section VII.

Using the job posting data and the distance to the inner-outer border, we run a simple linear regression model to estimate the relationship between the posted wage and the expected duration of a vacancy. Consider a set of job vacancies \( N \) with a sample size of \( n \). We denote an individual job vacancy as \( i \in N \). We define the dependent variable as the natural logarithm of duration of a job posting in days \( \ln(\tau_i) \). We opt to express the dependent variable in logarithmic form to reduce the skew in the non transformed data, as well as to reduce the effect of outliers. The change in the distribution resulting from the logarithmic transformation of the vacancy durations is shown in figure (3).

\(^6\)This was derived using the ESPG:3034 coordinates of each hospital which was found using each hospitals postcode. QGIS software was then used to calculate the hospitals distance to the Inner-Outer border in meters.
We define a dummy variable $Inner_i$, which takes a value of one when a vacancy for a hospital is located in inner London and zero if the hospital is located in outer London. This is the treatment variable which is assigned according to the distance to the border. Therefore, we include the assignment variable $Distance_i$. To ensure that we are comparing hospitals close to one another we assign each hospital in inner and outer London to a specific area “segment”. The segments are defined by the Strategic Health Areas (SHA’s) as outlined in the NHS Terms and Conditions. The SHA’s are called North West London, North Central London, North East London, South East London and South West London. The segments span across inner and outer London and collectively include all the areas in both zones. To visualise this segmentation approach, we plot the included hospitals in London on a map in figure (6). The hospitals colour coded blue, red, orange, green and pink are located in the North West, North Central, North East, South East and South West London SHA respectively.

<table>
<thead>
<tr>
<th>North West London SHA</th>
<th>Hammersmith &amp; Fulham, Kensington &amp; Chelsea, Westminster &amp; Brent, Ealing, Harrow, Hillingdon, Hounslow</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Central London SHA</td>
<td>Camden, Islington, Barnet Enfield, Haringey Brent, Ealing, Harrow, Hillingdon, Hounslow</td>
</tr>
<tr>
<td>North East London SHA</td>
<td>City &amp; Hackney, Tower Hamlets, Barking &amp; Dagenham, Havering, Newham, Redbridge, Waltham Forest</td>
</tr>
<tr>
<td>South West London SHA</td>
<td>Wandsworth, Croydon, Kingston, Richmond &amp; Twickenham, Sutton &amp; Merton</td>
</tr>
<tr>
<td>South East London SHA</td>
<td>Lambeth, Lewisham, Southwark, Bexley, Bromley, Greenwich</td>
</tr>
</tbody>
</table>

Table 3: PCT’s included in each SHA in Inner and Outer London (NHS Terms and Conditions of Service Handbook, 2023)

We describe a vector of dummy variables $Segment_i = (NW_i, ..., SW_i)$, each of which takes a value of one if vacancy $i$ is located in segment $j$ and zero otherwise.
Figure 4: Posted wages (£) against distance to the Inner-Outer London Border (m)
Figure 5: $\ln(\text{vacancy duration (Days)})$ against the distance to the Inner-Outer London Border (Meters)
Figure 6: Hospitals in the North West (Blue), North East (Yellow), North Central (Red), South West (Magenta), South East (Green) SHA’s
To control for seasonality trends in the labour market we also include a set of month dummies $Month_i = (January_i, February_i, ..., December_i)$ each of which takes a value of one if the vacancy $i$ was posted in that particular month and zero otherwise. We also describe a set of dummy variables $Band_i = (Band_{2i}, ..., Band_{8i})$ to control for the band of a particular job vacancy $i$.

We consider two approaches to deriving the causal effect of offered wages on vacancy durations. Firstly we run ordinary least squares using the vacancies starting wage as the dependent variable:

$$\ln(\tau_i) = \omega_0 + \omega_1 \ln(Wage_i) + \sum_{j=1}^{J} \phi_j Segment_{ji} + \sum_{t=1}^{T} \theta_t Month_{ti} + u_i$$  \hspace{1cm} (8)

The estimated coefficient $\hat{\omega}_1$ denotes the average causal effect of started wages on vacancy durations. However the validity of specification (8) relies on some strict assumptions that underpin linear estimation models (Greene 2020). Firstly the methodology requires that the independent variable of interest, in this case $Wage_i$ is exogenous such that $E[u_i|Wage_i] = u_i = 0$. Practically this requires that there are no factors, included in the error term, $u_i$ that are correlated with $Wage_i$. In this case the estimates of $\omega_1$ would be biased. Some factors that are not included in the specification include influences on workers demand for given hospitals. One such factor may be a hospitals workforce size, which is not controlled for. There is a chance that hospitals closer to the city center such as Guys, St. Thomas and Chelsea & Westminster Hospital have larger work forces. This is likely to translate into longer average vacancy durations. In this case $wage_i$ is likely correlated to a term included in the error term which also relates to $\tau_i$. This would result in upward bias in the $\hat{\omega}_1$ coefficient.

In recognition of this weakness, we also employ a sharp border discontinuity approach defined in equation (9).

$$\ln(\tau_i) = \beta_0 + \beta_1 Inner_i + \beta_2 Distance_i + \beta_3 (Distance_i \times Inner_i)$$

$$+ \sum_{b=1}^{B} \gamma_b Band_{bi} + \sum_{j=1}^{J} \phi_j Segment_{ji} + \sum_{t=1}^{T} \theta_t Month_{ti} + \epsilon_i$$  \hspace{1cm} (9)

Specification (9) is a canonical sharp border discontinuity approach which we describe in detail in the appendix. We include the $Inner_i \times Distance_i$ term to account for the varying effect of distance on vacancy durations in inner and outer London. We also consider the quadratic equivalent in specification 10.
\[ \ln(\tau_i) = \beta_0 + \beta_1 \text{Inner}_i + \beta_2 \text{Distance}_i + \beta_3 \text{Distance}_i^2 \]

\[
\begin{align*}
\beta_4 (\text{Distance}_i \times \text{Inner}_i) + \beta_4 (\text{Distance}_i^2 \times \text{Inner}_i) + \sum_{b=1}^{B} \gamma_b \text{Band}_bi + \sum_{j=1}^{J} \phi_j \text{Segment}_{ji} + \sum_{t=1}^{T} \theta_t \text{Month}_{ti} + \epsilon_i \end{align*}
\]

(10)

In both specifications (9) and (10) the coefficient on the \( \text{Inner}_i \), \( \beta_1 \) is of primary interest as it denotes the average treatment of the treated (ATT) of increases in annual wages on vacancy durations at the border, \( \text{distance}_i = 0 \). We include the entire sample for the estimation of (8) but limit the sample to hospitals within 1km of the inner-outer border for the estimation of (9) and (10). This is to improve the predictive power of the model by increasing the probability that hospitals in the analysis operate under similar economic conditions. This assumption is discussed in more detail in section VII.

We cluster the standard errors at the postcode level in all regressions. The reason for doing so is that \( \text{Distance}_i \) is treated as random however, once the hospitals location is fixed, the HCAP premium does not vary. This suggests that the use of clustered standard errors at the postcode level preferred to their robust counterparts.

VII Results

Table (4) shows the estimated coefficients of specifications (8), (9) and (10). We report the estimated coefficients of the regression (8) in column (1). The estimated coefficients of regression (9), excluding and including the set of band dummies, are reported in column (2) and column (3) respectively. In column (4) we show the estimates coefficients from specification (10) including all specified controls. All regressions include a set of segmentation and month dummies.

We first consider the results using the linear regression specification as outlined in specification (8). In column (1), when band controls are excluded, the estimated coefficient \( \hat{\omega}_1 \) is positive, with a coefficient of 0.147. This implies that a 1% increase in the starting wage predicts an increase in vacancy durations by approximately 0.15%. However, as previously explained, this naive approach could produce significant endogeneity in the \( \hat{\omega}_1 \) estimator.

We now consider the regression results using the sharp discontinuity design in equation (9). In this case the coefficient \( \text{Inner}_i \) is of primary interest as it describes the effect of moving from outer to inner London on expected vacancy durations. The only difference between vacancies in inner and outer London
is that the former pays a 20% markup against the base salary while the latter pays only 15%. Therefore the coefficient on \( \text{Inner}_i \) in table (4) represents the percentage change in the expected vacancy duration resulting from an increase in the starting wage of 4.34% at \( \text{Distance}_i = 0 \). In column (3) the coefficient on \( \text{Inner}_i \) is -0.151. This implies that a 4.34% increase in wages results in an average decrease in job vacancy posting duration by 14.9%. Therefore the "elasticity" of the vacancy duration with respect to the starting wage is approximately \(-3.43\). This result is large and statistically significant at the 1% confidence level. In column (3), when controlling for the band of particular job vacancy, the elasticity slightly weakens in magnitude but remains negative, changing from \(-3.44\) to \(-2.59\). The result result also remains statistically significant at the 1% level.

The estimated coefficients from the inclusion of the non linear \( \text{Distance}_i \) variable are shown in column (4). The inclusion of this variable allows us to capture non linear effects of distance on vacancy durations. The estimated effect of increasing wages by 4.34% on vacancy durations in this case is \(-7.1\%\). This translates into an approximate elasticity of \(-1.64\) which is much smaller than when the effect of distance on the vacancy duration is assumed to be linear. The inclusion of quadratic effects also produces an estimate that is significant at the 10% level.

The estimates coefficients in table 4 suggests that there exists large upward bias in the estimates when using linear OLS, as in specification (8). However this endogeneity is controlled for in column the sharp border approaches in column (2),(3) and (4). When using the sharp border discontinuity approach, the model replicates the relationship that is predicted by directed search theory. This is consistent with Marinescu & Wolthoff (2020) who find a positive relationship between wages and vacancy durations when job heterogeneity is not accounted for. They also find that the relationship turns negative when the adequate controls are included in their econometric specifications. This is also consistent with the directed search model presented in section IV.

However the sharp border discontinuity analysis cannot decipher whether there exists some reverse causality between the effect of wages on vacancy durations. It could be the case that, rather than the latter influencing the former, higher wages indicate that firms expect shorter vacancy durations. As a natural extension of these concerns, we hesitate to suggest that the results we present can be interpreted as causal. Rather we present these results simply as an empirical relationship. Further research could focus on these issues by establishing the validity of these concerns.

\footnote{To show this, consider a base salary \( x \). Workers in inner London earn \( 1.2x \) while workers in outer London earn \( 1.15x \). Calculating the percentage difference is \( \frac{1.2x - 1.15x}{1.15x} \times 100 \approx 4.34\% \).}
Dependent variable: ln(vacancy duration)

<table>
<thead>
<tr>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(Starting Wage)</td>
<td>0.147***</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>(0.022)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner</td>
<td>×</td>
<td>-0.149***</td>
<td>-0.115***</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.100)</td>
<td>(0.031)</td>
</tr>
<tr>
<td>Distance</td>
<td>×</td>
<td>-2.96×10^{-5}***</td>
<td>-2.50×10^{-4}***</td>
</tr>
<tr>
<td></td>
<td>(7.630×10^{-6})</td>
<td>(1.15×10^{-07})</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.775***</td>
<td>2.480***</td>
<td>2.392***</td>
</tr>
<tr>
<td></td>
<td>(0.233)</td>
<td>(0.008)</td>
<td>(0.020)</td>
</tr>
<tr>
<td>Inner × Distance?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Quadratic Distance Term?</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Inner × Quadratic Distance Term?</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Band Dummies?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Segmentation Dummies?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Month Dummies?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.021</td>
<td>0.022</td>
<td>0.030</td>
</tr>
<tr>
<td>Observations</td>
<td>35922</td>
<td>3912</td>
<td>3912</td>
</tr>
</tbody>
</table>

Table 4: Regression Outputs: Standard errors are clustered by postcode and are presented in parentheses. (***) (**) (*) denotes significance at the 1%, 5% and 10% confidence levels.

We evaluate the effect of increasing the distance from the border at which a hospital is eligible for inclusion for the border discontinuity approach in table (5). We estimate specification (10) with varying samples according to the hospitals distance from the border. Increasing the distance at which a hospital is included in the analysis by merely 250m produces estimates that are not significant at the 10% level. Moreover when the hospitals included in the analysis are less than or equal to 1.5km the estimates turn positive, albeit insignificant, indicating significant upward endogeneity. This suggests that the analysis is highly sensitive to this assumption, likely because of varying labour market conditions in different parts of London. For this reason we limit the distance to 1km as used.
in the derivation of the estimated coefficients in table (4). This improves the robustness of the model by ensuring that the probability that hospitals operate under similar economic conditions is maximised.

Dependent variable: ln(vacancy duration)

<table>
<thead>
<tr>
<th></th>
<th>1km</th>
<th>1.175km</th>
<th>1.25km</th>
<th>1.5km</th>
<th>1.75km</th>
<th>2km</th>
<th>3km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner</td>
<td>-0.071* (0.031)</td>
<td>-0.203*** (0.025)</td>
<td>-0.0967 (0.113)</td>
<td>0.162 (0.256)</td>
<td>0.171 (0.255)</td>
<td>0.019 (0.100)</td>
<td>0.026 (0.071)</td>
</tr>
<tr>
<td>Constant</td>
<td>2.733*** (0.307)</td>
<td>2.494*** (0.018)</td>
<td>2.371*** (0.032)</td>
<td>2.051*** (0.249)</td>
<td>2.042*** (0.249)</td>
<td>2.095*** (0.106)</td>
<td>2.12*** (0.070)</td>
</tr>
<tr>
<td>Inner × Distance?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Quadratic Distance Term?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Band Dummies?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Segmentation Dummies?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Month Dummies?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>3912</td>
<td>4871</td>
<td>5620</td>
<td>5979</td>
<td>6675</td>
<td>9689</td>
<td>13219</td>
</tr>
</tbody>
</table>

Table 5: Regression Outputs: Standard errors are clustered by postcode and are presented in parentheses. (***) (***) (*) denotes significance at the 1%, 5% and 10% confidence levels.

VIII Conclusion

The NHS has suffered with labour shortages since its inception (Rivett). This has adverse effects on health outcomes and the ability of the NHS to adequately accommodate increasing patient numbers. This paper utilised a sharp border discontinuity in London High Cost Payment Areas to analyse the effect of posted wages on the duration of the duration of vacancies. We find that differences in centrally determined pay scales translate into actual differences in wages for the NHS. We also find a significant negative relationship between posted wages and the duration of vacancies controlling for the band of job vacancies and seasonality. This result is consistent with the current literature when accounting for the strict pay structure of the NHS which only allows worker pay progression under strict experience and qualification conditions. We argue that this pay structure limits the variety of jobs available to workers in the NHS such that the jobs are essentially homogenous in the context of Shimer’s (2005) directed search.
model. In adapting Shimer’s (2005) model of heterogeneous agents with varying productivity by introducing homogenous firms who set wages exogenously, we find that our empirical results are consistent with the directed search theory. The model also predicts that increasing wages may also act as a mechanism to improve the composition of high-productivity applicants that apply to an open vacancy. However, we note that there exist some questions of endogeneity in the coefficient of interest. While we hesitate to characterise our empirical coefficients as causal these results may support the findings of the NHS pay review that increasing wages could act as a mechanism to relieve labour shortages and improve the quality of applicants and consequently improve health outcomes. Future research could assess the validity of our concerns relating to the methodology and improve on the econometric specification to more rigorously account for these issues.
IX Reference List


Morgan, B. (2022). NHS staffing shortages: Why do politicians struggle to give the NHS the staff it needs? The Kings Fund.


X  Appendix

A  Directed Search Model

In this section we prove that the decentralised solution in the model we present is characterised by equations (5) and (6) in the main text. Consider the expected utility of workers of type $h$ and $l$ as presented in equations (2) and (3). A job seeker of type $i$ chooses their mixed strategies $(p_{1i}, p_{2i})$ to maximise their expected utility, subject to the condition that the sum of these respective probabilities cannot exceed 1. First consider job seekers of type $h$ problem. Setting the Lagrange multiplier $L_i \forall i \in \{l, h\}$:

$$L_h = u_h + \lambda_h(1 - p_{1h} - p_{2h})$$  (11)

Taking the first order conditions of $L_h$ with respect to $(p_{1h}, p_{2h})$ and setting equal to zero yields:

$$\frac{\partial L_h}{\partial p_{1h}} = \frac{\partial u_h}{\partial p_{1h}} - \lambda_h = 0$$  (12)

$$\frac{\partial L_h}{\partial p_{2h}} = \frac{\partial u_h}{\partial p_{2h}} - \lambda_h = 0$$  (13)

This naturally implies that:

$$\lambda_h = \frac{\partial L_h}{\partial p_{1h}} = \frac{\partial L_h}{\partial p_{2h}}$$  (14)

Solving:

$$\frac{\partial u_h}{\partial p_{1h}} = \frac{\partial}{\partial p_{1h}} \left[ \frac{1 - e^{-p_{1h}\mu_h}}{\mu_h} \bar{w}_1 \right] = \bar{w}_1 e^{-p_{1h}\mu_h}$$  (15)

Using symmetry it follows that:

$$\frac{\partial u_h}{\partial p_{2h}} = \bar{w}_2 e^{-p_{2h}\mu_h}$$  (16)

Therefore using equation (12):

$$\bar{w}_1 e^{-p_{1h}\mu_h} = \bar{w}_2 e^{-p_{2h}\mu_h}$$  (17)

$$\ln \bar{w}_1 - p_{1h}\mu_h = \ln \bar{w}_2 - p_{2h}\mu_h$$  (18)

Rearranging expression (16) yields expression (6):

$$p_{2h}\mu_h - p_{1h}\mu_h = \ln(\bar{w}_2) - \ln(\bar{w}_1)$$

28
Now consider workers of type $l$. Analogous to workers of type $h$ they maximise their expected utility (4) subject to the probability constraint (5). Setting up the Lagrangian $L_l$:

$$L_l = u_l + \lambda_l (1 - p_{1l} - p_{2l})$$  \hspace{1cm} (19)

Taking the first order conditions of $L_l$ with respect to $(p_{1h}, p_{2h})$ and setting equal to zero yields:

$$\frac{\partial L_l}{\partial p_{1l}} = \frac{\partial u_l}{\partial p_{1l}} - \lambda_l = 0$$  \hspace{1cm} (20)

$$\frac{\partial L_l}{\partial p_{2l}} = \frac{\partial u_l}{\partial p_{2l}} - \lambda_l = 0$$  \hspace{1cm} (21)

This naturally implies that:

$$\lambda_l = \frac{\partial L_l}{\partial p_{1l}} = \frac{\partial L_l}{\partial p_{2l}}$$  \hspace{1cm} (22)

Solving:

$$\frac{\partial u_l}{\partial p_{1l}} = \frac{\partial}{\partial p_{1l}} \left[ e^{-p_{1h}\mu_h} (1 - e^{-p_{1l}\mu_l}) \right] = \bar{w}_1 e^{-p_{1h}\mu_h} e^{-p_{1l}\mu_l}$$  \hspace{1cm} (23)

Using symmetry it follows that:

$$\frac{\partial u_l}{\partial p_{2l}} = \bar{w}_2 e^{-p_{2h}\mu_h} e^{-p_{2l}\mu_l}$$  \hspace{1cm} (24)

Therefore using equation (20):

$$\bar{w}_1 e^{-p_{1h}\mu_h} e^{-p_{1l}\mu_l} = \bar{w}_2 e^{-p_{2h}\mu_h} e^{-p_{2l}\mu_l}$$  \hspace{1cm} (25)

$$\ln \bar{w}_1 - p_{1h}\mu_h - p_{1l}\mu_l = \ln \bar{w}_2 - p_{2h}\mu_h - p_{2l}\mu_l$$  \hspace{1cm} (26)

Rearranging expression (24) and substituting (6) yields expression (7):

$$p_{1l} = p_{2l}$$

B Sharp Border Discontinuity Approach

Assume we want to determine the effect of some treatment $D_i$ on a continuous variable $Y_i$. Consider a continuous variable $X_i$ which defines the individuals who are treated, denoted by $D_i$. Therefore $D_i$ is a deterministic function of $X_i, D_i = 1(X_i \geq c)$, where $c$ is the cutoff value.

Consider the linear relationship between $Y$ and $X$:
\[ Y_i = \beta_0 + \beta_1 D_i + \beta_3 X_i + \epsilon_i \]  
(27)

We can center the assignment variable at \( c \) using the specification:

\[ Y_i = \beta_0 + \beta_1 D_i + \beta_3 (X_i - c) + \epsilon_i \]  
(28)

We can therefore define:

\[ E[Y_i|D_i = 1, X_i = c] = \beta_0 + \beta_1 \]  
(29)

\[ E[Y_i|D_i = 0, X_i = c] = \beta_0 \]  
(30)

Therefore the average treatment effect at the border \( X_i = c \) is defined by:

\[ E[Y_i|D_i = 1, X_i = c] - E[Y_i|D_i = 0, X_i = c] = \beta_1 \]  
(31)

Note that in this case there is no interaction term. If we account for the varying effect of the \( X \) on \( Y \) according to \( D \). The specification can be written as:

\[ Y_i = \alpha_0 + \alpha_1 D_i + \alpha_2 (X_i - c) + \alpha_3 (X_i - c) \times D_i + \eta_i \]  
(32)

In this case \( \alpha_1 \) is the treatment effect at \( X_i = c \) since at \( X_i = c, X_i - c = 0 \).
C Included Hospitals

The following hospitals are included in the econometric analysis.

| Inner London | Camden Mews Day Hospital, Charing Cross Hospital, Chelsea and Westminster Hospital, Great Ormond Street Hospital, Guy's Hospital, Hammersmith & Fulham Mental Health Unit, Hammersmith Hospital, Homerton University Hospital, Hospital Of St John & St Elizabeth, Hospital Of St John & St Elizabeth, King's College Hospital, Lambeth Hospital, Lewisham Heather Close, Maudsley Hospital, Mile End Hospital, Queen Mary Hospital, Queen Mary's House, Royal Brompton Hospital, Royal Free Hospital, Royal Marsden Hospital, Springfield University Hospital, St Bartholomew's Hospital, St Charles Hospital, Mental Health Unit St George's Hospital, St Leonard's Hospital, St Mary's Hospital, St Pancras Hospital, St Thomas' Hospital, The Gordon Hospital, The Royal London Hospital, The Royal London Hospital For Integrated Medicine, The Royal Marsden Hospital (London), The Whittington Hospital, University College Hospital, University College Hospital at Westmoreland Street, University Hospital Lewisham |
| Outer London | Wanstead Hospital, Barking Community Hospital, Barnes Hospital, Barnet Hospital, Bethlem Royal Hospital, Bridgeways Day Hospital, Cassel Hospital, Central Middlesex Hospital, Chase Farm Hospital, Claypools Rehabilitation Hospital, Croydon University Hospital, Ealing Hospital, East Ham Care Centre, Edgware Community Hospital, Elderly Day Hospital, Eltham Community Hospital, Erith and District Hospital, Finchley Memorial Hospital, Gateway Surgical Centre, Goodmayes Hospital, Green Parks House, Hadley Wood Hospital, Harefield Hospital, Hillingdon Hospital, Hornsey Central Neighbourhood Health Centre, King George Hospital, Kingston Hospital, Memorial Hospital (Greenwich), Mount Vernon Hospital, New Victoria Hospital, Newham General Hospital, Nightingale Hospital, North Middlesex University Hospital Orpington Hospital, Princess Royal University Hospital, Purley War Memorial Hospital, Queen Elizabeth Hospital, Queen's Hospital, Royal National Orthopaedic Hospital, Spire London East Hospital, St Mark's Hospital, St Michaels Hospital, St. Ann's Hospital, St. Helier Hospital, Sutton Hospital, Teddington Memorial Hospital, The Royal Marsden Hospital (Sutton), Tolworth Hospital, Victoria Hospital (Romford), West Middlesex University Hospital, Whipps Cross Hospital Wilson Hospital |

Table 6: Hospitals in inner and outer London
## Community Staff Nurse | Oxleas NHS Foundation Trust

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<thead>
<tr>
<th>Posting date:</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Salary:</td>
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<tr>
<td>Additional salary information:</td>
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<td>Hours:</td>
<td>Part time</td>
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<tr>
<td>Closing date:</td>
<td>13 April 2023</td>
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<td>Location:</td>
<td>Bexley and Greenwich, SE2 0AY</td>
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<tr>
<td>Company:</td>
<td>Oxleas NHS Foundation Trust</td>
</tr>
<tr>
<td>Job type:</td>
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<td>Job reference:</td>
<td>5129397/277-4732343-CPH-E</td>
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Figure 7: An Example Job Advert on findajob.gov.uk