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Socioeconomic Inequality of Access to Healthcare: Does Choice Explain the Gradient?

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Abstract

Equity of access is a key policy objective in publicly-funded healthcare systems. However, observed inequalities of access by socioeconomic status may result from differences in patients' choices. Using data on non-emergency coronary revascularisation procedures in the English National Health Service, we found substantive differences in waiting times within public hospitals between patients with different socioeconomic status: up to 35% difference, or 43 days, between the most and least deprived population quintile groups. Using selection models with differential distances as identification variables, we estimated that only up to 12% of these waiting time inequalities can be attributed to patients' choices of hospital and type of treatment (heart bypass versus stent). Residual inequality, after allowing for choice, was economically significant: patients in the least deprived quintile group benefited from shorter waiting times and the associated health benefits were worth up to £850 per person.

Keywords: waiting times, inequalities, socioeconomic status, selection bias, choice.

JEL codes: I14, I11, I18, C34.

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1 Introduction

In the presence of public insurance and limited co-payments, waiting times and waiting lists are used as a non-price rationing mechanism in several OECD countries (Martin and Smith, 1999; Siciliani et al., 2013). The main justification for rationing public healthcare by waiting time, rather that price, is that this breaks the link between access and ability to pay (Manning et al., 1987). Patients in equal need are supposed to wait their turn on a 'first-come, first-served' basis, irrespective of ability to pay – or, indeed, race, family background or other social characteristics that may influence ability to pay. The price of accessing services to the patient, such as reduced health-related quality of life while waiting for treatment, is shared equally across patients of equal need. Waiting lists are therefore perceived as a way of ensuring equal access to public healthcare.

If richer patients wait less for public services than poorer patients then waiting times are not as equitable as they appear. A small but growing literature suggests that this may indeed be the case in relation to waiting times for a number of routine, low-risk hospital procedures (see Cooper et al., 2009, and Laudicella et al., 2012, for England; Monstad et al., 2014, and Kaarboe and Carlsen, 2014, for Norway; Johar et al., 2013, and Sharma et al., 2013, for Australia; and Siciliani, 2016, for a detailed overview). However, it is not known whether these waiting time inequalities are due to rich patients opting for providers with shorter waiting times or receiving treatments with shorter waiting times. Policies aimed at enhancing patient choice are increasingly popular in publicly-funded Western healthcare systems, including England (Thomson and Dixon, 2006). A better understanding of the effect of patient choices on waiting time inequalities is required to allow for a more complete assessment of the effect of these policies.

In this study, we estimate the contribution of patients' choice behaviour to waiting time inequality for two treatments for a severe and costly disease that has not previously been examined in the waiting time literature. Coronary heart disease was the largest single cause of years of life lost in the UK in 2010 (Murray et al., 2010) and consumed £1,9bn (just over 2%) of total public healthcare expenditure in England in 2011/12 (NHS England, 2013). We focus on two coronary revascularisation procedures, coronary artery bypass grafting (CABG) surgery and angioplasty (percutaneous coronary intervention, PCI), where patients have substantially reduced quality of life and may experience a non-negligible risk of dying while waiting. Due to the existence of a universal publicly-funded health system – the National

Health Service (NHS) – most coronary revascularisation procedures of this kind in England are carried out in public hospitals and we are therefore able to exploit data on all publicly-funded procedures. Our prior was that wait inequalities for coronary revascularisation are negligible since we expect the management of the list to be rigorous for a potentially life-threatening condition, and the health system more reluctant to let socioeconomically advantaged patients move ahead in the queue.

Perhaps surprisingly, we find instead economically large and statistically significant differences in waiting times across socioeconomic groups. Patients living in more income-deprived (poorer) areas wait longer than patients in less deprived areas that attend the same hospital. In 2002 coronary bypass patients in the least deprived quintile group waited 35% less (43 days) compared to the most deprived ones – considerably larger than the 8% differential (17 days) observed for hip replacement in 2001/02 (see Laudicella et al., 2012). The gradient in waiting times gradually falls to 9.5% in 2010, following the general reductions in waiting times at system level achieved by the English NHS in a sustained and costly 'war on waiting' in the 2000s through additional funding and an aggressive target regime (Department of Health, 2000). Similar patterns are observed for angioplasty.

One key economic factor explaining differences in waiting times by socioeconomic status (SES) is patient heterogeneity with respect to choice of hospital and treatment. Patients with different SES may differ in the way they exercise choice (either directly or mediated through their GP), with richer and more educated individuals being more likely to travel further, either because they have a stronger preference for shorter waiting times (and a higher quality) or because they have fewer financial or other constraints that limit their ability to travel. They may also differ in risk and time preferences over different revascularisation procedures. Hence, SES may have both a direct effect on waiting time (e.g. through discrimination) and an indirect effect (operating through patients' choices). Failure to account for patients' choices may lead to self-selection bias in estimates of the direct socioeconomic waiting time gradient.

Analytically, we allow for self-selection due to patient choice through a switching regression (Roy) model which includes selection correction adjustments in each outcome equation (Heckman, 2010). Patients have as many potential outcomes (i.e. different waiting times) as there are alternative choices (i.e. whether they bypass their local hospital or not; whether they are treated with a coronary bypass or angioplasty). The realised outcome is associated with the choice that provides the highest latent utility. We use exclusion criteria based on the differential distance between the closest and second closest provider, which is a strong predictor of the probability of bypassing the local hospital (and in line with the seminal work by McClellan et al., 1994, and literature that followed). This approach is novel and has not been used in the previous literature on waiting time inequalities. It allows us to identify how much of the socioeconomic gradient is explained by choice or self-selection. Conversely, the remainder of the gradient is more likely to represent waiting times inequalities that originate from the doctor-patient relationship within the hospital and are, thus, more amenable to regulatory intervention. Examples include hospital specialists being more susceptible to pressure from individuals with higher SES, either directly or via their social networks, or wealthier and more educated patients being more effective in expressing their needs. Alternatively, inequalities may be due to unconscious bias and 'statistical discrimination' by doctors (Van Ryn and Burke, 2000, Balsa and McGuire, 2001).

Our key finding is that patients with higher SES are more likely to exercise choice (directly or through the interaction with their GP) by bypassing the local hospital, but that patients' choices account for only up to 12% of waiting time inequalities. The remaining SES gradient is statistically and economically significant. By adjusting for *choice*, we recognise that we are adjusting for a combination of the preferences and constraints that drive choice. To estimate unfair inequality, it might be argued that the aim should be to adjust purely for differences in preferences, rather than also for differences in constraints that cause unequal opportunity to access timely services (Roemer, 1998; Fleurbaey and Schokkaert, 2009). If so, and insofar as the higher probability of deprived patients of going to the local hospital (i.e. not bypassing the closest hospital) is driven partly by constraints rather than preferences, then our estimate of the degree of unfair inequality can be seen as a conservative lower bound.

The study is organised as follows. Section 2 introduces the institutional background. Section 3 presents the econometric methods. Sections 4 and 5 describe respectively data and results. Section 6 provides some robustness checks. Section 7 concludes.

2 Institutional Setting

During the period 2002 to 2010 the English NHS experienced a phase of accelerated expenditure growth. This was the result of a perception that the NHS was under-funded and that quality was suffering as a result (Moran, 1999). A large investment plan was designed and implemented, leading to a 50% increase in the allocated budget and an approximately 33% increase in treatment capacity over a five-year period starting in 2003. This included funding for additional beds in existing hospitals, building of new hospitals and care centres, as well as employment of additional doctors, nurses and supporting staff.

Expenditure growth was accompanied by a number of major healthcare reforms. One of the most effective reforms was the implementation of centrally imposed waiting time targets with associated penalties for failure (Department of Health, 2001, 2002b, Commission for Health Improvement, 2003). This policy regime was explicitly aimed at reducing excessive waiting times for planned procedures. The maximum waiting time from addition to the waiting list to admission was gradually reduced from 18 months to 12 months in 2003, 9 months in 2004 and 6 months in 2005. This target was reformulated in 2010 and patients are now expected to wait no longer than 18 weeks from primary care referral to treatment (NHS England, 2013). The waiting time policy is a core part of a performance management strategy that required hospitals to meet targets to avoid regulatory interventions, either in the form of a senior-management change or take-over by a better performing hospital. These strong incentives contributed to the decline of waiting times for planned surgeries without measurable detriment to quality (Propper et al., 2010).

During the same period, a policy allowing patients to choose the hospital for planned treatment was introduced in the English NHS, with the aim of providing a competitive incentive for hospitals to improve quality and responsiveness to citizens' needs. This policy was part of a broader attempt to modernize the public sector by enhancing consumers' choice, both in UK and other countries (Besley and Ghatak, 2003, Pawson et al., 2006, Musset, 2012, Vrangbaek et al., 2012). The choice policy was rolled out in phases between 2006 and 2008.

For life-threatening conditions, including those requiring revascularisation procedures such as CABG surgery and angioplasty, pilot reforms offering a limited guarantee of patient choice were introduced from July 2002 (Department of Health, 2002a). From that date, patients who had been waiting for more than six months were given the option to choose from a range of alternative providers. The full choice reforms were then introduced from 2006, offering choice from the point of GP referral. In practice, however, patients have always been able to exercise a degree of choice via their GP, with well-informed patients more likely to influence their GP. The choice policy shifted the focus from the GP to the patient in making this choice.

3 Methods

3.1 Baseline model without accounting for patient's choices

We wish to quantify the extent of socioeconomic inequality in waiting time for NHS-funded elective surgery within English NHS hospitals, and its evolution over time. Our data are repeated cross-sections of individuals receiving a given revascularisation procedure, i.e. either CABG surgery or PCI. Our first econometric strategy uses a linear model with hospital fixed effects, estimated separately for each financial year and revascularisation procedure.

The regression model is specified as:

$$w_{ij} = h_j + \beta_1' y_{ij} + \beta_2' s_{ij} + \beta_3' x_{ij} + \varepsilon_{ij} \tag{1}$$

where $w_{ij} = \ln(W_{ij})$ and W_{ij} is the waiting time of patient i in hospital j. y_{ij} is a vector of dummy variables capturing SES as measured by income deprivation of the area where the patients resides. We split the income deprivation distribution into five quintiles, with the highest indicating the least deprived areas (our reference category). β_1 is the vector of coefficients of interest. Income-related inequalities favouring the rich arise if the elements of β_1 are positive.

The vector s_{ij} contains severity controls: age, gender, number of secondary diagnoses, number of hospital emergency admissions in the year preceding the procedure, and dummies for Charlson co-morbidities (Charlson et al., 1987). These proxies control for patients' latent health status, which is unknown to the econometrician but known to the doctor and/or the patient herself. Controlling for severity and comorbidity is important because these are legitimate reasons for higher priority on the waiting list which are also (negatively) correlated with income (Marmot et al., 1991, Smith, 1999, Wagstaff and Van Doorslaer, 2000). The vector x_{ij} includes non-severity variables such as month of admission.

h_j is a vector of hospital fixed effects. It controls for differences in waiting times across hospitals which may arise from unobserved demand and supply factors, such as the number of beds, nurses, doctors, infrastructure, management and organization, and clinical quality. Hence β_1 should be interpreted as waiting time inequalities arising *within* a hospital, as opposed to *across* hospitals.

Throughout the study we only present results which include hospital fixed effects and therefore focus on socioeconomic inequalities arising *within* the hospital rather than *across* hospitals. This is because in England the waiting time gradient hardly changes when we control for hospital fixed effects and when we do not (results available on request). This suggests that poorer individuals are not systematically located nearby hospitals with longer waiting times, and that waiting time inequalities arise within as opposed to across hospitals. This is not necessarily the case for other countries. Johar et al. (2013) show that in Australia about half of the waiting time inequalities are across hospitals and about half are within hospitals suggesting that poor patients have access to hospitals with long waits.

ε_{ij} is the idiosyncratic error. We estimate Equation (1) through OLS with Huber-White standard errors robust to unknown heteroscedasticity. We use the logarithm of waiting time as the dependent variable to reduce the skewness of its distribution. We calculate estimates of the waiting time inequalities on the natural scale by employing a Duan smearing adjustment (Duan, 1983).[1]

3.2 Endogenous switching regressions with selection correction

Despite the hospital fixed effects and the extensive controls on severity, OLS estimation of Eq.(1) the estimates of the income gradient β_1 does not account for the presence of selection (Heckman, 1979). We consider two types of selection: choice of hospital and type of treatment.

We may expect more deprived patients to be less willing to travel or experience more difficulties in travelling compared to less deprived patients, and therefore to be more likely to

[1] The estimated waiting times by income deprivation quintile are computed as $E[W \mid y = g] = \hat{\psi} \times \exp\left(\hat{\beta}_{1,g}\right)$, where $\hat{\psi} = (1/N)\sum_i \exp(\hat{\varepsilon}_{ij})$ is the Duan smearing estimator and $g = 1,\ldots,5$ is the income deprivation quintile (1 = most deprived).

seek care in the closest hospital. Hence, some of the observable differences in waiting time across SES groups (within the same hospital) may be the result of heterogeneity in preferences or constraints to the ability to travel. The waiting-time differential may increase non-linearly if more deprived patients are also unobservably sicker than less deprived ones.

Revascularisation procedures also have different risk/benefit profiles: CABG surgery carries a higher risk of short-term mortality but also exhibits better long-term survival rates and post-operative quality of life than PCI for patients older than 65 or those with certain co-morbidities such as diabetes (The BARI investigators, 1996, 2007, Hlatky et al., 2009, Taggart, 2009). We have proxies of patient health status and severity as control variables but cannot observe the exact patient pathology. Furthermore, even for a given pathology, PCI and CABG may still be substitutes for some patient profiles (Griffin et al., 2007, Dalton et al., 2016), and patients' risk and time preferences may thus determine the choice of treatment. The two procedures have different in-hospital lengths of stay (two days for PCI; nine days for CABG), which implies different opportunity costs. Whether less deprived patients have higher or lower opportunity costs is a priori ambiguous. On one hand, less deprived patients forgo higher wages. On the other hand, they may have lower time preference discount rates (e.g. because they are not in precarious employment and thus less likely to lose their job due to absence), and so be more likely to undergo a CABG procedure, if they perceive it as a procedure delivering greater long-run health benefits and longevity despite imposing greater short-term risk, inconvenience and loss of time.

We estimate Roy model regressions (Roy, 1951, Heckman and Honoré, 1990, Heckman, 2010), also known as switching regression models, with a correction term to control for self-selection that is due to patients choosing i) a hospital which is different from the local one, and ii) a revascularisation procedure (coronary bypass versus PCI).[2] We model and estimate the two choices separately, as we are interested in the separate effect of each self-selection mechanism on the waiting time gradient.[3]

[2] For another application of switching regression methods, see for example Perotin et al. (2013), which investigates differences in patients' satisfaction between public and private providers.
[3] We provide estimates of a joint (2x2) self-selection model for procedures and hospital location in Appendix C. The key insights would be similar but the presentation of the results more involved.

We model the choice of the hospital with a selection equation for bypassing the closest hospital.[4] Define n_{ij} as a dummy equal to 1 if the patient bypasses the closest hospital and 0 otherwise. The Roy model is then defined as

$$\begin{cases} n_{ij} = I\left(\gamma_0' z_{ij} + \gamma_1' y_{ij} + \gamma_2' s_{ij} + \gamma_3' x_{ij} + v_{ij} > 0\right),\ n_{ij} = \{0,1\}, \\ w_{ijn}^* = w_{ij1} = h_j + \beta_{1,1}' y_{ij1} + \beta_{2,1}' s_{ij1} + \beta_{3,1}' x_{ij1} + \varepsilon_{ij1},\ \text{if } n_{ij} = 1, \\ w_{ijn}^* = w_{ij0} = h_j + \beta_{1,0}' y_{ij0} + \beta_{2,0}' s_{ij0} + \beta_{3,0}' x_{ij0} + \varepsilon_{ij0},\ \text{if } n_{ij} = 0 \end{cases} \tag{2}$$

where w_{ij1} and w_{ij0} represent the observed log waiting times for patients selecting respectively into the non-closest or closest hospital, and w_{ijn}^* is the latent waiting time outcome for every patient before self-selecting into a given hospital.

The estimating equations of this model are

$$n_{ij} = I\left(\gamma_0' z_{ij} + \gamma_1' y_{ij} + \gamma_2' s_{ij} + \gamma_3' x_{ij} + v_{ij} > 0\right),\ n_{ij} = \{0,1\} \tag{3}$$

$$E\left\{w_{ij1} \mid h_j, y_{ij1}, s_{ij1}, x_{ij1}, \widehat{p}_z\right\} = h_j + \beta_{1,1}' y_{ij1} + \beta_{2,1}' s_{ij1} + \beta_{3,1}' x_{ij1} + \rho_1 \lambda_{ij1}\left(\widehat{p}_z\right) \tag{4}$$

$$E\left\{w_{ij0} \mid h_j, y_{ij0}, s_{ij0}, x_{ij0}, \widehat{p}_z\right\} = h_j + \beta_{1,0}' y_{ij0} + \beta_{2,0}' s_{ij0} + \beta_{3,1}' x_{ij0} + \rho_0 \lambda_{ij0}\left(\widehat{p}_z\right) \tag{5}$$

The unobserved error terms $v, \varepsilon_0, \varepsilon_1$ follow a degenerate trivariate Gaussian distribution, i.e. $(v, \varepsilon_0, \varepsilon_1) \sim TN(0, \Omega_n)$, with mean zero and covariance matrix Ω_n, where $\Omega_n = \begin{bmatrix} \sigma_v^2 & \sigma_{\varepsilon 0} & \sigma_{\varepsilon 1} \\ \sigma_{\varepsilon 0} & \sigma_{\varepsilon 0}^2 & \cdot \\ \sigma_{\varepsilon 1} & \cdot & \sigma_{\varepsilon 1}^2 \end{bmatrix}$. The covariance between ε_1 and ε_0 is not defined, as w_1 and w_0 are both potential outcomes of which only one can be observed at any time.

Patients are assumed to self-select into the hospital that provides the highest latent utility (Eq. (3)). Their choice is potentially driven by all factors affecting waiting times, i.e. severity, co-

[4] We do not model the choice among all hospitals, but focus only on whether the patient bypassed the local provider. This reduces computational burden and is realistic given the high market concentration of revascularisation procedures. Moreover, it allows us to formulate our empirical models in a purely counterfactual framework in which the patient is faced with only two alternatives. We expect that this simplification has no substantial effect on our results.

morbidities, age, other patient characteristics and income deprivation. We observe Eq.(4) when patients bypass the closest hospital and Eq.(5) when not. No hospital fixed effect is included in the selection equation. Hospital fixed effects would be endogenous in a selection equation for the choice of bypassing the closest hospital because the share of patients choosing a given hospital (i.e hospital fixed effect) is a function of whether the hospital is close by (dependent variable). Similarly, we do not include average hospital quality or waiting times in the choice equation, as they would behave as a hospital fixed effect. As such, the unobserved variation in the choice outcome due to hospital characteristics (quality, waiting times) is included in the residuals v_{ij}. This variation is then controlled for in the waiting time outcome equations (4) and (5) by the selection correction terms $\lambda_1(\hat{p})$ and $\lambda_0(\hat{p})$.[5]

The model can be identified through nonlinearities (Cameron and Trivedi, 2005), but it is good practice to include at least one exclusion restriction variable (instrument) in the selection equation to avoid collinearity problems in the outcome equation (Newey, 1999). Our instrument z_{ij} measures the difference in the distances between the closest and the second closest hospital for a given procedure from the patient's area of residence (which we refer to as 'first' and 'second' available hospital). It is therefore based on distances from the patient's residence to the location of the (two) closest hospitals. Such computation is based on the geographical coordinates corresponding to the hospital postcodes, and the geographical coordinates of the small area level (LSOA) where the patient resides. The ordering of hospitals is based on the distance to the patient's residence. Patients are expected to choose the closest hospital, all else equal. The instrument is therefore not based on the distance to the hospital chosen by the patient.[6]

The *differential distance* between the closest and second closest provider is a measure of the relative opportunity cost of attending different hospitals. The use of differential distance as a

[5] Model (2) therefore accounts both for the within hospitals variation in waiting times and for the correlation between waiting times and self-selection patterns due to the differences in average hospitals characteristics (average waits, quality).

[6] We have also considered alternative exclusion restrictions based on other geographical variables, e.g. the number of hospitals within a fixed radius from the patient's residence, or the rurality of patient's residence. However these other variables are likely to affect directly the outcome of interest (waiting times), thus not constituting valid exclusion restrictions. Moreover, Newey (1999) shows that one valid exclusion restriction is sufficient for the consistent estimation of sample selection models with non-Gaussian error terms.

source of exogenous variation (and therefore suitable instrumental variable or exclusion restriction variable) has been introduced in the health economics literature by the seminal work of McClellan et al. (1994; see also Newhouse and McClellan, 1998). Subsequently, it has been applied in different contexts, e.g. on the effect of hospital ownership on quality (Sloan et al., 2001; Shen, 2002; Lien, 2008).[7] Patients are assumed not to have chosen where to reside on the basis of expected waiting time for a treatment for which they face uncertain demand in the future.[8]

We estimate the model in two steps (Brave and Walstrum, 2014). We first retrieve the propensity score p (Rosenbaum and Rubin, 1983) from the estimation of a probit model for the selection equation. The selection correction terms for the two outcome equations are then computed as $\lambda_1(\hat{p}_z) = \phi\left[\Phi^{-1}(\hat{p}_z)\right] / \left[1 - \hat{p}_z\right]$ and $\lambda_0(\hat{p}_z) = -\phi\left[\Phi^{-1}(\hat{p}_z)\right] / \left[\hat{p}_z\right]$. In the second step, two separate equations for the waiting time outcomes are estimated, one for each regime of hospital choice (closest versus not closest). Selection correction for the two conditional means is addressed by the terms $\lambda_1(\hat{p})$ and $\lambda_0(\hat{p})$. Non-zero coefficients on these terms indicate self-selection. Estimation is performed by OLS on the original covariates plus the selection correction term. Standard errors are bootstrapped to account for the two-step estimation process (Murphy and Topel, 2002).

Including hospital fixed-effects h_j in the waiting times equations of the Roy model is crucial to identify the *within-hospital* waiting-times gradient due to SES. We include hospital effects that are equal in the two switching regimes because they represent unobservable supply or quality shifters that are valid for the same hospital, independently on the choice of the patient.

[7] The results from the *probit* regression in the Roy model (presented below in Tables 5 and 6) show that differential distance between the second and the first closest hospitals is a strong predictor of the propensity of the patient to bypass or not the closest hospital, for both CABG and PCI treatments.

[8] While the differential distance between the two closest hospitals is a good predictor of the choice of bypassing the first closest hospital, such difference is unlikely to have a direct effect on the individual waiting time outcome. To our knowledge, there is no evidence of residential sorting for hospital care in England. It is possible that patients in need of repeated treatments, like haemodialysis or chemotherapy, are more likely to locate closer to hospitals to minimize travel. But patients are less likely to change their residence for one-off treatments like CABG or PCI. Moreover, even if patients did marginally sort their residence according to distance and/or average waiting times of the first closest hospital, they would be less likely to choose their residence according to distances and average waiting times of both the first and the second closest hospitals. As such, it is plausible that the differential distances between second and first closest hospitals constitutes a valid exclusion restriction variable with respect to waiting times, especially as the exogeneity has to hold just conditional on the covariates included in the selection equation (i.e. weak exogeneity).

Hence we constrain the hospital level effects to be the same as those estimated by OLS in Eq.(1).

We estimate a similar Roy model for the choice between CABG surgery and PCI, with analogous specifications and distributional assumptions of the error terms. As exclusion restriction, we compute for each individual patient the difference between i) the average distance from patient address to the three closest hospitals offering CABG and ii) the average distance from patient address to the three closest hospitals offering PCI.[9] Ceteris paribus, the patient is assumed to select the procedure with the 'highest availability' in her location. If hospitals providing CABG surgery are further away from the patient than PCI providers, the patient is more likely to choose PCI to reduce her travel costs.[10] In this case, we allow for different hospital fixed-effects in the waiting time equations, h_{j1} and h_{j0}, as the unobserved supply factors that we want to control for might have different impact on the two revascularization procedures.

3.3 Estimates of patients' welfare loss due to waiting

Waiting causes disutility to the patient, mostly because health benefits are postponed and suffering is prolonged. We estimate the monetary value of the health forgone due to waiting for revascularisation treatment to quantify the re-distributing effect of socioeconomic inequality in waiting time. The estimated cost of waiting, M_g, for deprivation group $g = Q1,\ldots,Q5$ (with $Q1$ the most and $Q5$ the least deprived groups), is computed as

$$\hat{M}_g = E\left[M \mid y = g\right] = \Delta U \times \hat{W}_g \times WTP\left(U\right) \qquad (6)$$

where $\hat{W}_g$ are the estimates of the waiting times by deprivation quintiles, and ΔU is the change in the patient's utility (due to health gains) following revascularisation. $WTP\left(U\right)$ is the willingness to pay for one year of life in full health (standardised to one utility unit),

[9] Formally, define $\bar{d}_{3,CABG}$ ($\bar{d}_{3,PCI}$) respectively as the average distance from each patient's address and the address of the three closest hospitals providing elective CABG (PCI). The exclusion restriction variable for each patient is $\Delta\bar{d}_3 = \bar{d}_{3,CABG} - \bar{d}_{3,PCI}$.

[10] The set of English hospitals providing elective CABG surgery is substantially smaller compared to PCIs. While in 2002 the number of hospitals was similar (32 for CABG and 37 for PCI), by 2010 the number of hospitals offering PCIs had more than doubled (32 for CABG and 83 for PCI). For only about 30% of the patients in our sample the nearest three hospitals offer both PCI and CABG surgery, so there is substantial variation in our exclusion restriction variable.

currently assumed to be £60,000 by the English Department of Health (2013).[11,12] We utilise a common WTP estimate for all socioeconomic groups to ensure comparability.

4 Data

We use data from Hospital Episode Statistics (HES) for the nine financial years (April to March) 2002/03 to 2010/11. HES is an administrative dataset containing records of all NHS-funded hospital admissions in England.[13] The sample includes all elective patients admitted for CABG surgery or PCI.[14] We exclude duplicates, incomplete admission records, or records with missing information on important covariates. Elective inpatient waiting time measures the total time between the patient being added to the waiting list and being admitted to hospital for treatment. We extract information on patients' age, gender, month of admission, and severity controls (see section 3.1).

We approximate socioeconomic status through the income domain of the Economic Deprivation Index (EDI) (Gill, 2012). The EDI measures the proportion of people aged 18 to 59 in each of the 32,482 small areas in England (Lower Super Output Areas (LSOAs), with about 1,500 residents) who are living in low-income households (more specifically, benefit units) that are claiming out-of-work means-tested social security benefits (either Income Support (IS) or income-based Jobseeker's Allowance (JSA-IB)). The data are provided per quarter and aggregated at annual level. EDI is comparable over the study period since it accounts for changes to the tax and benefit systems over time. LSOAs are ranked according to the level of economic deprivation in each year. We generate a set of dummy variables,

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[11] A similar figure is provided by Ryen and Svensson (2014).

[12] ΔU is computed as the discounted utility of the patients' health status six years after revascularization treatment minus the discounted utility associated with receiving medical management treatment (i.e. no intervention). The discounted utilities from CABG and PCI are respectively 0.69 and 0.65, while the utility from medical management is 0.54, according to estimates from Griffin et al. (2007).

[13] We do not have information regarding privately insured or self-funded patients who are treated by private sector hospitals. The private sector accounted for only 2.1% (6.8%) of planned CABG (PCI) interventions during the years 2008/2011 in England (Ludman, 2012, NICOR, 2012). If we assume that private treatments is sought mainly by the wealthiest patients, living in the least income deprived areas, our estimates of the income-deprivation gradient on waiting times will be downward biased.

[14] We define elective patients as all non-emergency patients classified in HES as *booked*, *waiting list* or *planned* patients. We identify as CABG patients those having a K40-K46 OPCS-4 procedure code, excluding patients treated contemporaneously with a PCI or a heart valve procedure (codes K25-K38). We identify as PCI patients those not treated with a CABG procedure, and having a K49-K50 or a K75 or K508 and K718 OPCS-4 within their treatments. For reference, see also: https://indicators.ic.nhs.uk/download/NCHOD/Specification/Spec_09F_211ISR1CPP2_12_V1.pdf (updated February 2014).

corresponding to the five quintile groups of the income deprivation distribution at LSOA level in each year of the sample.

Straight-line distances are computed between the centroid of patients' LSOA of residence (available in HES) and the postcode of the relevant hospitals in a given year through their geographic coordinates. For each patient and procedure, we compute the differential distance between the closest hospital and the second closest hospital (which we use in the selection equation of bypassing the closest hospital). For each patient, we also compute the difference between i) the average distance from patient address to the three closest hospitals offering CABG and ii) the average distance from patient address to the three closest hospitals offering PCI (see footnote 10 for a formal definition). The hospital choice sets for patients are computed separately by procedure and then merged.

5 Results

5.1 Descriptive statistics

More than 320,000 publicly-funded, elective revascularisation procedures have been performed in the English NHS over the period 2002 to 2010 (Table 1). The number of PCIs has increased markedly over time and the number of CABG surgery has fallen, which suggests that the two procedures are potentially substitutes.

Table 1: Treated patients and average waiting times by year and procedure

Years	PCI		CABG surgery	
	Patients Treated	Average waiting time (days)	Patients treated	Average waiting time (days)
Pooled sample	*211,589*	*57.6*	*109,487*	*83.2*
2002	16,099	89.8	14,661	153.5
2003	20,144	93.0	14,219	106.1
2004	24,358	83.7	14,074	98.3
2005	25,632	56.5	12,060	65.4
2006	26,775	52.5	11,536	65.9
2007	25,553	44.3	12,218	64.4
2008	25,404	37.4	11,831	57.8
2009	23,862	40.0	10,000	49.5
2010	23,762	39.2	8,888	50.4

Waiting times for both procedures have declined sharply over time (Table 1). Figure 1(a) and Figure 1(b) illustrate the trends in the average waiting time by income deprivation for the two revascularisation procedures. PCI patients living in the most deprived LSOAs (Q1) waited longer that those patients living in the least deprived areas (Q5) in all years. This is also true for CABG patients until 2008. From 2008 the most deprived patients received treatment more quickly compared to the least deprived.

Table 2: Sample descriptive statistics by procedure.

	Mean PCI	Mean CABG
Waiting Times (days)	57.57	83.17
EDI Income - 1st Quintile (most deprived)	18.66%	19.13%
EDI Income - 2nd Quintile	19.70%	20.09%
EDI Income - 3rd Quintile	20.89%	20.89%
EDI Income - 4th Quintile	20.92%	20.82%
EDI Income - 5th Quintile	19.82%	19.07%
Patient bypasses the closest hospital	38.61%	35.96%
Number of diagnosis	4.37	5.72
Emergency utilization in the past 365 days	0.37	0.28
Patient age	64.09	65.33
Patient is female	25.85%	18.09%
Distance between patient's LSOA and chosen hospital (km)	24.53	32.41
Congestive Heart Failure	2.45%	7.09%
Peripheral Vascular Disease	4.16%	7.36%
Cerebrovascular Disease	0.63%	2.74%
Chronic Obstructive Pulmonary Disease	7.01%	8.55%
Rheumatoid Disease	0.86%	0.99%
Peptic Ulcer Disease	0.17%	0.43%
Mild Liver Disease	0.16%	0.19%
Diabetes	16.76%	20.76%
Diabetes & Complications	0.59%	0.98%
Renal Disease	2.52%	3.48%
Cancer	0.73%	0.82%
Admission Month: January	8.31%	8.53%
Admission Month: February	8.48%	8.06%
Admission Month: March	9.19%	8.62%
Admission Month: April	7.79%	8.14%
Admission Month: May	7.76%	8.26%
Admission Month: June	8.74%	8.92%
Admission Month: July	8.80%	8.79%
Admission Month: August	7.96%	8.50%
Admission Month: September	8.54%	8.72%
Admission Month: October	8.67%	8.72%
Admission Month: November	9.01%	8.52%
Admission Month: December	6.75%	6.23%
Distance between the closest and second closest hospital (CABG)		22.15
Distance between the closest and second closest hospital (PCI)	16.07	
*Difference in distances to the closest CABG and PCI hospitals**	12.92	10.80

Notes. EDI = Economic Deprivation Index. * Difference between i) the average distance from patient address to the three closest hospitals offering CABG and ii) the average distance from patient address to the three closest hospitals offering PCI.

Table 2 reports descriptive statistics of the patient sample. Both PCI and CABG patients are on average 64-65 years old and over three quarters are male. PCI patients have fewer comorbidities and have been admitted to hospital as an emergency more frequently in the preceding year compared to CABG patients. Both patient groups exhibit a similar socioeconomic composition. The average distance travelled to the chosen hospital is higher for CABG patients (32km) than for PCI patients (26km) since fewer hospitals offer this procedure. More than 35% of all patients have bypassed the closest hospital.

The exclusion restriction variables (discussed in Section 3.2) are based on differential distance between the closest and second closest hospital, and are reported at the bottom of Table 2. For patients who underwent CABG surgery, the average difference between the closest and second closest hospital is 22km, and for a quarter of patients exceeds 42km. For patients who had PCI the differential distance between the closest and second closest hospital is 16km and exceeds 33km for a quarter of patients.

Table A1 in the Appendix shows mean waiting time, proportion of patients bypassing the closest hospital, and mean differential distance by procedure, year and quintile of the EDI distribution.

5.2 Socioeconomic gradient, not accounting for patients' choices

Table 3 and Table 4 show the effect of income deprivation on waiting time for CABG and PCI patients, respectively. These results control for a number of factors but are not adjusted for self-selection. The inequality gradient is statistically significant at 1% level for the two most deprived income quintiles in each year for PCI and for most years for CABG.

Figure 1(c) and Figure 1(d) plot conditional waiting times in days, after applying a Duan smearing adjustment. In 2002, CABG patients who were most deprived waited 48 days ([188.9-140.7]/140.7 = 34%) longer than the least deprived patients. The effect reduced over time, but remained between 18% and 10% in all years after 2005. The relative waiting time inequality is larger for patients who underwent PCI. In 2002, patients who were most deprived waited 53% longer than the least deprived patients. The gap is at least 18% in all years up to 2007 and at least 12% thereafter.[15]

[15] Differences in trends shown in Figure 1(a) and Figure 1(c) are due to covariate adjustment. Figure 1(a) shows the mean of the actual (i.e. observed) waiting times, stratified by income deprivation quintiles. Figure 1(c) shows the conditional mean waiting times by income deprivation quintiles that are obtained from the regression

Most of the case-mix variables showed the expected sign and were statistically significant in most specifications. In particular, the effect of the number of past hospital emergency admissions in the previous year is negative and significant at 1% level for both CABG and PCI patients, which is consistent with prioritisation on severity. Conversely, covariates like age and the number of secondary co-morbidity diagnosis are not always significant and are often associated with longer waiting times. The unexpected sign may indicate that these variables do not proxy severity related to cardiovascular pathology under treatment but reflect other unobserved factors that may prolong waits (e.g. propensity to miss outpatient appointments), or may require postponing revascularization treatment (e.g. co-morbidities not yet adequately treated).

We also estimated quintile regression models and found a similar pattern of inequalities at different percentiles of the waiting time distribution (see Appendix E).

model controlling for case-mix. The divergence between figures after 2007 is driven by the case-mix adjustment; not to the smearing adjustment. The latter is set to be constant within procedures and equal across deprivation quintiles in order to allow for comparison.

Table 3: Effect of income deprivation (quintiles of yearly income deprivation distribution) on the log of CABG waiting times, by year.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	2002	2003	2004	2005	2006	2007	2008	2009	2010
EDI income 1st quintile (most deprived)	0.2942***	0.2333***	0.1681***	0.1346***	0.1627***	0.1260***	0.0702**	0.0779***	0.0921**
EDI income 2nd quintile	0.2092***	0.1871***	0.1013***	0.1150***	0.1451***	0.1623***	0.0656**	0.0819***	0.0935**
EDI income 3rd quintile	0.1529***	0.0903**	0.1341***	0.0983***	0.0834**	0.0724***	0.0485*	0.0270	0.0648*
EDI income 4th quintile	0.0221	0.0582*	0.0528**	0.0628**	0.0343	0.0947***	0.0279	0.0081	0.0326
Constant	4.2215***	4.0960***	4.0651***	3.6726***	3.7363***	3.6791***	3.6018***	3.4662***	3.4424***
Patient Age (demeaned)	0.0007	0.0024	0.0055	0.0001	0.0034	0.0040	0.0016	-0.0012	0.0065**
Female Patient	0.0684**	0.0658**	0.0544***	0.0537**	0.0363	0.0390*	0.0613***	0.0658**	-0.0078
Num. of Diagnosis	-0.0005	0.0198**	0.0099*	0.0129**	0.0057	0.0151***	0.0163***	0.0067	0.0063
Emergency Past Admissions past year	-0.2736***	-0.2428***	-0.2050***	-0.1316***	-0.1132***	-0.1181***	-0.1274***	-0.0668***	-0.0808***
Patients	14654	14213	14074	12060	11536	12218	11829	10000	8888
Hospital Sites	32	35	34	32	32	33	34	32	32
R^2	0.19	0.19	0.12	0.13	0.17	0.22	0.17	0.17	0.15

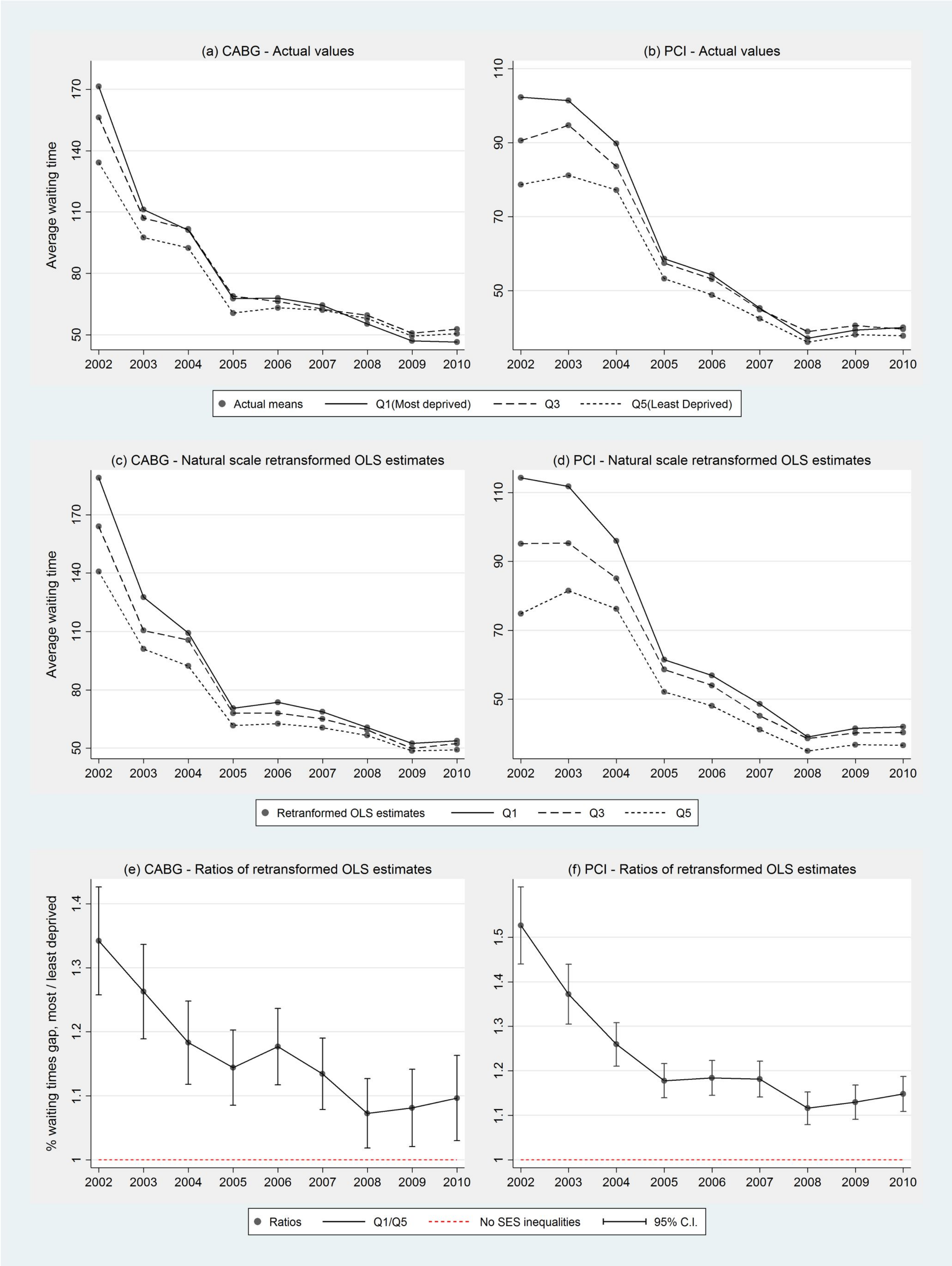
Notes. Controls: Age, age bands dummies, admission month, Charlson comorbidities dummies, gender, number of secondary diagnoses, past emergency utilization, hospital fixed effects. EDI = Economic Deprivation Index. * p<0.10, ** p<0.05, *** p<0.01

Table 4: Effect of income deprivation (quintiles of yearly income deprivation distribution) on log of PCI waiting times, by year.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	2002	2003	2004	2005	2006	2007	2008	2009	2010
EDI income 1st quintile (most deprived)	0.4231***	0.3164***	0.2306***	0.1637***	0.1688***	0.1667***	0.1098***	0.1217***	0.1381***
EDI income 2nd quintile	0.3402***	0.2654***	0.1980***	0.1581***	0.1638***	0.1204***	0.0954***	0.1186***	0.1193***
EDI income 3rd quintile	0.2402***	0.1569***	0.1102***	0.1164***	0.1171***	0.0924***	0.0986***	0.0887***	0.0966***
EDI income 4th quintile	0.1078***	0.0931***	0.0487**	0.0361*	0.0667***	0.0667***	0.0520***	0.0539**	0.0490**
Constant	3.7968***	3.9128***	3.9489***	3.5820***	3.5585***	3.2195***	3.2286***	3.1844***	3.2231***
Patient Age (demeaned)	-0.0004	0.0039	0.0012	0.0016	0.0039***	0.0040**	0.0035**	0.0025	0.0001
Female Patient	0.1062***	0.0673***	0.0691***	0.0501***	0.0467***	0.0490***	0.0389***	0.0281***	0.0184*
Num. of Diagnosis	0.0254**	0.0256**	0.0168*	0.0232***	0.0192***	0.0225**	0.0153***	0.0196***	0.0223***
Emergency Past Admissions past year	-0.1973***	-0.1844***	-0.1282***	-0.0895***	-0.0842***	-0.0628***	-0.0402***	-0.0271***	-0.0219**
Patients	16095	20140	24355	25632	26772	25545	25399	23861	23759
Hospital Sites	37	42	44	52	60	66	73	76	83
R^2	0.13	0.14	0.13	0.12	0.10	0.15	0.16	0.18	0.16

Notes. Controls: Age, age bands dummies, admission month, Charlson comorbidities dummies, gender, number of secondary diagnoses, past emergency utilization, hospital fixed effects. EDI = Economic Deprivation Index. * p<0.10, ** p<0.05, *** p<0.01

Figure 1: Actual and estimated absolute and percentage income-related inequalities in waiting times over years 2002/2010.



5.3 Switching regression for bypassing the closest hospital

Tables 5 and 6 show the effect of income deprivation on waiting times accounting for self-selection due to bypassing the closest hospital.[16] CABG and PCI patients are analysed separately. In almost every year, the selection correction term is statistically significant, providing evidence of self-selection. In both samples, the first stage probit suggests that less deprived patients are more mobile (either due to a stronger preference for shorter waits and higher quality, or fewer constraints and difficulties with travelling) and therefore inclined to bypass the closest hospital than more deprived patients. A higher differential distance between providers (our exclusion restriction) is associated with a lower probability of bypassing the local hospital and it is always statistically significant at the 1% level for both procedures.

Figure 2 and Figure 3 plot the conditional estimates (in days) from the Roy model allowing for bypassing the closest hospital. Until 2006, the socioeconomic gradient for patients bypassing their local hospital is less pronounced than for those treated at their local hospital for both procedures. The most deprived CABG (PCI) patients admitted to their local hospital waited around 44% (54%) longer in 2002 and 11% (15%) longer in 2010 compared to the least deprived patients. Instead, the most deprived CABG (PCI) patients who bypassed their local hospital waited 18% (50%) longer in 2002 and 7% (15%) longer in 2010. From 2008 onwards the gradient tends to fade away in size and is not always statistically significant for CABG patients, while it remains statistically significant for PCI patients. Overall, the second stage regressions confirm the presence of significant (both quantitatively and statistically) socioeconomic gradients in waiting times for both patients bypassing and attending their local hospital.

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[16] We also formally test for the hypothesis of switching regimes by revascularisation procedure and by choice of closest hospital bypassing, through a Chow test (Chow, 1960); and for the common support of the propensity score across self-selection arms, via histograms. Results are reported respectively in Appendices B and C and confirm both the switching regimes hypothesis and the presence of a substantial common support for the propensity score.

Table 5: Roy model. Income inequalities in CABG waiting times, accounting for selection of hospital.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	2002	2003	2004	2005	2006	2007	2008	2009	2010
Patients not choosing the closest CABG hospital site – Equation (4)									
EDI income 1st quintile	0.1671***	0.2229***	0.2274***	0.0818*	0.1429***	0.1636***	0.0153	0.0976**	0.0660
EDI income 2nd quintile	0.1086**	0.1947***	0.0856*	0.0797*	0.1353***	0.1760***	0.0150	0.1095**	0.1583***
EDI income 3rd quintile	0.0474	0.0807*	0.1564***	0.0716*	0.0690	0.1062***	0.0421	0.0724	0.0227
EDI income 4th quintile	-0.0035	0.0691	0.0381	0.0272	0.0104	0.1395***	0.0076	0.0265	0.0484
IMR1 - Not closest	0.1277**	0.1970***	0.2664***	0.0086	-0.0465	0.0187	0.1122**	0.0505	-0.0653
Constant	4.3941***	4.1392***	4.3827***	3.7694***	3.7312***	3.6206***	3.6255***	3.6014***	3.3693***
Patients choosing the closest CABG hospital site – Equation (5)									
EDI income 1st quintile	0.3666***	0.2527***	0.1469***	0.1687***	0.1762***	0.1089***	0.1114***	0.0692**	0.1020***
EDI income 2nd quintile	0.2711***	0.1846***	0.1166***	0.1405***	0.1523***	0.1535***	0.0985***	0.0708**	0.0608*
EDI income 3rd quintile	0.2172***	0.1045***	0.1287***	0.1172***	0.0933***	0.0514*	0.0689**	0.0057	0.0847**
EDI income 4th quintile	0.0427	0.0577	0.0690**	0.0883***	0.0513	0.0693**	0.0433	-0.0009	0.0265
IMR0 – Closest	-0.0174	-0.0091	-0.0988**	-0.0172	0.0281	-0.0234	0.0522	0.0014	0.0719**
Constant	4.1892***	4.1937***	4.0696***	3.6239***	3.7021***	3.7343***	3.6118***	3.4253***	3.4176***
1st Stage Probit for Choice of provider by distance: CLOSEST vs NOT CLOSEST hospital - only CABG – Equation (3)									
Distance difference 2nd - 1st provider	-0.0339***	-0.0184***	-0.0182***	-0.0316***	-0.0366***	-0.0282***	-0.0318***	-0.0329***	-0.0380***
EDI income 1st quintile	-0.1832***	-0.2132***	-0.2065***	-0.2825***	-0.3233***	-0.2321***	-0.2405***	-0.1738***	-0.1348***
EDI income 2nd quintile	-0.0185	-0.0361	-0.0186	-0.0800**	-0.0185	-0.0854**	-0.0165	-0.0561	-0.0017
EDI income 3rd quintile	-0.0233	-0.0503	-0.0229	-0.0110	-0.0868**	-0.0273	-0.0725*	0.0130	0.0187
EDI income 4th quintile	-0.0265	-0.0171	-0.0426	-0.0313	-0.0706*	-0.0546	0.0397	0.0268	0.0591
Constant	0.2726***	0.1231**	0.0626	0.2071***	0.2775***	0.1454**	0.1883***	0.1853***	0.2735***
Patients	14654	14213	14074	12060	11536	12218	11829	10000	8888
Chi-squared p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.14	0.08	0.09	0.15	0.18	0.13	0.15	0.14	0.18

Notes. Roy model on CABG sample based on Model (2). Exclusion restriction in the 1st stage regression: differential distance between second closest and closest CABG hospital site. Controls: Age, age bands dummies, admission month, Charlson comorbidities dummies, Gender, Number of diagnosis, Emergency Past utilization in the previous year, hospital fixed effects (excluded in 1st stage probit choice). IMR = Parametric selection correction (Inverse Mills Ratio). EDI = Economic Deprivation Index. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 6: Roy model. Income inequalities in PCI waiting times, accounting for selection of hospital.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	2002	2003	2004	2005	2006	2007	2008	2009	2010
Patients not choosing the closest PCI hospital site – Equation (4)									
EDI income 1st quintile	0.4043***	0.2845***	0.1846***	0.1478***	0.1422***	0.2120***	0.1269***	0.1496***	0.1425***
EDI income 2nd quintile	0.3251***	0.2956***	0.1930***	0.1516***	0.1340***	0.1537***	0.1314***	0.1612***	0.1119***
EDI income 3rd quintile	0.2375***	0.1595***	0.0912***	0.1169***	0.0881***	0.1424***	0.1174***	0.1277***	0.0824***
EDI income 4th quintile	0.0710	0.0890**	0.0013	0.0474*	0.0645**	0.1115***	0.0717***	0.0980***	0.0771***
IMR1 - Not Closest	-0.1001**	-0.0272	-0.0386	-0.0018	-0.0648**	-0.0106	-0.0575**	0.0263	-0.0054
Constant	3.5600***	3.8989***	3.8665***	3.5116***	3.4935***	3.1513***	3.1757***	3.2392***	3.2156***
Patients choosing the closest PCI hospital site – Equation (5)									
EDI income 1st quintile	0.4344***	0.3219***	0.2493***	0.1747***	0.1841***	0.1363***	0.1004***	0.1090***	0.1374***
EDI income 2nd quintile	0.3447***	0.2394***	0.1992***	0.1634***	0.1868***	0.0966***	0.0735***	0.0946***	0.1228***
EDI income 3rd quintile	0.2412***	0.1471***	0.1204***	0.1171***	0.1362***	0.0537**	0.0855***	0.0689***	0.1061***
EDI income 4th quintile	0.1292***	0.0909***	0.0735***	0.0292	0.0654***	0.0333	0.0400*	0.0301	0.0336
IMR0 - Closest	0.1104***	0.0279	-0.0073	-0.0035	-0.0267	-0.0093	-0.0102	0.0286	0.0037
Constant	3.8188***	3.9022***	3.9710***	3.6293***	3.5824***	3.2653***	3.2319***	3.1540***	3.2218***
1st Stage Probit for Choice of provider by distance: CLOSEST vs NOT CLOSEST hospital - only PCI – Equation (3)									
Distance difference 2nd - 1st provider	-0.0342***	-0.0419***	-0.0385***	-0.0408***	-0.0174***	-0.0224***	-0.0302***	-0.0422***	-0.0423***
EDI income 1st quintile	-0.3843***	-0.3981***	-0.3217***	-0.2464***	-0.1281***	-0.0521**	-0.0282	-0.1350***	-0.1433***
EDI income 2nd quintile	-0.1111***	-0.1223***	-0.0101	-0.0190	-0.0220	0.0588**	0.0614**	-0.0193	-0.0569**
EDI income 3rd quintile	-0.0792**	-0.0775**	-0.0409	-0.0400	0.0102	0.0317	0.0642**	0.0313	0.0308
EDI income 4th quintile	-0.0871***	-0.0644**	-0.0442	-0.0030	-0.0008	-0.0036	0.1045***	0.0278	0.0270
Constant	0.2822***	0.3393***	0.2140***	0.3757***	0.0823**	0.1052***	0.0909**	0.0974**	0.1691***
Patients	16095	20140	24355	25632	26772	25545	25399	23861	23759
Chi-squared p-value	0	0	0	0	0	0	0	0	0
Pseudo R^2	0.14	0.18	0.16	0.16	0.05	0.07	0.08	0.1	0.09

Notes. Roy model on PCI sample based on Model (2). Exclusion restriction in the 1st stage regression: differential distance between second closest and closest PCI hospital site. Controls: Age, age bands dummies, admission month, Charlson comorbidities dummies, Gender, Number of diagnosis, Emergency Past utilization in the previous year, hospital fixed effects (excuded in 1st stage probit choice). IMR = Parametric selection correction (Inverse Mills Ratio). EDI = Economic Deprivation Index. * p<0.10, ** p<0.05, *** p<0.01

Figure 2: Estimated CABG waiting times for patients choosing the closest hospital and bypassing the local hospital by deprivation quintile.

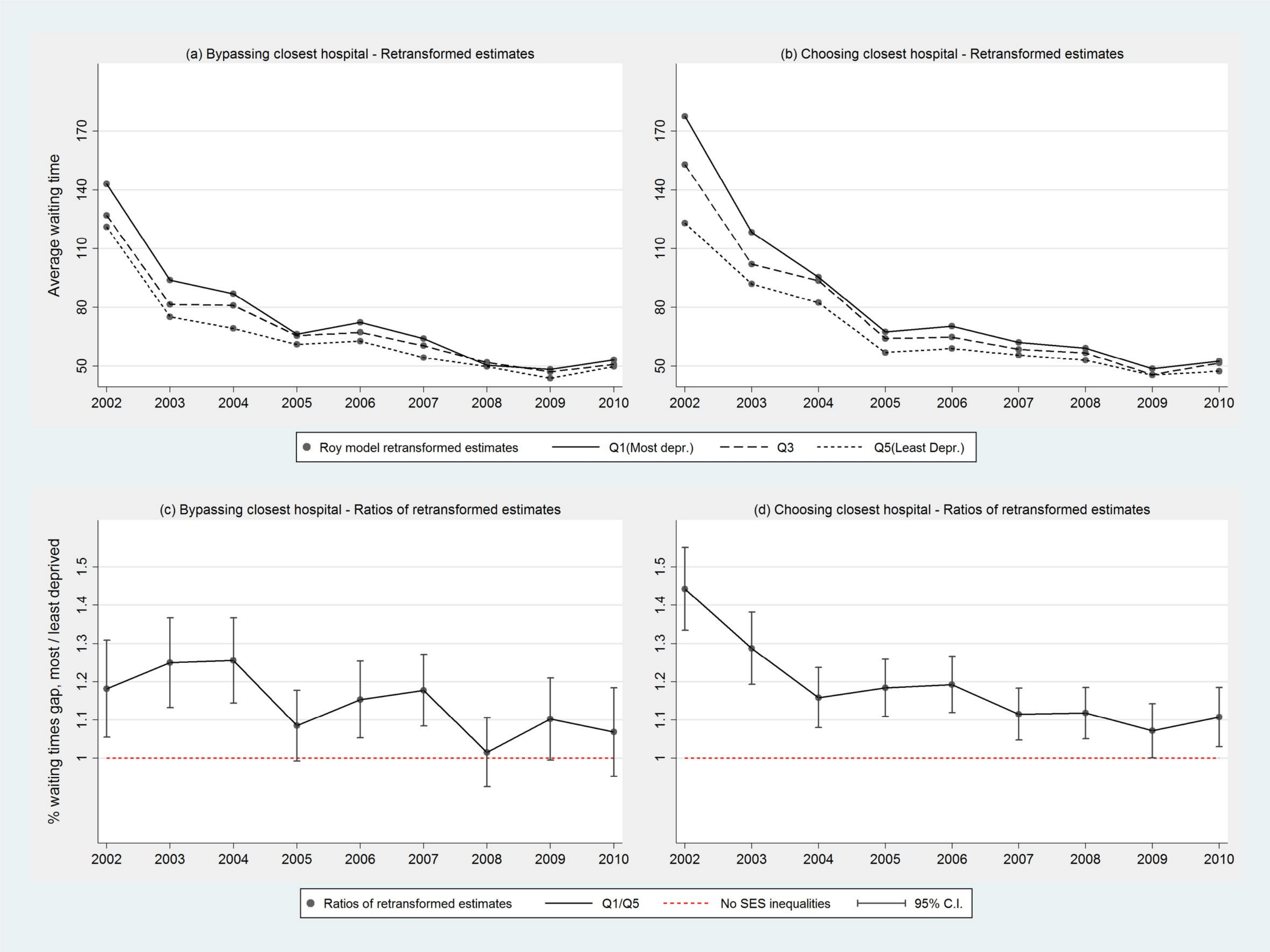
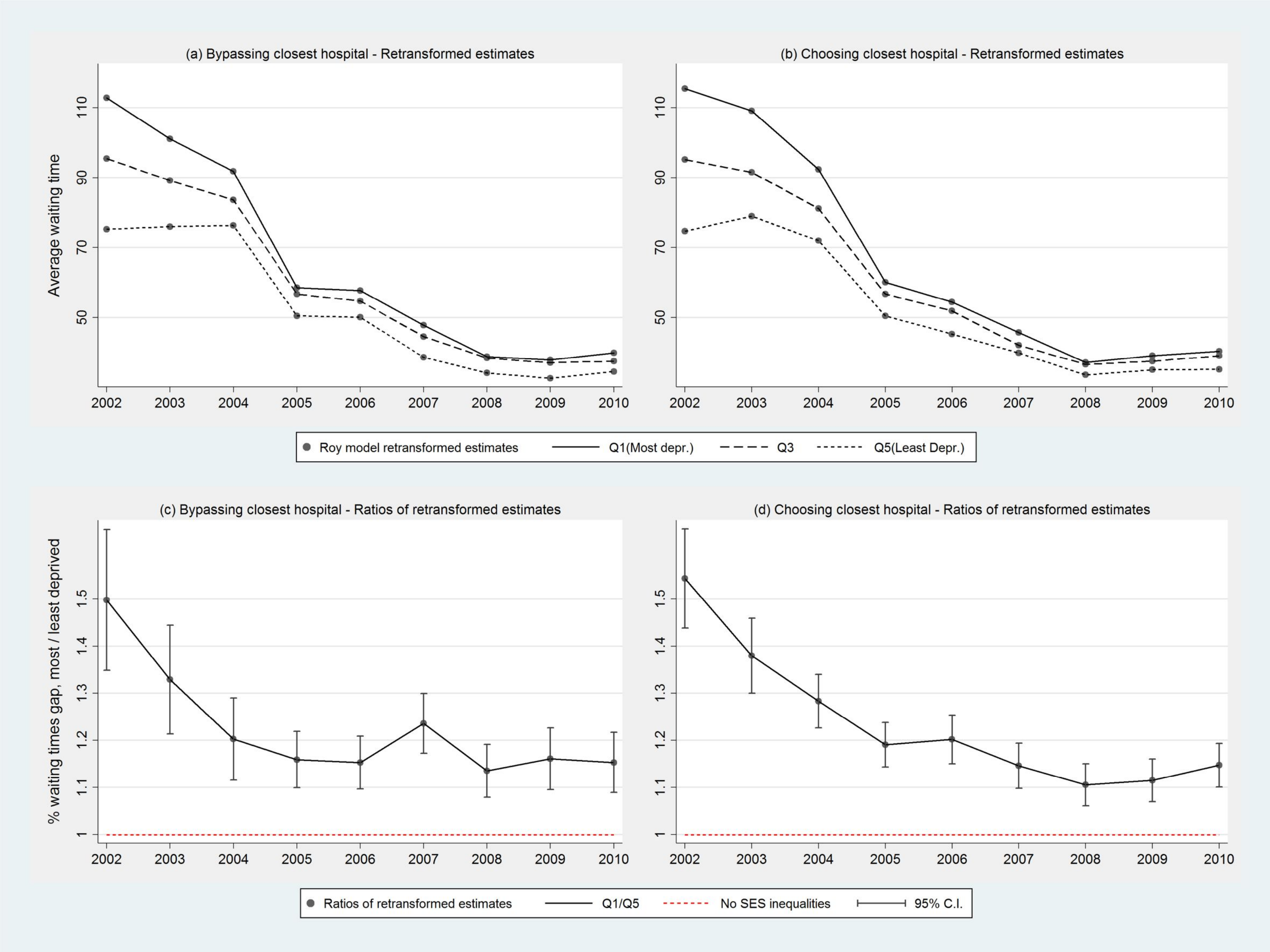


Figure 3: Estimated PCI waiting times for patients choosing the closest hospital and bypassing the local hospital by deprivation quintile.



By design, the magnitude of the overall gradient in waiting time is a weighted average of the two estimated gradients of the switching regression model, with weights equal to the proportion of patients bypassing the local hospital. We utilise this property to calculate the overall gradient after adjusting for selection and compare this to the gradient in Section 5.2 which does not adjust for selection. Table 7 provides i) the expected waiting time for the most (Q1) / least (Q5) deprived patient groups in a given year based on the unadjusted pooled gradient (Columns B and C), ii) the gradient for patients bypassing (D and E) and not bypassing the closest hospital (F and G), and iii) the overall adjusted gradient (H and I).

Columns L and M in Table 7 show how the adjusted overall gradient differs from the unadjusted gradient, both in absolute and relative terms. The results suggest that the unadjusted model exhibits a larger socioeconomic waiting time gradient by up to 12% for CABG patients and by up to 7% for PCI patients.

Table 7: Differences in the estimates of the overall waiting time gradient (in days) with and without adjusting for selection into hospitals.

			Pooled - unadjusted		**Roy model – bypassing closest hospital**		**Roy model – choosing closest hospital**		**Pooled – adjusted**		**Difference in estimates between unadjusted and adjusted waiting time gradient**	
		A	B	C	D	E	F	G	H	I	L	M
Year	Procedure	% Bypassing local hospital	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5	Absolute	Relative
2002	CABG	35.9%	188.9	140.7	143.1	121.1	177.6	123.1	165.2	122.4	-5.37	-11.0%
2003	CABG	40.4%	127.5	101	94	75.2	118.4	92	108.5	85.2	-3.17	-12.0%
2004	CABG	39.0%	109.2	92.3	87	69.3	95.4	82.4	92.1	77.3	-2.07	-12.1%
2005	CABG	34.9%	70.6	61.7	66.3	61.1	67.5	57	67.1	58.4	-0.25	-2.7%
2006	CABG	35.3%	73.7	62.6	72.5	62.8	70.5	59.1	71.2	60.4	-0.30	-2.7%
2007	CABG	36.0%	68.7	60.6	64.1	54.4	62.1	55.7	62.8	55.2	-0.51	-6.8%
2008	CABG	34.8%	60.7	56.6	50.5	49.7	59.3	53	56.2	51.9	0.29	5.6%
2009	CABG	33.0%	52.5	48.6	48.3	43.8	48.7	45.4	48.6	44.9	-0.20	-7.0%
2010	CABG	31.3%	53.9	49.1	53.1	49.7	52.5	47.4	52.7	48.1	-0.23	-3.8%
2002	PCI	35.4%	114.2	74.8	112.8	75.3	115.4	74.7	114.5	74.9	0.17	0.3%
2003	PCI	36.7%	111.8	81.5	101	76	109	79	106.1	77.9	-2.13	-7.1%
2004	PCI	34.3%	96	76.2	91.8	76.3	92.3	72	92.1	73.5	-1.15	-5.4%
2005	PCI	40.4%	61.5	52.2	58.6	50.5	60.1	50.5	59.5	50.5	-0.31	-3.1%
2006	PCI	44.0%	56.9	48.1	57.8	50.1	54.5	45.3	56.0	47.4	-0.26	-3.9%
2007	PCI	41.7%	48.7	41.2	47.8	38.7	45.8	39.9	46.6	39.4	-0.27	-3.5%
2008	PCI	40.6%	39.1	35	38.8	34.2	37.2	33.6	37.8	33.8	-0.09	-1.8%
2009	PCI	35.6%	41.6	36.8	38	32.7	39.1	35.1	38.7	34.2	-0.34	-6.0%
2010	PCI	36.3%	42.1	36.6	39.9	34.6	40.4	35.2	40.2	35.0	-0.26	-3.7%

Notes. Q1 (Q5) = patients living in most (least) income-deprived English LSOAs. A = Percentage of patients bypassing the closest hospital. B, C = baseline OLS estimates of average waiting time for most (Q1) / least (Q5) income-deprived patients (Eq.(1)). D, E = Roy model estimates of average waiting time for most/least income-deprived patients bypassing the closest hospital (Eq.(4))..F, G = Roy model estimates of average waiting time for most/least income-deprived patients choosing the closest hospital (Eq.(5)). H = A*D+(1-A)*F = estimates of average waiting time for most income-deprived patients, after correction for self-selection. I = A*E+(1-A)*G = estimates of average waiting time for least income-deprived patients, after correction for self-selection. L = (H-I)-(B-C) = absolute difference in the SES waiting time gradient due to selection. M = [(H-I)-(B-C)] / (B-C) = percentage difference in the SES waiting time gradient due to selection.

Table 8: Roy model. Income inequalities in waiting times on CABG and PCI samples, after accounting for selection of revascularisation procedure.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	2002	2003	2004	2005	2006	2007	2008	2009	2010
Patients choosing CABG – Equation **(4)**									
EDI income 1st quintile	0.3605***	0.2238***	0.1614***	0.1319***	0.1544***	0.1260***	0.0695***	0.0783***	0.0927***
EDI income 2nd quintile	0.2557***	0.1711***	0.1028***	0.1107***	0.1425***	0.1623***	0.0708***	0.0809***	0.0925***
EDI income 3rd quintile	0.1868***	0.0894***	0.1423***	0.0959***	0.0878***	0.0724***	0.0481*	0.0267	0.0679**
EDI income 4th quintile	0.0450	0.0685**	0.0602**	0.0578**	0.0336	0.0947***	0.0225	0.0080	0.0300
IMR1 - CABG	-0.5930**	0.7736**	0.5971**	0.1162	0.3761	-0.0025	-0.2828	0.1087	0.1413
Constant	3.9205***	4.7000***	4.2609***	3.8637***	4.2500***	3.9414***	3.0829***	3.2087***	3.3728***
Patients choosing PCI – Equation **(5)**									
EDI income 1st quintile	0.5063***	0.3105***	0.2323***	0.1661***	0.1688***	0.1670***	0.1093***	0.1189***	0.1364***
EDI income 2nd quintile	0.3974***	0.2556***	0.1977***	0.1622***	0.1638***	0.1193***	0.0988***	0.1215***	0.1214***
EDI income 3rd quintile	0.2819***	0.1568***	0.1083***	0.1189***	0.1171***	0.0903***	0.0985***	0.0898***	0.0906***
EDI income 4th quintile	0.1365***	0.0998***	0.0469**	0.0406**	0.0667***	0.0672***	0.0486***	0.0547***	0.0541***
IMR0 - PCI	-0.7795*	0.5696	-0.1959	-0.1536	0.0035	0.1766	-0.2522	-0.5481***	-0.4976***
Constant	4.2005***	3.5923***	4.1968***	3.6976***	3.5055***	3.0236***	3.5466***	3.4960***	3.4379***
1st Stage Probit for Choice of procedure: CABG vs PCI – Equation **(3)**									
Differential distance of first 3 hospitals by procedure	-0.0016***	0.0001	-0.0013***	-0.0008**	-0.0004	0.0009***	-0.0003	-0.0008**	-0.0020***
EDI income 1st quintile	0.1810***	0.0191	0.0173	0.0338	0.0295	-0.0008	-0.0030	-0.0087	-0.0053
EDI income 2nd quintile	0.1254***	0.0314	-0.0024	0.0543**	0.0077	0.0148	0.0281	0.0139	0.0104
EDI income 3rd quintile	0.0909***	0.0016	-0.0176	0.0314	-0.0171	0.0252	-0.0014	0.0039	-0.0300
EDI income 4th quintile	0.0636***	-0.0210	-0.0177	0.0612***	0.0017	-0.0050	-0.0284	0.0013	0.0282
Constant	-0.0714**	-0.1671***	-0.3132***	-0.4841***	-0.4246***	-0.2987***	-0.3746***	-0.4634***	-0.5697***
Patients	30749	34353	38429	37692	38308	37763	37228	33861	32647
Chi2_pval	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.07	0.07	0.07	0.07	0.08	0.08	0.10	0.10	0.13

Notes. Roy model on joint CABG and PCI samples. Exclusion restriction in the 1st stage regression: (average) distance between the three closest hospitals providing CABG and the three closest hospitals providing PCI. Controls: Age, age bands dummies, admission month, Charlson comorbidities dummies, Gender, Number of diagnosis, Emergency Past utilization previous year, hospital fixed effects (except for 1st stage probit choice). IMR = Parametric selection correction (Inverse Mills Ratio). EDI = Economic Deprivation Index. * p<0.10, ** p<0.05, *** p<0.01

5.4 Switching regressions for choice of procedure

Table 8 shows the effect of income deprivation on waiting times accounting for self-selection into revascularisation procedure. The first stage probit suggests that SES is not associated with the choice of treatment alternative. However, the IMRs are statistically significant at 5% level in 5 of 9 years. Accounting for self-selection into treatment has negligible effects on the estimated socioeconomic gradient. Because policy makers are usually concerned with waiting times for individual cardiac revascularisation procedures, we do not calculate an adjusted overall gradient.

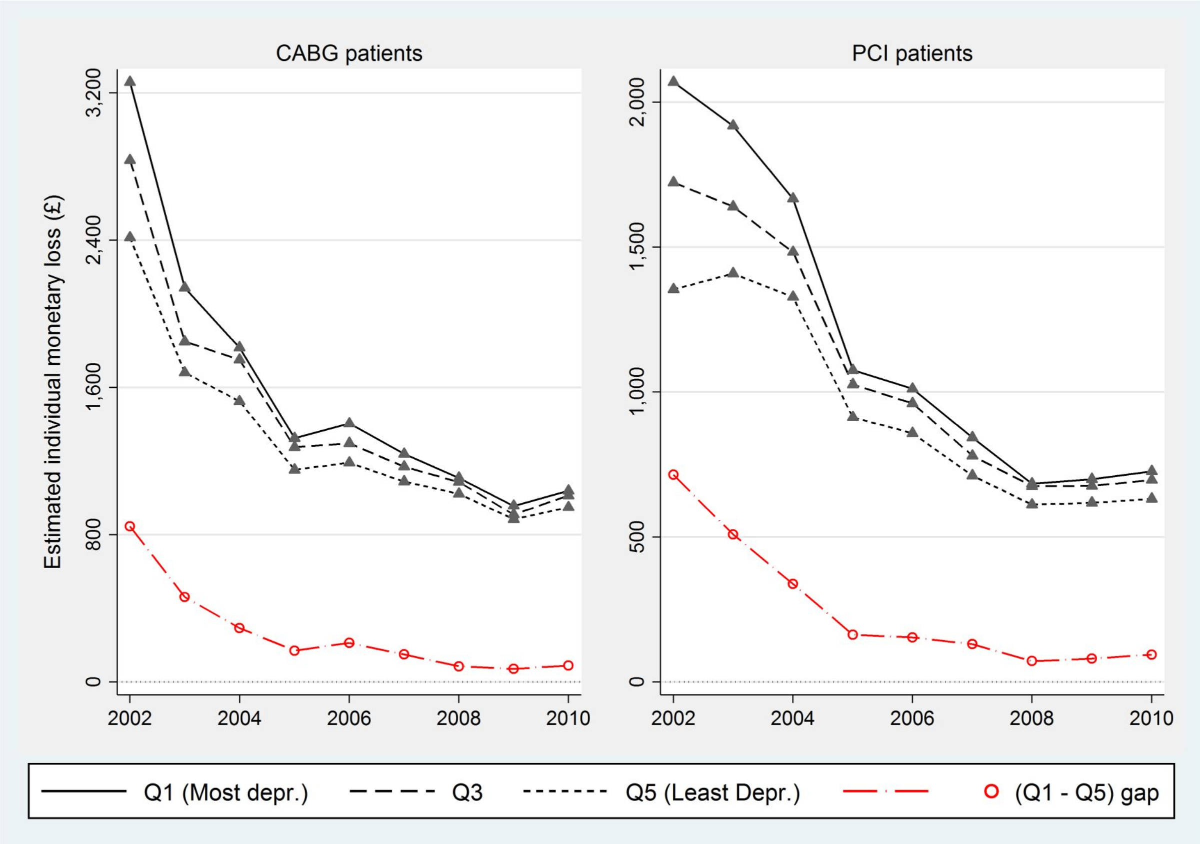
The coefficient of the exclusion restriction variable in the first stage regression is negative and statistically significant at 1% level in five of the nine years analysed. As expected, a larger differential distance to CABG provider reduces the probability of choosing CABG surgery.

The results are qualitatively similar (and available upon request from the authors) when we used waiting times as opposed to its log transformation, though the SES gradient is less pronounced. The appropriateness of employing the logarithmic transformation of waiting times versus the actual waits has been formally tested with Akaike and Bayesian Information Criteria, Shapiro-Francia normality test, Breusch-Pagan and Cameron-Trivedi heteroscedasticity tests, and non-parametric graphical inspection methods (i.e. histograms of regression residuals). The results support the use of the log transformation.

5.5 Value of health forgone while waiting for treatment

Figure 4 shows the individual monetary value of the health forgone while waiting for revascularisation by SES. This is based on Eq.(6) with $\hat{W}_g$ computed from the Roy model results (Eq.(4) and Eq.(5)) weighted by the proportion of patients bypassing the closest hospital (i.e. the adjusted overall gradient). CABG patients forgo more health while waiting than PCI patient because they wait longer and because CABG surgery is more effective (larger health benefit). Patients living in most deprived areas bear larger losses than those in the average or least deprived LSOAs due to the unfavourable waiting time gradient. The differences between the most and least deprived patients are very large in the early years of the sample, and amount to approximately £850 for CABG and £715 for PCI in 2002. These socioeconomic inequality gaps reduce sharply over time in line with the waiting time gradient, but do not disappear. In 2010, the waiting time gap between most and least deprived patients is worth approximately £90 for both CABG and PCI patients. Comparing this to a hypothetical scenario in which waiting times across all patients are equal to the national average[17] the total re-distributing effect of waiting time inequalities is about £295,000 for CABG patients and £750,000 for PCI patients in 2010 alone.

Figure 4: Estimated monetary value of health forgone while waiting (by procedure and deprivation quintile).



6 Robustness checks

6.1 Hospital characteristics and choice of bypassing the closest hospital

The choice of bypassing the closest hospital may be a function not only of the distance to providers, but also their quality and waiting times. A recent study by Gaynor et al. (2016) shows that CABG patients in England are more likely to choose hospitals with higher quality, as measured by lower risk-adjusted mortality, when patient choice policies were enhanced, but are not sensitive to variations in waiting times.

[17] In a capacity constrained health system, reductions in waiting times for the more deprived are likely to be achieved through increases for the less deprived.

We investigate whether the SES gradient in waiting times shown in Table 7 (based on the selection equations of bypassing the local hospital in Tables 5 and 6) is robust to the inclusion of quality and waiting times in the selection equations. To avoid simultaneity bias between volume and quality (e.g. due to learning-by-doing or congestion effects), we include quality and waiting times lagged by one year, which is also consistent with a demand specification with adaptive expectations.[18]

The quality and wait indicators are computed, similarly to the distance variables, as differences to the closest provider. For each revascularization procedure (CABG, PCI), the differential quality and waiting times variables are computed respectively as $\Delta q = \bar{q}_5 - q_1$ and $\Delta w = \bar{w}_5 - w_1$, where q_1 and w_1 are hospital quality and waiting times in the closest (hospital) Trust, lagged by one year, and $\bar{q}_5$ and $\bar{w}_5$ are the average quality and waiting times in the 5 second closest Trusts, lagged by one year.

As a proxy of quality we use standardized mortality rates computed according to the Dr Foster Intelligence methodology.[19] As a proxy of wait we compute the proportion of patients waiting in excess of the 3rd quartile (e.g. 75%) of the procedure-specific wait distributions. The latter is in line with evidence suggesting that patients dislike *long* waiting times (Gutacker et al., 2016). As an additional indicator of hospital quality, we include a dummy variable when the closest hospital is predominantly a specialist cardiothoracic hospital: patients should be less likely to bypass the closest hospital if it is a specialist one.

The use of lagged variables reduces the sample in the presence of hospital entry since we cannot include lagged quality and waiting times for hospitals entering the market in a given year.[20] We therefore also estimate the Roy models based on the restricted sample with the selection equations including distance but excluding quality and waiting times (as in the main model in Section 5) to isolate the effect of the latter variables from changes to the sample.

The key results are reported in Table 9. Columns A, B and C report respectively the proportionate difference in waiting times between the lowest and highest SES group when the selection equation includes: i) distance only; ii) distance, quality and waiting times on the restricted sample, and iii) distance only on the restricted sample. The gradients are very

[18] The use of lagged hospitals characteristics is in line with previous studies on hospital choice (Beukers et al., 2014; Gutacker et al., 2016; Moscelli et al., 2016).
[19] See http://www.drfoster.com/wp-content/uploads/2014/09/HSMR_Toolkit_Version_9_July_2014.pdf.
[20] During the period 2002-2010, the number of hospital sites offering PCI almost tripled but stayed approximately constant for CABG.

similar under the three specifications, and we therefore conclude that our results are robust to the inclusion of quality and waiting times in the selection equations.

The selection equations are shown in Tables F1 and F2 in the Appendix. For CABG, Table F1 shows that after the introduction of patient choice in 2006 patients are more likely to choose hospitals with lower mortality. This is not the case before the choice policies and likely to reflect the restricted choice that patients faced. Patients are more likely to bypass the local hospital when waiting times are long throughout the period considered, except for the last two years when waiting times were very short and may act as residual category of reputation (hospitals with high demand have longer waits). The results are plausible and in line with Gaynor et al (2016) which show that CABG patients choose hospitals by lower mortality when patient choice policies were enhanced.[21]

6.2 Patient severity, SES and choice of revascularization procedure

A possible concern is that the choice between CABG and PCI is limited only to the most severe patients, especially in last period of our sample when PCI seems to increasingly substitute for CABG. If the most severe patients also come from the most deprived areas, then the estimates of the selection equation might be biased. To ascertain whether this is the case, we estimate also a Roy Model with choice between CABG and PCI, whose selection equation allows for interaction terms between the SES indicators and: i) the number of past emergency admissions; and ii) the number of co-morbidities.

The results are reported in Table 10, which compares the SES gradient in waiting times with (column B) and without (column A) the interactions. The results are very similar. For completeness, the coefficients of the Roy Model are shown in Appendix Table G1 and are in line with Table 8: patients become more likely to choose CABG over PCI as the number of

[21] For PCI, Table F2 shows that after 2006 patients were less likely to bypass their closest hospital if it was a specialist cardiothoracic centre. They are also more likely to bypass their closest hospital when waiting times are long in the first three years but this is not so in the later years when the coefficients are positive and again this could be due to the shorter waiting times acting as a proxy of reputation. The coefficients on mortality go from positive in the first three years to negative in the following two years, which is to some extent in line with CABG results, but are positive in the last four years. The counter-intuitive results for the latter could be due to the smaller variation of mortality in PCI (since the risk of mortality is low, i.e. 0.36% in our sample), the limitation imposed by the reduced-form modelling using a *probit* model instead of more complex *discrete choice model*, and the fact that the specialisation dummy discussed above may act as a better quality indicator than mortality.

co-morbidities increases and the number of past emergency admissions decreases[22], but the interactions terms with the SES are mostly insignificant.

6.3 Patient costs, SES and choice of revascularization procedure

The choice between CABG and PCI could be a function of the expected recovery time and costs. CABG surgery requires considerably more recovery time than PCI, with an in-hospital Length of Stay (LoS) of 7 to 10 days, and a full expected recovery after 12 weeks, compared to a 1 to 2 days in-hospital LoS and a week recovery period for PCI. These differences in LoS and recovery time might affect differently the choice of individuals with different SES.

To allow for this, we estimate a Roy Model where the selection equation between CABG and PCI allows for differences in LoS between the two procedures. More precisely, we compute the difference in the average LoS between the two procedures, $\Delta \mathrm{LoS} = \overline{\mathrm{LoS}}_{\mathrm{CABG}} - \overline{\mathrm{LoS}}_{\mathrm{PCI}}$, where $\overline{\mathrm{LoS}}_{\mathrm{CABG}}$ and $\overline{\mathrm{LoS}}_{\mathrm{PCI}}$ are averaged across the five closest hospitals. ΔLoS represents a proxy of differential expected 'recovery costs', which may affect the choice of CABG vs. PCI.[23] The selection equation of the Roy Model includes i) ΔLoS and ii) the interactions between ΔLoS and SES.

The SES gradient in waiting times based on this Roy model is reported in column D of Table 10. The gradient is very similar to our baseline one (in column A). The results are therefore robust to this extension. (Full results of the Roy model are reported in the Appendix, Table G2 and are in line with Table 8). The selection equation suggests that patients prefer CABG over PCI the shorter is the average LoS for CABG compared to PCI. The effect of ΔLoS and its interaction terms with SES are mostly insignificant, except for the most deprived patients in 2007 and 2008.

[22] The same pattern arises in Table 8, whose full estimation results of the selection equation are reported in the Appendix, Table G3, Panel C.
[23] We do not have information regarding out-of-hospital recovery costs for the two procedures. We assume that the out-of-hospital recovery costs are positively correlated to the in-hospital length of stay.

Table 9. Comparison of SES gradient controlling for selection due to patients bypassing the closest hospital.

					A	B	C	D	E
Year	Sample	% bypassing closest hospital	Smaller sample due to hospital entry	% bypassing closest hospital; Smaller sample	SES gradient	SES gradient	95% Confidence Intervals	SES gradient	95% Confidence Intervals
					CABG				
2002	14,661	35.9%	14,654	35.9%	34.9%	34.5%	[23.1%; 46.0%]	34.9%	[23.4%; 46.4%]
2003	14,219	40.4%	13,678	38.4%	27.2%	27.6%	[17.1%; 38.2%]	27.6%	[17.1%; 38.1%]
2004	14,074	39.0%	14,074	39.0%	19.6%	19.6%	[10.5%; 28.8%]	19.6%	[10.5%; 28.7%]
2005	12,060	34.9%	12,060	34.9%	14.9%	14.9%	[6.8%; 23.0%]	14.9%	[6.9%; 23.0%]
2006	11,536	35.3%	11,536	35.3%	17.9%	17.9%	[9.6%; 26.2%]	17.9%	[9.6%; 26.2%]
2007	12,218	36.0%	11,245	32.3%	13.8%	13.5%	[5.6%; 21.5%]	13.4%	[5.5%; 21.3%]
2008	11,831	34.8%	11,635	33.9%	8.2%	8.3%	[0.8%; 15.8%]	8.4%	[0.9%; 15.9%]
2009	10,000	33.0%	10,000	33.0%	8.2%	8.1%	[-0.2%; 16.3%]	8.2%	[-0.1%; 16.4%]
2010	8,888	31.3%	8,888	31.3%	9.5%	9.5%	[0.6%; 18.4%]	9.5%	[0.6%; 18.4%]
					PCI				
2002	16,099	35.4%	15,600	33.5%	52.8%	53.4%	[41.1%; 65.7%]	53.4%	[41.1%; 65.7%]
2003	20,144	36.7%	18,413	32.4%	36.1%	35.6%	[26.1%; 45.0%]	35.5%	[26.1%; 45.0%]
2004	24,358	34.3%	23,668	33.5%	25.6%	26.5%	[19.7%; 33.3%]	26.4%	[19.6%; 33.2%]
2005	25,632	40.4%	20,524	29.4%	17.8%	19.3%	[13.3%; 25.3%]	19.5%	[13.5%; 25.5%]
2006	26,775	44.0%	23,470	39.3%	18.0%	18.0%	[12.5%; 23.6%]	18.0%	[12.5%; 23.6%]
2007	25,553	41.7%	21,814	36.2%	18.4%	17.4%	[11.6%; 23.3%]	17.4%	[11.5%; 23.2%]
2008	25,404	40.6%	22,767	36.6%	11.8%	11.8%	[6.6%; 17.0%]	11.8%	[6.6%; 17.0%]
2009	23,862	35.6%	22,609	34.0%	13.2%	12.8%	[7.5%; 18.2%]	12.8%	[7.5%; 18.2%]
2010	23,762	36.3%	22,196	33.3%	14.9%	14.3%	[9.0%; 19.7%]	14.2%	[8.9%; 19.6%]
					Controls included in the selection equation				
Differential distances					YES	YES	YES	YES	YES
Hospital quality and waiting times					NO	YES	YES	NO	NO

Notes. A = 100*[(column H of Table 7 / column I of Table 7) -1]; B = same as A, but using estimates and samples from Tables F1 and F2, with selection accounting for distance, hospital quality and waiting times; C = 95% confidence interval around B; D = same as C, but estimated on samples as in Tables F1 and F2, excluding hospital quality and waiting times; E = 95% confidence interval around D.

Table 10. Comparison of SES gradient controlling for selection due to choice of procedure.

	A	B	C	D	E
Year	SES gradient		95% confidence interval	SES gradient	95% confidence interval
			CABG		
2002	41.4%	36.5%	[27.1%; 45.9%]	36.4%	[27.0%; 45.7%]
2003	25.1%	25.7%	[18.5%; 32.9%]	25.7%	[18.5%; 32.9%]
2004	17.4%	17.4%	[11.1%; 23.7%]	17.7%	[11.4%; 24.0%]
2005	14.1%	14.3%	[8.5%; 20.1%]	14.5%	[8.7%; 20.3%]
2006	16.8%	17.4%	[11.5%; 23.2%]	17.0%	[11.2%; 22.9%]
2007	13.4%	13.4%	[8.0%; 18.9%]	13.4%	[8.0%; 18.8%]
2008	7.2%	7.2%	[2.0%; 12.5%]	7.1%	[1.8%; 12.4%]
2009	8.1%	8.1%	[2.2%; 13.9%]	8.1%	[2.2%; 14.0%]
2010	9.6%	9.6%	[3.1%; 16.0%]	9.6%	[3.2%; 16.0%]
			PCI		
2002	61.2%	56.2%	[46.2%; 66.2%]	56.4%	[46.5%; 66.4%]
2003	36.5%	36.8%	[30.2%; 43.3%]	36.9%	[30.4%; 43.4%]
2004	26.1%	25.6%	[20.9%; 30.4%]	25.9%	[21.2%; 30.7%]
2005	18.0%	18.0%	[14.3%; 21.7%]	18.0%	[14.2%; 21.7%]
2006	18.4%	18.2%	[14.4%; 22.0%]	18.2%	[14.4%; 22.0%]
2007	18.2%	18.2%	[14.4%; 22.0%]	18.2%	[14.3%; 22.0%]
2008	11.5%	11.6%	[8.1%; 15.0%]	11.6%	[8.1%; 15.1%]
2009	12.8%	12.8%	[9.1%; 16.5%]	12.8%	[9.1%; 16.5%]
2010	14.8%	14.8%	[11.0%; 18.5%]	14.8%	[11.0%; 18.5%]
			Controls included in the selection equation		
Difference in distances to the closest CABG and PCI hospitals	YES	YES	YES	YES	YES
SES * past emergency admissions	NO	YES	YES	NO	NO
SES * comorbidities	NO	YES	YES	NO	NO
LoS, SES * LoS	NO	NO	NO	YES	YES

Notes. Column A results are from models reported in Table 8. Column B results from models in Table 8, adding interactions terms of SES indicator variables with number of past emergency admissions and number of comorbidities in the selection equation of the Roy Model. Column D results from models in Table 8, adding both the average LoS (Length of Stay) in the five closest hospitals and the interactions terms of SES indicator variables with the average LoS in the selection equation of the Roy Model. See footnote 10 for formal definition of "Difference in distances to the closest CABG and PCI hospitals".

7 Conclusions

Several studies suggest that publicly-funded health systems are prone to pro-rich inequalities in hospital waiting times for elective procedures (Siciliani, 2016), even in countries like England and Norway with well-funded and mature systems of universal health coverage. This study improves our understanding of such inequalities and provides four key results and policy insights.

First, waiting time inequalities by socioeconomic status within hospitals tend to be larger in relative terms for complex tertiary interventions for *life threatening* conditions like coronary heart disease than for conditions which are not life threatening such as osteoarthritis, which is frequently treated by hip replacement surgery. We find that patients living in the most deprived fifths of small areas wait 35% longer compared to the least deprived fifths for CABG and 53% longer for PCI in 2002, falling to 9.5% and 15% respectively in 2011. These differences are economically meaningful: the health that more deprived CABG patients forgo due to waiting longer than less deprived patients was worth approximately £850 per person in 2002/03, reducing to £90 in 2010/11. In contrast, Laudicella et al. (2012) estimate a 7.7% gap in waiting time within hospitals between the most and least deprived groups of patients who underwent hip replacement surgery in England in 2001 (see also Cooper et al., 2009, showing smaller gaps for cataract surgery and knee replacement within and across hospitals). This indicates that socioeconomic inequalities in waiting times may be exacerbated when patients seek care for potentially life-threatening diseases.

Second, waiting time inequalities are not primarily due to choice of hospital or type of treatment for the life-threating condition which we investigate. Only up to 12% of the overall waiting time gradient is due to choice, and this effect did not increase after 2006 when the English NHS choice reforms were introduced. Moreover, the substantial fall in pro-rich inequality began in 2002 when average waiting times started to fall (Propper et al., 2010) but had largely finished by 2006 when the choice policy was introduced (Cookson et al., 2012a).

The study by Gaynor et al. (2016) shows that choice of hospital for patients in need of CABG responded to quality (in particular the more severe and low income patients) but not to waiting times when the choice policies were introduced in 2006 (with high income patients having at most a higher, rather than lower, willingness to travel for long waiting times; p. 3545). Therefore, patients with higher socioeconomic status (or higher severity) did not benefit from reduced waiting times by being able to exercise choice and travelling further. This further confirms that the enhancement of patient choice did not contribute to the reduction in waiting time inequalities, and this may be due to the willingness or ability to travel being driven mostly by quality considerations as opposed to waiting times ones for a serious cardiovascular condition.

The role of choice may be different for less serious and more standardised procedures such as cataract and hip replacements, though demand elasticities to waiting times remain low and around 0.1 (Sivey, 2012, Gutacker et al., 2016, Moscelli et al., 2016). Future work could adopt our framework to quantify the role of choice in explaining wait inequalities for these conditions, though we conjecture the role of choice will remain limited due to low demand elasticities to waiting times. There is an extensive literature which tests if quality affects patients' choices in the US (Gaynor and Town, 2011), but waiting times are low in the US (Schoen et al., 2010) and therefore unlikely to affect choice. Our study has implications mostly for those publicly-funded systems (either NHS or social insurance ones) where i) waiting times remain long due to restrained public budgets and excess demand, and ii) patient choice policies are increasingly encouraged and supported by public reporting of quality indicators (Siciliani, Chalkley and Gravelle, 2017).

Third, we show that waiting time inequalities tend to be larger in both absolute and relative terms when average waiting times are high. Inequalities reduced when the average waiting time fell. This suggests that the level of pro-rich inequality in waiting time depends more on the overall duration of the wait than on the extent of patient choice. As discussed in Section 2, the reduction in average waiting times were obtained by a mix of sustained and unusually high public health care expenditure growth in England during the 2000s and an aggressive maximum waiting time target regime, and this fall was not associated with choice reform from 2006. Our analysis suggests that policies which reduce average waiting times also reduce inequalities in waiting times. This is consistent with other studies of the pattern of reduced inequality in the English NHS during the 2000s in the utilisation of health care (Cookson et al., 2012b, 2013). Waiting times have recently stagnated or started to rise again due to adverse financial climate and general reduction in public spending. Our analysis suggests that countries which experience increases in waiting times will also experience increase in inequalities in waiting times.

Fourth, we have shown that substantial socioeconomic inequalities occur within the same hospital in the English health system, for patients waiting for effective treatment for a serious heart condition. Since these inequalities are not primarily due to differences in patient choice of hospital or procedure, several other mechanisms may explain the presence of a gradient in waiting times after controlling for selection due to patients' choices. One plausible mechanism is what one might call *elbowing behaviour* by less deprived patients. More socioeconomically advantaged patients are likely to be better endowed with information, networking skills, contacts and consciousness of their rights, enabling them to exercise more effective pressure to get prioritised for treatment. Moreover, the practice of *defensive medicine* by medical staff and hospital management may imply that richer patients are riskier to disappoint if the health of the patient deteriorates while waiting, and they (or their families) are more likely to take legal recourse for medical malpractice since they can afford the legal expenses for the losing party in a medical malpractice litigation in England (Miller, 1985).[24] Finally, the phenomenon of *unconscious bias* can occur if doctors are better able to understand and interpret the health symptoms of patients who are more similar to them in terms of socioeconomic status.

Future research could explore in greater detail which of these mechanisms is at work to guide policy developments.[25] Since policy makers in Europe and other OECD countries have explicit policy goals to ensure equality of access based on need, waiting time inequalities are cause for concern and need to be addressed. If it is the poor who fall behind because they are more likely to miss appointments and maintain contact with the hospital, policies that facilitate access and communication may be appropriate. If it is instead the rich who jump ahead of the queue, a more robust management of the waiting list is required.[26]

[24] "[..][S]ince British litigants who do not qualify for publicly funded legal services must pay for the assistance of counsel themselves, financial considerations can be a substantial deterrent to the pursuit of legal remedies. In addition, a losing party in a lawsuit usually must reimburse the prevailing party's litigation expenses.' In deciding whether or not to file suit, a potential plaintiff must therefore consider not only his own legal expenses, but also his opponents' expenses" (Miller, 1985; p. 436).

[25] Sinko et al. (2015) study waiting time distributions and find that waiting times for less severe patients have been reducing over-proportionally after the introduction of the maximum waiting time policy in the English NHS across different specialties. This may be interpreted as a move towards a 'first-come-first-serve' prioritisation rule, and is consistent with the increased equity in waiting times that we have observed towards the end of our study period. Gutacker et al. (2016) analyse detailed data on patients' self-reported pre-operative health and still find evidence for severity-based prioritisation in elective hip and knee replacement surgery.

[26] These policies focus on socioeconomic inequalities which arise *within* the hospital, which is the focus of our analysis. This is justified since there are little inequalities in waiting times *across* hospitals in England for the treatments considered. Inequalities across hospitals can be important in some health systems such as Australia (Johar et al., 2013) and could be potentially be addressed by a better allocation of resources. Our study shows that socioeconomic inequality in waiting time *within* hospitals can occur also in universal health systems where allocation of resources between hospitals follows a need based allocation formula.

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Appendix.

Appendix A:

Table A1: Observed waiting times, patients bypassing the closest hospital and distances to closest hospital, by year and income deprivation quintiles

		2002	2003	2004	2005	2006	2007	2008	2009	2010
(a) CABG observed waiting times.	EDI Income 1st quint. (Most Deprived)	171.3	111.3	101.1	67.7	68.0	64.5	55.4	47.1	46.5
	EDI Income 2nd quint.	157.9	109.7	98.5	65.3	67.7	66.6	58.2	51.2	51.1
	EDI Income 3rd quint.	156.3	107.1	101.7	68.9	66.3	62.6	59.6	50.9	52.9
	EDI Income 4th quint.	144.5	104.7	97.6	64.0	64.6	66.4	57.7	48.9	50.5
	EDI Income 5th quint. (Least Deprived)	134.2	97.5	92.4	60.7	63.2	62.1	58.0	49.5	50.6
(b) PCI observed waiting times.	EDI Income 1st quint. (Most Deprived)	102.3	101.4	89.8	58.6	54.3	45.3	37.2	39.4	40.1
	EDI Income 2nd quint.	96.9	99.3	87.7	58.7	53.5	44.5	37.3	41.8	39.7
	EDI Income 3rd quint.	90.6	94.7	83.6	57.5	53.2	44.9	39.0	40.6	39.7
	EDI Income 4th quint.	81.7	88.4	80.2	54.4	52.9	44.3	37.0	40.3	39.0
	EDI Income 5th quint. (Least Deprived)	78.7	81.2	77.2	53.3	48.9	42.5	36.2	38.1	37.9
(c) % CABG bypassing closest hospital.	EDI Income 1st quint. (Most Deprived)	31.8%	35.7%	35.3%	29.2%	28.9%	32.5%	30.0%	30.1%	29.4%
	EDI Income 2nd quint.	38.3%	41.8%	41.0%	36.2%	39.8%	36.8%	37.0%	33.2%	32.7%
	EDI Income 3rd quint.	36.0%	39.6%	38.7%	34.9%	34.3%	35.9%	32.6%	33.9%	31.2%
	EDI Income 4th quint.	35.1%	40.9%	38.1%	35.6%	34.5%	35.7%	36.9%	33.7%	32.3%
	EDI Income 5th quint. (Least Deprived)	38.8%	43.8%	41.6%	38.4%	39.2%	39.2%	37.4%	34.1%	30.6%
(d) % PCI bypassing closest hospital.	EDI Income 1st quint. (Most Deprived)	27.9%	29.2%	27.8%	35.5%	40.8%	40.7%	40.5%	33.5%	34.3%
	EDI Income 2nd quint.	37.5%	39.0%	37.8%	42.9%	45.0%	44.2%	41.6%	37.0%	36.2%
	EDI Income 3rd quint.	36.1%	37.0%	34.2%	39.0%	43.9%	40.8%	39.9%	35.7%	36.7%
	EDI Income 4th quint.	35.5%	37.1%	34.4%	41.0%	44.1%	40.4%	41.6%	35.2%	36.4%
	EDI Income 5th quint. (Least Deprived)	39.5%	41.0%	37.3%	43.7%	46.2%	42.7%	39.4%	36.7%	37.3%
(e) distance to closest CABG hospital.	EDI Income 1st quint. (Most Deprived)	17.6	17.2	16.9	18.5	18.4	17.6	17.8	18.3	17.7
	EDI Income 2nd quint.	23.7	24.8	25.7	26.0	26.2	24.3	23.8	23.2	23.3
	EDI Income 3rd quint.	28.3	27.8	30.1	30.4	32.1	29.0	28.3	29.8	27.9
	EDI Income 4th quint.	28.8	29.8	29.8	30.8	31.4	29.6	28.5	29.8	28.1
	EDI Income 5th quint. (Least Deprived)	26.4	26.3	26.3	27.2	27.9	25.2	26.1	26.6	26.0
(f) distance to closest PCI hospital.	EDI Income 1st quint. (Most Deprived)	15.3	14.9	14.7	12.9	12.0	11.3	10.7	10.6	9.7
	EDI Income 2nd quint.	22.2	21.7	20.8	18.4	15.7	14.9	13.6	13.6	12.9
	EDI Income 3rd quint.	24.9	26.2	25.2	23.1	18.4	18.1	16.1	15.3	14.8
	EDI Income 4th quint.	27.0	27.2	26.9	23.3	19.6	18.1	16.6	16.5	15.9
	EDI Income 5th quint. (Least Deprived)	23.0	22.8	23.5	21.2	18.8	17.3	15.7	16.1	15.2
(g) Δ distance (2nd - 1st) closest CABG hosp.	EDI Income 1st quint. (Most Deprived)	20.2	17.9	18.1	19.6	20.4	21.1	22.4	21.4	21.2
	EDI Income 2nd quint.	20.6	18.4	20.2	20.3	20.9	22.5	23.2	23.6	23.5
	EDI Income 3rd quint.	23.5	21.5	23.5	25.4	25.4	26.1	26.7	25.6	26.1
	EDI Income 4th quint.	23.2	21.3	22.8	22.2	24.4	24.4	24.8	25.4	25.5
	EDI Income 5th quint. (Least Deprived)	19.4	17.3	19.7	20.5	20.5	22.4	21.2	23.1	25.1
(h) Δ distance (2nd - 1st) closest PCI hospital.	EDI Income 1st quint. (Most Deprived)	18.7	18.3	17.7	16.6	15.5	14.7	11.4	12.9	11.3
	EDI Income 2nd quint.	17.0	16.8	17.0	16.3	15.0	15.1	13.3	13.3	12.4
	EDI Income 3rd quint.	19.7	19.5	19.7	18.8	18.4	18.2	15.5	15.6	14.7
	EDI Income 4th quint.	20.0	19.9	19.6	18.2	17.3	16.9	14.7	15.9	14.4
	EDI Income 5th quint. (Least Deprived)	19.0	18.5	18.4	16.3	14.4	14.1	12.5	13.0	11.6

Appendix B: Chow F-test for switching regimes

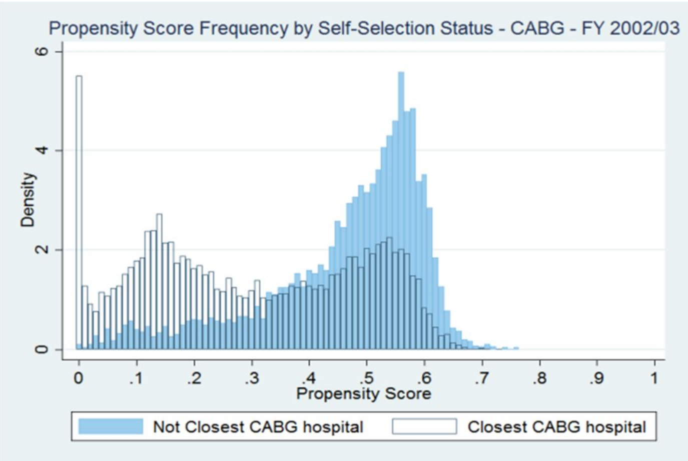
Table B1: Chow F-test for switching regimes.

CHOW test on Procedures (a)									
Years	2002	2003	2004	2005	2006	2007	2008	2009	2010
Chow F-stat value	34.557	19.704	14.357	14.584	16.588	27.703	27.063	12.416	11.108
F-stat 90% C.L.	1.216	1.205	1.205	1.198	1.189	1.183	1.176	1.174	1.170
F-stat 95% C.L.	1.285	1.270	1.270	1.261	1.249	1.240	1.231	1.229	1.223
F-stat 99% C.L.	1.422	1.399	1.399	1.384	1.367	1.353	1.339	1.336	1.327
CHOW test on Closest Hospital Bypassing - CABG sample (b)									
Years	2002	2003	2004	2005	2006	2007	2008	2009	2010
Chow F-stat value	3.432	2.339	2.326	1.278	1.756	1.668	1.466	1.385	1.197
F-stat 90% C.L.	1.228	1.223	1.224	1.228	1.228	1.226	1.224	1.228	1.228
F-stat 95% C.L.	1.301	1.294	1.297	1.301	1.301	1.299	1.297	1.302	1.302
F-stat 99% C.L.	1.447	1.436	1.440	1.447	1.447	1.444	1.440	1.448	1.448
CHOW test on Closest Hospital Bypassing - PCI sample (c)									
Years	2002	2003	2004	2005	2006	2007	2008	2009	2010
Chow F-stat value	3.237	3.776	2.754	3.252	2.403	3.115	2.457	2.545	1.703
F-stat 90% C.L.	1.219	1.212	1.209	1.199	1.190	1.185	1.178	1.176	1.171
F-stat 95% C.L.	1.290	1.280	1.276	1.262	1.251	1.243	1.235	1.231	1.224
F-stat 99% C.L.	1.430	1.414	1.408	1.387	1.369	1.357	1.345	1.340	1.329

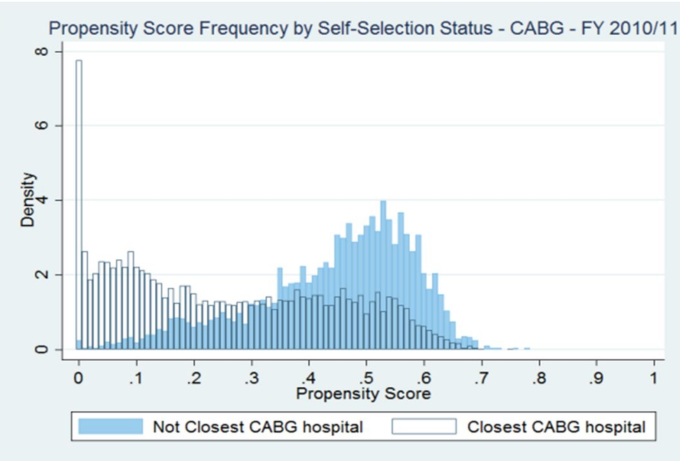
In each year, the Chow F-test rejects the hypothesis of the conditional waiting times for the two revascularisation procedures coming from the same data generating process at 99% confidence level. The test also rejects the hypothesis of conditional waiting times for each procedure coming from the exact same process for people treated or not at their closest hospital site, at 99% confidence level for PCI and at least 95% confidence level for CABG (excluding the last year of the sample). These results support the use of switching regression models as the correct empirical specification for our analysis.

Appendix C: Propensity score by self-selection status.

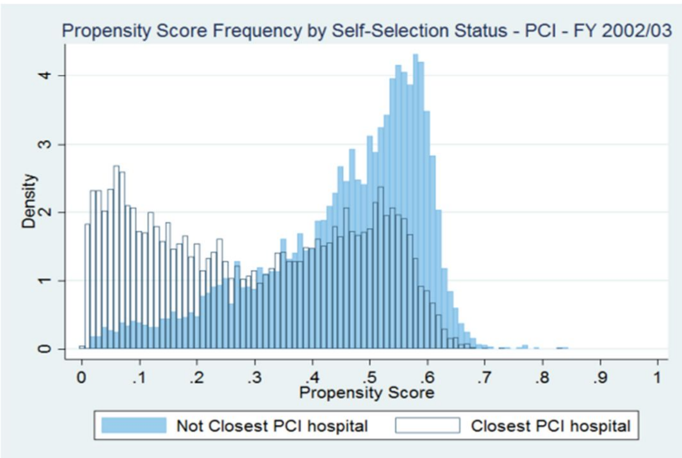
Figure C1: Propensity score by self-selection status.



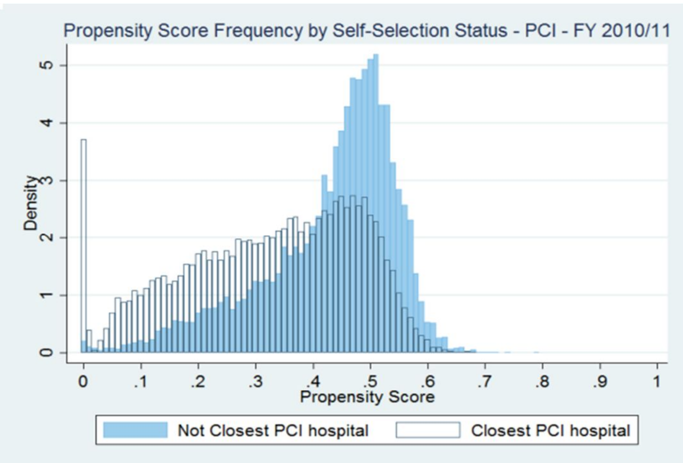
(a) CABG patients - Year 2002/03 - Hospital bypassing



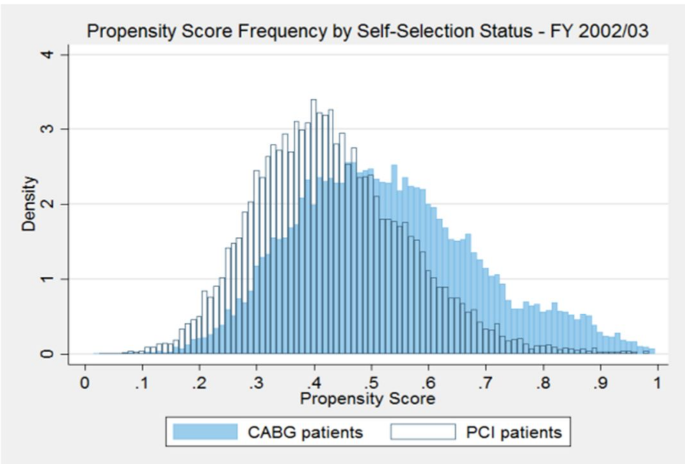
(b) CABG patients - Year 2010/11 - Hospital bypassing



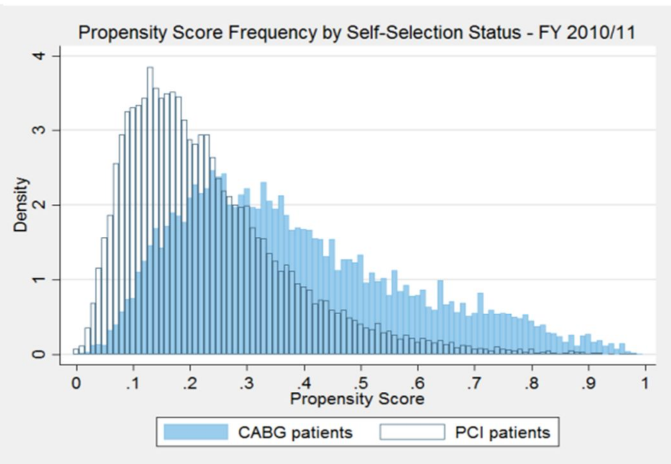
(c) PCI patients - Year 2002/03 - Hospital bypassing



(d) PCI patients - Year 2010/11 - Hospital bypassing



(e) All patients - Year 2002/03 - procedure choice



(f) All patients - Year 2010/11 - procedure choice

In Figure C1 we plot a graphical representation of the estimated parametric propensity score computed in financial years 2002/03 and 2010/11, based on the observable covariates included in the model. The top two graphs in Figure C1 show the propensity score frequency in the CABG sample based on the estimates of Eq.(3), the middle ones show the propensity score frequency in the PCI sample based on the estimates of Eq.(3) and the bottom ones the propensity score frequency in the pooled CABG and PCI patients' sample based on the estimates of Eq.(3).

The plots show the validity of the common support assumption in our models. If patients in the different selection regimes were so different to the point of not being comparable, then the plots in Figure C1 would show a complete lack of overlap of the frequencies of the estimated propensity score by bandwidth (vertical axis). The overlap of the distributions instead is evident. The specification of the first stage probit seems to be capturing adequately the common underlying risk factors behind the self-selection choices and the estimated propensity score for the two treatment subgroups in each plots lies roughly in the same domain (horizontal axis). Hence, the sub-populations of treated patients are still comparable and not too heterogeneous on their observable health risk profiles, when they are split by self-selection regime.

Appendix D: Self-selection model with joint choice of procedure and bypassing of the closest hospital

In Table D1 we show the results for a Roy model for the joint choice of selection into procedure and selection of bypassing the closest hospital. The selection correction is computed parametrically and based on the modification of the Dubin and McFadden (1984) multinomial logit selection correction proposed by Bourguignon et al. (2007). With this method, there are as many selection correction terms as the switching regimes, which are four in our case: two for the choice of closest hospital bypassing and two for choice of procedure. Both exclusion restrictions based on distance are used in the first step multinomial logit regression.

Results. The estimation of the joint model for selection of hospital bypassing and procedure suggests very similar results to those in Table 5 and Table 6. A positive and statistically significant socio-economic gradient is found in each year for CABG patients choosing the closest hospital, as well as for both categories of PCI patients. The estimates of the gradient for CABG patients bypassing the closest hospital show a more erratic behaviour, and are significant for most but not all the years. It is likely that the estimation is fuzzier in this case, as this is also the category with the smallest sample size. However, the results for the remaining three categories clearly show a statistically significant but decreasing socio-economic gradient in waiting time due to income deprivation. The estimated coefficients are larger and always significant in the most income deprived group, for both CABG and PCI patients choosing the closest hospitals. Hence, this confirms that most of the more income-deprived patients needing cardiac revascularisation have been subject to waiting time inequalities due to SES in the English NHS between 2002 and 2010.

References

Dubin, J. A., and McFadden, D. L. (1984). An econometric analysis of residential electric appliance holdings and consumption. Econometrica, 345-362.

Bourguignon, F., Fournier, M., and Gurgand, M. (2007). Selection bias corrections based on the multinomial logit model: Monte Carlo comparisons. Journal of Economic Surveys, 21(1), 174-205.

Table D1: Roy model with joint correction for choice of bypassing the closest hospital and procedure.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	2002	2003	2004	2005	2006	2007	2008	2009	2010
				CABG patients – bypassing the closest hospital					
EDI income 1st quintile	0.1299*	0.2387***	0.2063***	0.0622	0.1413***	0.1615***	0.0655	0.0795	0.0353
EDI income 2nd quintile	0.0790	0.1950***	0.0831*	0.0668*	0.1379***	0.1755***	0.0261	0.1040**	0.1417**
EDI income 3rd quintile	0.0168	0.0845*	0.1577***	0.0674	0.0673	0.1057***	0.1113**	0.0703	0.0235
EDI income 4th quintile	-0.0239	0.0759	0.0348	0.0133	0.0092	0.1384***	0.0815	0.0235	0.0467
Selection correction 1	0.1435	-0.1877*	-0.5304***	-0.1159	0.0304	-0.0157	-0.9992***	-0.1767	-0.1528
Selection correction 2	1.4671**	-0.2402	-1.6556***	-0.9507**	-0.3961	0.0602	-1.3930***	-0.5345	-0.2145
Selection correction 3	1.5134**	0.0629	-0.8693	-0.2172	-0.3878	-0.0589	1.4203**	-0.3329	0.1872
Selection correction 4	1.3843	0.4407	-0.6518	-0.0103	-0.0606	-0.1390	-0.7395	-0.7689	-1.2848**
Constant	5.6196***	4.3065***	3.7506***	3.5749***	3.4398***	3.5693***	4.7056***	3.1947***	3.1095***
				CABG patients – choosing the closest hospital					
EDI income 1st quintile	0.3231***	0.2423***	0.1447***	0.1553***	0.1559***	0.1116***	0.1216***	0.0673**	0.0915**
EDI income 2nd quintile	0.2398***	0.1653***	0.1143***	0.1242***	0.1524***	0.1448***	0.1099***	0.0716**	0.0556
EDI income 3rd quintile	0.1948***	0.0994**	0.1401***	0.1094***	0.0894***	0.0405	0.0789**	0.0040	0.0718**
EDI income 4th quintile	0.0269	0.0683*	0.0763**	0.0746**	0.0435	0.0693**	0.0419	-0.0025	0.0290
Selection correction 1	0.4425**	-0.1876	0.2403	0.3175	-0.2225	-0.3966	0.0094	-0.2023	-0.0819
Selection correction 2	0.2123	-0.3353*	-0.2835	-0.1094	-0.2841*	-0.2369**	0.3056*	0.0511	0.1948*
Selection correction 3	0.9843**	0.5516	0.6292	0.3296	-0.0895	0.4122	-0.0133	-0.0504	-0.2675
Selection correction 4	1.2962**	1.0995*	1.4148**	0.7802	0.2199	0.6098**	-0.4410	-0.2979	-0.5977*
Constant	4.8880***	5.1171***	5.2154***	4.2758***	4.0679***	4.2878***	3.1040***	3.1771***	2.8286***

	PCI patients – bypassing the closest hospital								
EDI income 1st quintile	0.3005***	0.2947***	0.1851***	0.1409***	0.1219***	0.2022***	0.1729***	0.1434***	0.1411***
EDI income 2nd quintile	0.2632***	0.2754***	0.1866***	0.1502***	0.1337***	0.1551***	0.1327***	0.1631***	0.1055***
EDI income 3rd quintile	0.1904***	0.1731***	0.0875**	0.1173***	0.0938***	0.1491***	0.1468***	0.1309***	0.0780***
EDI income 4th quintile	0.0366	0.1146**	-0.0051	0.0474	0.0633**	0.1074***	0.0885***	0.0990***	0.0706**
Selection correction 1	-0.4432	-1.7725**	0.7086	0.7006	-0.9006	0.8850	-1.6384***	-0.6523	-0.6232
Selection correction 2	-1.4632	-1.0162	-0.6435	-0.0597	-1.2222**	0.4955	0.0408	-0.1519	0.1458
Selection correction 3	0.1203	0.4246***	-0.1077	0.0043	-0.0671	-0.0993	0.1486**	-0.2483***	-0.0698
Selection correction 4	0.5363	1.4040**	0.1466	0.2880	-0.6262*	-0.1983	-0.3049	-1.0517***	-0.3934
Constant	3.0727***	3.1742***	4.0644***	3.7554***	2.8033***	3.5259***	2.6148***	2.8115***	3.0442***
	PCI patients – choosing the closest hospital								
EDI income 1st quintile	0.3513***	0.3094***	0.2421***	0.1750***	0.1948***	0.1462***	0.0876***	0.1052***	0.1327***
EDI income 2nd quintile	0.2932***	0.2199***	0.1972***	0.1600***	0.1837***	0.0923***	0.0654***	0.0943***	0.1175***
EDI income 3rd quintile	0.2038***	0.1413***	0.1276***	0.1155***	0.1428***	0.0436*	0.0789***	0.0712***	0.1030***
EDI income 4th quintile	0.1021**	0.1034***	0.0769***	0.0233	0.0711***	0.0360	0.0423**	0.0329	0.0343
Selection correction 1	-0.1947	-0.2666	-0.3714	-0.4835**	-0.4667	-0.9468**	-0.1649	-0.0197	-0.4650*
Selection correction 2	-0.6268	-1.2616***	-1.3795***	-0.3843	0.1909	-0.6834*	-0.8073**	-0.4645	0.0988
Selection correction 3	0.4207	0.4263	-0.1828	-0.1140	0.1630	0.4140**	-0.1878	-0.3433**	-0.3266**
Selection correction 4	0.4816	0.4529**	0.0691	-0.1169	-0.1133	0.1804	-0.0244	-0.1742	-0.3293***
Constant	3.2925***	3.1745***	3.3433***	3.4709***	3.6752***	2.8312***	2.8950***	3.0352***	3.2928***

Notes. Roy model on joint cardiac revascularisation procedures (CABG and PCI) sample based on multinomial logit selection correction. Exclusion restrictions in the 1st stage regression: a) differential distance between second and first hospital site (by procedure); b) (average) distance between the first three hospitals providing CABG and the first three ones providing PCI. Controls: Age, age bands dummies, admission month, Charlson comorbidities dummies, Gender, Number of diagnosis, Emergency Past utilization in the previous year, hospital fixed effects (except for 1st stage multinomial logit regression). * p<0.10, ** p<0.05, *** p<0.01

Appendix E: Fixed effects quantile regressions.

We estimate quantile regression models accounting for hospital fixed effects to test how the gradient differs at different points of the waiting time distribution. Hospital fixed effects are introduced following the method proposed by Canay (2011). Provided that h_j is a pure location shift of the conditional quantile function, the parameters of interest can be consistently identified by running a quantile regression of the difference between the individual outcome and the fixed effects ($\bar{w}_{ijn} = w_{ijn} - h_j$) on the usual covariate set. The outcome equation for the τth conditional quantile (Q_τ) is given by

$$Q_\tau\left(\bar{w}_{ij} \mid y_{ij}, s_{ij}, x_{ij}\right) = \beta_1'(\tau)y_{ij} + \beta_2'(\tau)s_{ij} + \beta_3'(\tau)x_{ij} + Q_\tau\left(\varepsilon_{ij}(\tau)\right) \quad (7)$$

The estimated waiting times by waiting times quantile are computed as $E[W \mid y = g] = \exp\left[\hat{\beta}_{1,1,y}(\tau)\right]$.

Figure E 1 shows the estimated waiting times for the first, third and fifth SES quintile groups, at the 25th and 75th quantiles of the waiting times distribution (the full results for quantile regressions are provided in Tables E 1 and E 2). Socioeconomic inequalities are found both when the waiting times are short (25th quantile) or long (75th quantile). Hence, inequalities affected the entire waiting time distribution and were not confined to hospitals with either relatively short or long waiting times.

A larger relative socioeconomic gradient in waiting times is found at lower conditional waiting times (25th quantile), for both CABG and PCI patients, across all years. This pattern is consistent with severely ill patients, who have a relatively short expected waiting time but a larger risk of dying while waiting, having a greater incentive to play the system than those in less severe conditions. In line with previous results, the relative income gradient decreases almost monotonically over time.

Quantile regressions results show that inequalities are pervasive and present across the waiting time distribution.

Table E1: Quantile Regression with hospital fixed effects (Equation (7)). Income inequalities in waiting times. CABG patients.

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		2002	2003	2004	2005	2006	2007	2008	2009	2010
Q10	EDI income 1st quintile	0.4781***	0.3623***	0.1852**	0.2308***	0.1857**	0.2108**	0.1797**	0.1173*	0.1224
	EDI income 2nd quintile	0.3441***	0.2063**	0.1333	0.3140***	0.2455**	0.3423***	0.1507*	0.1380*	0.0968
	EDI income 3rd quintile	0.1438	0.1042	0.3044***	0.2311***	0.1746*	0.2012**	0.1857**	0.0525	0.0831
	EDI income 4th quintile	0.0392	0.0204	0.0742	0.1675**	0.0227	0.2250***	0.1355*	0.1347**	0.0665
	Constant	2.6351***	2.7324***	2.4530***	2.2791***	2.4700***	2.5190***	2.5164***	2.2392***	2.1420***
Q25	EDI income 1st quintile	0.4076***	0.2912***	0.2459***	0.1217***	0.1500***	0.1073**	0.1029**	0.0274	0.0860*
	EDI income 2nd quintile	0.2803***	0.2719***	0.1611***	0.1403***	0.1658***	0.2006***	0.0201	0.0964**	0.0801*
	EDI income 3rd quintile	0.2522***	0.1281**	0.2197***	0.1473***	0.1407***	0.0958**	0.0925**	0.0676	0.1162***
	EDI income 4th quintile	0.0645	0.1213**	0.1196**	0.1193**	0.0463	0.1552***	0.0445	0.0054	0.0747*
	Constant	3.6949***	3.6300***	3.6097***	3.3185***	3.4895***	3.4133***	3.2577***	3.0262***	2.9401***
Q50	EDI income 1st quintile	0.3345***	0.1708***	0.1266***	0.0981***	0.0909***	0.0547***	0.0417*	0.0500*	0.0348
	EDI income 2nd quintile	0.2652***	0.1521***	0.0754**	0.0649***	0.0902***	0.0586***	0.0473**	0.0400	0.0556*
	EDI income 3rd quintile	0.1997***	0.0900***	0.0758***	0.0503***	0.0537***	0.0145	0.0157	0.0177	0.0717**
	EDI income 4th quintile	0.0776**	0.0831***	0.0688***	0.0220	0.0123	0.0097	0.0121	-0.0058	0.0449
	Constant	4.4834***	4.2945***	4.3179***	3.9716***	3.9942***	3.8896***	3.7613***	3.6483***	3.6208***
Q75	EDI income 1st quintile	0.1666***	0.1572***	0.1038***	0.1110***	0.0733***	0.0914***	0.0478**	0.0699***	0.0611**
	EDI income 2nd quintile	0.1154***	0.1267***	0.0583***	0.0722***	0.0678***	0.0676***	0.0580***	0.0713***	0.0764***
	EDI income 3rd quintile	0.0943***	0.0758***	0.0417**	0.0536***	0.0123	0.0025	-0.0035	-0.0064	0.0165
	EDI income 4th quintile	0.0158	0.0513**	0.0130	0.0115	0.0007	0.0188	0.0009	-0.0169	0.0206
	Constant	5.0263***	4.7974***	4.8169***	4.2386***	4.2504***	4.2022***	4.1475***	4.1075***	4.0677***
Q90	EDI income 1st quintile	0.1246***	0.1572***	0.1269***	0.2071***	0.1492***	0.1270***	0.0634**	0.1068***	0.0931**
	EDI income 2nd quintile	0.0673**	0.0826***	0.0832***	0.0963***	0.0672**	0.1195***	0.0547**	0.0808***	0.0730**
	EDI income 3rd quintile	0.0729***	0.0235	0.0261	0.1418***	0.0097	0.0181	-0.0061	0.0186	-0.0086
	EDI income 4th quintile	-0.0398	0.0064	0.0114	0.0423	0.0064	0.0492*	-0.0252	-0.0341	-0.0359
	Constant	5.4508***	5.2016***	5.1144***	4.4868***	4.5393***	4.5039***	4.4267***	4.3707***	4.4607***
	Patients	14654	14213	14074	12060	11536	12218	11829	10000	8888

Notes. Sample: CABG patients only. Controls: Age, age bands dummies, Charlson comorbidities dummies, Gender, Number of diagnosis, Emergency Past utilization in the previous year, hospital fixed effects. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table E2: Quantile Regression with hospital fixed effects (Equation (7)). Income inequalities in waiting times. PCI patients.

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		2002	2003	2004	2005	2006	2007	2008	2009	2010
Q10	EDI income 1st quintile	0.5347***	0.6444***	0.4813***	0.3905***	0.4859***	0.4600***	0.2968***	0.3182***	0.3839***
	EDI income 2nd quintile	0.4944***	0.5205***	0.4590***	0.4294***	0.4193***	0.3107***	0.2569***	0.2808***	0.3241***
	EDI income 3rd quintile	0.3526***	0.2711***	0.2661***	0.2765***	0.3062***	0.2480***	0.2604***	0.2150***	0.2933***
	EDI income 4th quintile	0.1697***	0.1847***	0.1071*	0.0948*	0.1548***	0.1789***	0.1513***	0.1225**	0.1468***
	Constant	2.2762***	2.1458***	2.6752***	2.4491***	2.3963***	1.9818***	2.1178***	2.0808***	2.0726***
Q25	EDI income 1st quintile	0.5478***	0.4538***	0.3173***	0.2200***	0.2393***	0.1999***	0.1251***	0.1640***	0.1394***
	EDI income 2nd quintile	0.4572***	0.3758***	0.2781***	0.1969***	0.2126***	0.1406***	0.1156***	0.1771***	0.1437***
	EDI income 3rd quintile	0.2863***	0.2468***	0.1435***	0.1612***	0.1671***	0.1349***	0.1197***	0.1322***	0.1216***
	EDI income 4th quintile	0.0950*	0.1418***	0.1018***	0.0475	0.0994***	0.1159***	0.0722***	0.0731***	0.0756***
	Constant	3.1844***	3.3229***	3.5771***	3.2415***	3.2364***	2.8132***	2.8449***	2.8313***	2.8654***
Q50	EDI income 1st quintile	0.4000***	0.2463***	0.1590***	0.0902***	0.0993***	0.0637***	0.0575***	0.0667***	0.0762***
	EDI income 2nd quintile	0.3139***	0.2306***	0.1374***	0.0882***	0.0977***	0.0580***	0.0590***	0.0527***	0.0706***
	EDI income 3rd quintile	0.1906***	0.1495***	0.0633***	0.0762***	0.0585***	0.0616***	0.0710***	0.0507***	0.0624***
	EDI income 4th quintile	0.0580*	0.1045***	0.0477**	0.0155	0.0382***	0.0446***	0.0367**	0.0239	0.0427***
	Constant	4.0244***	4.2324***	4.1930***	3.8407***	3.7552***	3.4175***	3.3684***	3.3757***	3.3635***
Q75	EDI income 1st quintile	0.2892***	0.1276***	0.0786***	0.0560***	0.0475***	0.0433***	0.0336**	0.0429***	0.0331**
	EDI income 2nd quintile	0.2042***	0.1341***	0.0629***	0.0592***	0.0642***	0.0433***	0.0300**	0.0398***	0.0444***
	EDI income 3rd quintile	0.1620***	0.0748***	0.0238	0.0477***	0.0346***	0.0194	0.0302**	0.0313**	0.0353***
	EDI income 4th quintile	0.0418	0.0504***	-0.0057	0.0095	0.0180	0.0181	0.0139	0.0192	0.0136
	Constant	4.6330***	4.7744***	4.6121***	4.1564***	4.1107***	3.8019***	3.7545***	3.7348***	3.7794***
Q90	EDI income 1st quintile	0.2444***	0.1234***	0.0630***	0.0330**	0.0417***	0.0212	0.0190	0.0263	0.0100
	EDI income 2nd quintile	0.1551***	0.0939***	0.0611***	0.0401***	0.0645***	0.0211	0.0277	0.0313*	0.0300
	EDI income 3rd quintile	0.1178***	0.0352	0.0184	0.0106	0.0480***	-0.0083	0.0167	0.0252	0.0116
	EDI income 4th quintile	0.0346	0.0021	-0.0075	-0.0168	0.0272**	-0.0109	0.0029	0.0107	-0.0163
	Constant	5.0896***	5.1053***	4.9312***	4.3945***	4.3773***	4.1261***	4.0557***	4.0240***	4.0714***
	Patients	16095	20140	24355	25632	26772	25545	25399	23861	23759

Notes. Sample: PCI patients only. Controls: Age, age bands dummies, Charlson comorbidities dummies, Gender, Number of diagnosis, Emergency Past utilization in the previous year, hospital fixed effects. * p<0.10, ** p<0.05, *** p<0.01

Appendix F: Robustness checks on Roy Model on closest hospital bypassing.

Table F1. Roy model. Income inequalities in CABG waiting times, with selection of hospital based on distance, quality and waiting times

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	2002	2003	2004	2005	2006	2007	2008	2009	2010
Patients not choosing the closest CABG hospital site – Equation (4)									
EDI income 1st quintile	0.1599***	0.2297***	0.2269***	0.0821*	0.1427***	0.1516***	0.0183	0.0952**	0.0657
EDI income 2nd quintile	0.1082**	0.1919***	0.0858*	0.0796**	0.1351***	0.1723***	0.0150	0.1087**	0.1577***
EDI income 3rd quintile	0.0462	0.0944*	0.1560***	0.0716*	0.0689	0.0739*	0.0656	0.0720	0.0232
EDI income 4th quintile	-0.0060	0.0773	0.0383	0.0273	0.0104	0.0923**	0.0140	0.0261	0.0488
IMR1 - Not closest	0.0676	0.2534***	0.2603***	0.0116	-0.0463	0.0880**	0.1386***	0.0217	-0.0674
Constant	4.3409***	4.2039***	4.3749***	3.7719***	3.7315***	3.7080***	3.6457***	3.5746***	3.3679***
Patients choosing the closest CABG hospital site – Equation (5)									
EDI income 1st quintile	0.3657***	0.2529***	0.1476***	0.1678***	0.1759***	0.1150***	0.1100***	0.0689**	0.1019***
EDI income 2nd quintile	0.2710***	0.1859***	0.1166***	0.1401***	0.1523***	0.1522***	0.0985***	0.0708**	0.0607*
EDI income 3rd quintile	0.2168***	0.1051***	0.1290***	0.1168***	0.0932***	0.0514	0.0683**	0.0057	0.0850**
EDI income 4th quintile	0.0423	0.0566	0.0694**	0.0880***	0.0512	0.0781**	0.0433	-0.0010	0.0268
IMR0 – Closest	-0.0273	-0.0237	-0.0919**	-0.0237	0.0270	-0.0195	0.0426	-0.0043	0.0692*
Constant	4.1944***	4.2033***	4.0651***	3.6272***	3.7028***	3.7162***	3.6197***	3.4278***	3.4190***
1st Stage Probit for Choice of provider by distance: CLOSEST vs NOT CLOSEST hospital - only CABG – Equation (3)									
Distance difference 2nd - 1st provider	-0.0351***	-0.0183***	-0.0202***	-0.0318***	-0.0367***	-0.0320***	-0.0299***	-0.0318***	-0.0385***
Δq (difference in CABG mortality rates)	0.0268	0.0280**	0.0357***	0.1075***	-0.0346**	-0.0517***	-0.1481***	-0.1537***	-0.2211***
Δw (difference in CABG long waits)	-1.0344***	-0.4551***	-0.8113***	-0.7125***	0.0482	-0.4762***	-0.0667	0.8455***	1.2529***
Specialist closest hospital	0.0287	-0.1089**	-0.1395***	-0.0652	-0.0140	-0.1033	-0.1518**	-0.0242	-0.1847**
EDI income 1st quintile	-0.1875***	-0.1483***	-0.1890***	-0.2837***	-0.3223***	-0.2513***	-0.2956***	-0.2382***	-0.2218***
EDI income 2nd quintile	-0.0229	0.0110	-0.0132	-0.0948**	-0.0142	-0.1419***	-0.0584	-0.0815*	-0.0425
EDI income 3rd quintile	-0.0257	-0.0260	-0.0189	-0.0253	-0.0807**	-0.0956**	-0.1003**	-0.0030	-0.0288
EDI income 4th quintile	-0.0355	0.0048	-0.0417	-0.0486	-0.0664	-0.1320***	0.0097	0.0151	0.0341
Constant	0.2815***	0.0264	0.0895	0.2007***	0.2780***	0.1744***	0.1050	0.1946***	0.3120***
Patients	14654	13678	14074	12060	11536	11245	11635	10000	8888
Chi-squared p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.15	0.08	0.09	0.16	0.19	0.16	0.16	0.16	0.20

Notes. Sample: CABG patients only. Controls: Age, age bands dummies, Charlson comorbidities dummies, Gender, Number of diagnosis, Emergency Past utilization in the previous year, hospital fixed effects (in Eq.(4) and (5) only). * p<0.10, ** p<0.05, *** p<0.01

Table F2. Roy model. Income inequalities in PCI waiting times, with selection of hospital based on distance, quality and waiting times

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	2002	2003	2004	2005	2006	2007	2008	2009	2010
Patients not choosing the closest PCI hospital site – Equation (4)									
EDI income 1st quintile	0.4109***	0.2626***	0.2011***	0.1527***	0.1303***	0.2050***	0.1225***	0.1496***	0.1245***
EDI income 2nd quintile	0.3289***	0.2338***	0.2118***	0.1664***	0.1066***	0.1604***	0.1404***	0.1592***	0.1038***
EDI income 3rd quintile	0.2501***	0.1143**	0.1198***	0.1270***	0.0984***	0.1425***	0.1130***	0.1212***	0.0701**
EDI income 4th quintile	0.0616	0.0767*	0.0161	0.0707**	0.0652**	0.1171***	0.0358	0.0967***	0.0565*
IMR1 - Not closest	-0.0855*	-0.0408	-0.0302	-0.0341	-0.0126	-0.0521	-0.0226	0.0451	-0.0076
Constant	3.5364***	3.8925***	3.8744***	3.3853***	3.5481***	3.1311***	3.1944***	3.2669***	3.2044***
Patients choosing the closest PCI hospital site – Equation (5)									
EDI income 1st quintile	0.4365***	0.3239***	0.2519***	0.1862***	0.1880***	0.1345***	0.1047***	0.1054***	0.1386***
EDI income 2nd quintile	0.3466***	0.2400***	0.2022***	0.1837***	0.1864***	0.1036***	0.0755***	0.0872***	0.1235***
EDI income 3rd quintile	0.2410***	0.1470***	0.1207***	0.1326***	0.1327***	0.0519**	0.0880***	0.0668***	0.1086***
EDI income 4th quintile	0.1327***	0.0924***	0.0808***	0.0342	0.0709***	0.0276	0.0375*	0.0296	0.0353*
IMR0 – Closest	0.1191***	0.0223	-0.0040	-0.0152	-0.0408*	0.0049	-0.0038	0.0257	0.0241
Constant	3.8224***	3.9053***	3.9699***	3.6210***	3.5696***	3.2635***	3.2400***	3.1571***	3.2163***
1st Stage Probit for Choice of provider by distance: CLOSEST vs NOT CLOSEST hospital - only PCI – Equation (3)									
Distance difference 2nd - 1st provider	-0.0374***	-0.0416***	-0.0420***	-0.0512***	-0.0477***	-0.0195***	-0.0322***	-0.0412***	-0.0450***
Δq (difference in PCI mortality rates)	0.0473*	0.2004***	0.6574***	-0.2752***	-0.1853***	0.5335***	0.0298*	0.1716***	0.6811***
Δw (difference in PCI long waits)	-0.8491***	-0.6840***	-0.1305***	0.1888***	1.0622***	0.5846***	-0.2134***	0.2489***	1.0689***
Specialist closest hospital	0.0150	0.0285	0.0464	0.0996*	-0.4429***	-0.4665***	-1.0110***	-0.8188***	-0.3209***
EDI income 1st quintile	-0.4033***	-0.2966***	-0.3241***	-0.3528***	-0.1135***	-0.0472	-0.0022	-0.1492***	-0.1918***
EDI income 2nd quintile	-0.1345***	-0.0940***	-0.0460	-0.0747**	-0.0335	0.0637**	0.1000***	-0.0145	-0.1131***
EDI income 3rd quintile	-0.1082***	-0.0341	-0.0540*	-0.0824**	-0.0008	0.0810***	0.0770***	0.0206	-0.0101
EDI income 4th quintile	-0.1433***	-0.0231	-0.0457	-0.0092	-0.0353	0.0428	0.0932***	0.0208	0.0178
Constant	0.2801***	0.2235***	0.2040***	0.2473***	0.3624***	-0.0829*	0.0004	0.0594	0.1675***
Patients	15600	18413	23668	20524	23470	21814	22767	22609	22196
Chi-squared p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.16	0.18	0.19	0.20	0.16	0.07	0.09	0.11	0.14

Notes. Sample: PCI patients only. Controls: Age, age bands dummies, Charlson comorbidities dummies, Gender, Number of diagnosis, Emergency Past utilization in the previous year, hospital fixed effects (in Eq.(4) and (5) only). * p<0.10, ** p<0.05, *** p<0.01

Appendix G: Robustness checks on Roy model with selection on heart revascularization procedure.

Table G1. Roy Model estimates with selection of procedure, including interactions of SES indicators with comorbidities and past emergency admissions.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	2002	2003	2004	2005	2006	2007	2008	2009	2010
Patients choosing CABG – Equation (4)									
EDI income 1st quintile	0.3700***	0.2246***	0.1630***	0.1352***	0.1582***	0.1263***	0.0695***	0.0785***	0.0953***
EDI income 2nd quintile	0.2615***	0.1724***	0.1034***	0.1160***	0.1443***	0.1621***	0.0676***	0.0814***	0.0938***
EDI income 3rd quintile	0.1929***	0.0898***	0.1408***	0.0989***	0.0867***	0.0717***	0.0479**	0.0268	0.0691**
EDI income 4th quintile	0.0477	0.0656**	0.0595**	0.0642**	0.0334	0.0949***	0.0243	0.0082	0.0292
IMR1 - CABG	-0.6570**	0.6399**	0.5899***	-0.0316	0.2994	0.0443	-0.1516	0.0696	0.1594
Constant	3.8657***	4.5790***	4.2556***	3.6980***	4.1648***	3.9892***	3.2212***	3.1647***	3.3939***
Patients choosing PCI – Equation (5)									
EDI income 1st quintile	0.4928***	0.3122***	0.2289***	0.1675***	0.1672***	0.1664***	0.1096***	0.1207***	0.1391***
EDI income 2nd quintile	0.3893***	0.2585***	0.1982***	0.1643***	0.1633***	0.1185***	0.0987***	0.1208***	0.1221***
EDI income 3rd quintile	0.2743***	0.1566***	0.1119***	0.1201***	0.1181***	0.0896***	0.0987***	0.0895***	0.0924***
EDI income 4th quintile	0.1328***	0.0988***	0.0502**	0.0420**	0.0667***	0.0674***	0.0497***	0.0548***	0.0524***
IMR0 - PCI	-0.6769*	0.4395	0.1547	-0.2085	0.1113	0.2402	-0.2050	-0.3411**	-0.3898***
Constant	4.1241***	3.6822***	3.9812***	3.7254***	3.4458***	2.9850***	3.5187***	3.3813***	3.3805***
1st Stage Probit for Choice of procedure: CABG vs PCI – Equation (3), including (past admissions, co-morbidities) * SES interactions									
Differential distance of first 3 hospitals by procedure	-0.0016***	0.0001	-0.0013***	-0.0008**	-0.0004	0.0009***	-0.0003	-0.0008**	-0.0020***
EDI income 1st quintile	0.1829***	0.0212	-0.0019	0.0630**	0.0333	0.0171	0.0111	0.0473*	0.0232
EDI income 2nd quintile	0.1234***	0.0217	-0.0337	0.0693***	0.0000	0.0262	0.0388	0.0390	0.0213
EDI income 3rd quintile	0.1006***	-0.0065	-0.0487**	0.0345	-0.0291	0.0245	0.0047	0.0456*	-0.0362
EDI income 4th quintile	0.0738***	-0.0174	-0.0403*	0.0631**	0.0141	0.0103	-0.0314	0.0031	0.0522*
Number of comorbidities (N.C.)	0.1112***	0.1044***	0.1116***	0.1245***	0.1424***	0.1496***	0.1659***	0.1693***	0.1941***
EDI income 1st quintile * N.C.	0.0205*	0.0068	-0.0075	-0.0202**	-0.0238***	-0.0213**	-0.0062	-0.0167*	-0.0385***
EDI income 2nd quintile * N.C.	0.0067	0.0143	0.0043	-0.0224**	-0.0112	-0.0129	-0.0136	-0.0065	-0.0172*
EDI income 3rd quintile * N.C.	0.0165	0.0001	0.0185**	-0.0134	0.0034	-0.0013	-0.0056	-0.0055	-0.0078
EDI income 4th quintile * N.C.	-0.0020	0.0081	0.0134	0.0067	-0.0002	-0.0013	-0.0120	-0.0035	0.0023
Number of past year emergency admissions (N.P.A.)	-0.1417***	-0.1405***	-0.1884***	-0.0939***	-0.1324***	-0.1072***	-0.1250***	-0.0657**	-0.1710***
EDI income 1st quintile * N.P.A.	-0.0025	-0.0024	0.0869***	-0.0378	0.0082	-0.0287	-0.0371	-0.1140***	-0.0162
EDI income 2nd quintile * N.P.A.	0.0128	0.0358	0.1097***	0.0059	0.0254	-0.0278	-0.0201	-0.0676*	-0.0161
EDI income 3rd quintile * N.P.A.	-0.0293	0.0345	0.0885**	0.0209	0.0321	-0.0028	-0.0172	-0.1165***	0.0179
EDI income 4th quintile * N.P.A.	-0.0306	-0.0103	0.0693**	-0.0262	-0.0436	-0.0529	0.0179	-0.0048	-0.0824**
Constant	-0.0760**	-0.1647***	-0.2912***	-0.4942***	-0.4229***	-0.3062***	-0.3803***	-0.4830***	-0.5787***
Patients	30749	34353	38429	37692	38308	37763	37228	33861	32647
Chi^2 p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.07	0.07	0.07	0.07	0.08	0.08	0.10	0.10	0.13

Notes. Sample: CABG and PCI patients. Controls: Age, age bands dummies, Charlson comorbidities dummies, Gender, Number of diagnosis, Emergency Past utilization in the previous year, hospital fixed effects (in Eq.(4) and (5) only). * p<0.10, ** p<0.05, *** p<0.01

Table G2. Roy Model estimates with selection of procedure, including differential Length of Stay and interactions of Length of Stay with SES indicators.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	2002	2003	2004	2005	2006	2007	2008	2009	2010
Patients choosing CABG – Equation (4)									
EDI income 1st quintile	0.3205***	0.2336***	0.1647***	0.1350***	0.1536***	0.1261***	0.0661**	0.0784***	0.0928***
EDI income 2nd quintile	0.2294***	0.1752***	0.1029***	0.1165***	0.1420***	0.1630***	0.0705***	0.0810***	0.0925***
EDI income 3rd quintile	0.1681***	0.0905***	0.1398***	0.0992***	0.0871***	0.0737***	0.0469*	0.0267	0.0679**
EDI income 4th quintile	0.0323	0.0677**	0.0585**	0.0647**	0.0338	0.0943***	0.0193	0.0081	0.0300
IMR1 - CABG	-0.2822	0.6291**	0.4279*	-0.0481	0.3363	-0.0887	-0.3686**	0.1015	0.1415
Constant	4.1918***	4.5481***	4.0854***	3.6809***	4.2090***	3.8500***	2.9991***	3.2006***	3.3729***
Patients choosing PCI – Equation (5)									
EDI income 1st quintile	0.4683***	0.3166***	0.2305***	0.1648***	0.1671***	0.1669***	0.1093***	0.1183***	0.1362***
EDI income 2nd quintile	0.3734***	0.2589***	0.1980***	0.1615***	0.1633***	0.1199***	0.0961***	0.1213***	0.1214***
EDI income 3rd quintile	0.2652***	0.1572***	0.1102***	0.1185***	0.1180***	0.0914***	0.0984***	0.0895***	0.0904***
EDI income 4th quintile	0.1245***	0.0986***	0.0487**	0.0401**	0.0666***	0.0671***	0.0511***	0.0545***	0.0543***
IMR0 - PCI	-0.5246**	0.4311	0.0046	-0.1432	0.1239	0.0965	-0.0627	-0.5403***	-0.5110***
Constant	4.0248***	3.6747***	4.0732***	3.6952***	3.4396***	3.0741***	3.4367***	3.4918***	3.4448***
1st Stage Probit for Choice of procedure: CABG vs PCI – Equation (3), including average ΔLoS and average ΔLoS *SES interactions									
Differential distance of first 3 hospitals by procedure	-0.0001	0.0010**	-0.0007**	-0.0001	-0.0008**	0.0005	0.0004	-0.0007*	-0.0020***
ΔLoS in closest 5 Hospitals	-0.0619**	-0.0476***	0.0081	-0.0756***	0.0711***	-0.0055	-0.1123***	-0.0100	0.0049
EDI income 1st quintile	1.1201***	0.1568	0.4020*	-0.7123**	-0.1391	-1.3146***	-1.5008***	0.5644	0.0817
EDI income 2nd quintile	1.2468***	0.1539	0.2165	0.0835	0.4529	-0.5776**	-0.6765**	-0.0339	0.1988
EDI income 3rd quintile	1.1523***	0.1863	0.7270***	-0.0288	0.3903	-0.1376	-0.3096	-0.2154	-0.1191
EDI income 4th quintile	0.9034***	-0.2348	0.1402	-0.1626	0.0277	-0.5212*	-0.9035***	-0.0021	0.4259
EDI income 1st quintile * ΔLoS	-0.1027***	-0.0166	-0.0388*	0.0742**	0.0181	0.1280***	0.1521***	-0.0581	-0.0084
EDI income 2nd quintile * ΔLoS	-0.1194***	-0.0130	-0.0217	-0.0044	-0.0439	0.0572**	0.0702**	0.0047	-0.0182
EDI income 3rd quintile * ΔLoS	-0.1124***	-0.0190	-0.0737***	0.0052	-0.0402	0.0157	0.0303	0.0217	0.0086
EDI income 4th quintile * ΔLoS	-0.0890**	0.0207	-0.0156	0.0217	-0.0025	0.0495*	0.0876***	0.0003	-0.0383
Constant	0.5213**	0.3131**	-0.3932**	0.2788	-1.1460***	-0.2439	0.7439***	-0.3610	-0.6208*
Patients	30749	34353	38429	37692	38308	37763	37228	33861	32647
Chi^2 p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.08	0.07	0.07	0.07	0.08	0.08	0.10	0.10	0.13

Notes. Sample: CABG and PCI patients. Controls: Age, age bands dummies, Charlson comorbidities dummies, Gender, Number of diagnosis, Emergency Past utilization in the previous year, hospital fixed effects (in Eq.(4) and (5) only). * p<0.10, ** p<0.05, *** p<0.01

Table G3. Full estimates of Roy Model in Table 8 (excluding hospital sites fixed effects). Income inequalities in waiting times on CABG and PCI samples, after accounting for selection of revascularisation procedure.

	(1) 2002	(2) 2003	(3) 2004	(4) 2005	(5) 2006	(6) 2007	(7) 2008	(8) 2009	(9) 2010
Panel A - Patients choosing CABG – Equation (4)									
EDI income 1st quintile (most deprived)	0.3605***	0.2238***	0.1614***	0.1319***	0.1544***	0.1260***	0.0695***	0.0783***	0.0927***
EDI income 2nd quintile	0.2557***	0.1711***	0.1028***	0.1107***	0.1425***	0.1623***	0.0708***	0.0809***	0.0925***
EDI income 3rd quintile	0.1868***	0.0894***	0.1423***	0.0959***	0.0878***	0.0724***	0.0481*	0.0267	0.0679**
EDI income 4th quintile	0.0450	0.0685**	0.0602**	0.0578**	0.0336	0.0947***	0.0225	0.0080	0.0300
Patient age	0.0041	-0.0020	0.0014	-0.0007	0.0009	0.0040	0.0032	-0.0014	0.0067**
age range 0-39 years	-0.1175	-0.1880	0.0379	0.0296	0.1356	-0.0293	-0.1390	-0.1620	0.0222
age range 40-49 years	-0.1383	-0.0089	0.1460**	-0.1085	-0.0394	0.0071	-0.0225	-0.0636	0.0849
age range 50-59 years	-0.0655	0.0160	0.0340	-0.0243	0.0077	-0.0141	-0.0204	-0.0555	0.0363
age range 70-79 years	0.0392	-0.0382	-0.0374	0.0457	-0.0027	-0.0010	-0.0089	0.0219	-0.0055
age range over 80 years	-0.2443**	0.0540	0.0691	0.1356	0.1592*	-0.0246	-0.0897	0.0519	-0.0369
Female patient	-0.0470	0.2396***	0.2003***	0.0798	0.1274*	0.0385	-0.0048	0.0918	0.0223
Number of Comorbidities	0.0402*	-0.0330	-0.0350*	0.0040	-0.0287	0.0153	0.0456*	-0.0049	-0.0106
Past Year Emergency Admissions	-0.3317***	-0.1760***	-0.1584***	-0.1233***	-0.0795***	-0.1183***	-0.1542***	-0.0571**	-0.0619**
Congestive Heart Failure	0.2622**	-0.3133**	-0.1999**	-0.1132	-0.0627	0.0255	0.0400	-0.0085	0.0047
Peripheral Vascular Disease	0.1157**	-0.0566	-0.0223	0.0208	0.0297	0.0183	0.0118	0.0287	-0.0175
Cerebrovascular Disease	0.1314	-0.1396	-0.1803*	0.0570	-0.0457	-0.0310	-0.0754	-0.0383	0.0025
Chronic Obstructive Pulmonary Disease (COPD)	0.0319	0.1578***	0.1172***	0.0572*	0.0495	-0.0197	0.0172	-0.0114	0.0553*
Rheumatoid Disease	-0.1438	-0.0723	0.0337	-0.0684	-0.0643	0.0114	-0.0199	-0.0017	0.0346
Peptic Ulcer Disease	-0.0701	0.0615	0.0074	0.0011	-0.0928	-0.1765	0.0120	-0.1600	-0.2659*
Mild Liver Disease	-0.0901	0.0450	-0.1702	0.1877	0.4365***	-0.1830	0.0515	0.2816**	0.1551
Diabetes	0.0714**	0.0644**	0.0758***	0.0322	0.0329*	0.0262	0.0199	0.0426*	0.0695***
Diabetes + Complications	0.0167	0.0195	0.1485	0.0798	0.2272***	0.0329	0.0705	0.1671**	0.0756
Renal Disease	0.1017	0.1187*	0.0534	0.0868	0.0459	0.0781	0.0588	0.1023**	0.0291
Cancer	-0.2728**	-0.1908	-0.1763	-0.4280***	-0.1193	-0.4230***	-0.4257***	0.1096	-0.3735***
Jan	0.1689***	0.0814*	0.1217***	0.2626***	0.1461***	0.1662***	0.1621***	0.1289***	0.1933***
Feb	0.0438	0.1891***	0.1061**	0.1987***	0.0951**	0.1177***	0.0740*	0.0844*	0.2846***
Mar	0.0640	0.1113**	0.0271	0.1936***	0.0219	0.0606	0.0096	0.0432	0.1066**
April	0.2830***	-0.1214**	0.1006**	0.1361***	0.0887**	0.0671	0.1383***	0.1264***	0.0844
May	0.2199***	-0.0741	0.0348	0.0869*	0.1446***	0.1075**	0.0802*	0.1149**	0.0424
June	0.3488***	-0.0313	-0.0318	0.1007**	0.0988**	0.1292***	0.1136***	0.0981**	0.0563
July	0.2906***	-0.0521	0.0794*	0.0429	0.0644	0.0728*	0.1296***	0.0664	-0.0385
Aug	0.2546***	-0.0690	0.0355	-0.0039	0.0832**	0.0669*	0.1992***	0.0266	-0.0311
Sept	0.3280***	-0.1379***	0.0652	0.0872**	0.0971**	0.0752*	0.1818***	0.0587	0.0681
Oct	0.2415***	-0.0355	0.0496	0.0684	0.0431	0.1141***	0.0763*	-0.0397	0.0371
IMR1 - CABG	-0.5930**	0.7736**	0.5971**	0.1162	0.3761	-0.0025	-0.2828	0.1087	0.1413
Constant	3.9205***	4.7000***	4.2609***	3.8637***	4.2500***	3.9414***	3.0829***	3.2087***	3.3728***
Hospital sites Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES

Panel B - Patients choosing PCI – Equation (5)									
EDI income 1st quintile (most deprived)	0.5063***	0.3105***	0.2323***	0.1661***	0.1688***	0.1670***	0.1093***	0.1189***	0.1364***
EDI income 2nd quintile	0.3974***	0.2556***	0.1977***	0.1622***	0.1638***	0.1193***	0.0988***	0.1215***	0.1214***
EDI income 3rd quintile	0.2819***	0.1568***	0.1083***	0.1189***	0.1171***	0.0903***	0.0985***	0.0898***	0.0906***
EDI income 4th quintile	0.1365***	0.0998***	0.0469**	0.0406**	0.0667***	0.0672***	0.0486***	0.0547***	0.0541***
Patient age	0.0039	0.0012	0.0022	0.0023	0.0039**	0.0039**	0.0045**	0.0031	-0.0003
age range 0-39 years	-0.2899**	-0.1326	-0.0907	-0.0282	0.0030	-0.0414	0.0325	-0.0689	-0.0783
age range 40-49 years	-0.1659**	-0.0185	-0.0942*	-0.0602	0.0331	-0.0027	-0.0036	-0.0392	-0.0973**
age range 50-59 years	-0.1166***	-0.0117	-0.0582**	-0.0180	0.0012	0.0080	-0.0062	-0.0416*	-0.0399*
age range 70-79 years	0.0138	-0.0415	-0.0162	0.0205	-0.0068	-0.0219	-0.0100	0.0226	0.0349
age range over 80 years	-0.2598**	-0.0339	-0.0841	-0.0213	-0.0519	-0.0373	-0.1009**	-0.1010**	-0.0168
Female patient	-0.0350	0.1720**	0.0335	0.0269	0.0473	0.0731**	0.0004	-0.0522*	-0.0421**
Number of Comorbidities	0.0822***	-0.0105	0.0294	0.0322**	0.0189	0.0094	0.0356***	0.0633***	0.0641***
Past Year Emergency Admissions	-0.2618***	-0.1470***	-0.1390***	-0.0967***	-0.0840***	-0.0521***	-0.0555***	-0.0554***	-0.0574***
Congestive Heart Failure	0.4385*	-0.3581*	0.0974	0.0612	-0.0334	-0.0677	-0.0443	0.0181	0.0148
Peripheral Vascular Disease	0.1071	-0.0958*	0.0107	0.0344	-0.0377	0.0284	-0.0104	0.0216	-0.0057
Cerebrovascular Disease	0.1338	-0.2785*	0.0446	0.0232	-0.0204	-0.0668	-0.0104	0.1489*	-0.0049
Chronic Obstructive Pulmonary Disease (COPD)	-0.0242	0.0366	0.0067	-0.0227	0.0268	-0.0095	-0.0153	-0.0385*	-0.0092
Rheumatoid Disease	-0.2182*	0.1538	-0.0084	-0.0459	0.0052	0.0303	-0.0008	0.0436	-0.1250***
Peptic Ulcer Disease	0.2453	0.0024	0.1484	0.1976*	-0.3109**	-0.0050	0.1627	0.0040	0.1584
Mild Liver Disease	-0.0437	-0.5138	-0.0825	-0.3445	0.1868*	-0.3831**	0.0867	-0.0785	0.0072
Diabetes	0.0674**	0.0169	0.0291*	0.0011	0.0126	0.0312**	-0.0019	0.0062	0.0035
Diabetes + Complications	0.0173	0.1285	-0.2658**	-0.0360	-0.0088	0.0586	0.0699	-0.1397*	-0.0521
Renal Disease	-0.0679	0.0894	-0.1970***	-0.0036	-0.0303	0.0553	-0.0723**	0.0088	-0.0732**
Cancer	-0.5820***	-0.6193***	-0.6811***	-0.4789***	-0.2419***	-0.2565***	-0.3410***	-0.3030***	-0.3702***
Jan	0.1499***	0.2542***	0.1778***	0.1635***	0.1770***	0.2005***	0.1864***	0.2591***	0.2553***
Feb	0.1046**	0.2199***	0.1316***	0.1590***	0.0894***	0.1016***	0.1120***	0.1523***	0.1230***
Mar	0.1160**	0.1639***	0.1194***	0.1004***	-0.0035	0.0687**	0.0689***	0.1099***	0.1309***
April	-0.0028	-0.1379**	0.0459	0.2050***	0.0950***	0.3907***	0.0876***	0.1347***	0.1734***
May	-0.0046	0.0247	0.0337	0.1293***	0.1336***	0.3507***	0.0144	0.1187***	0.1298***
June	0.0434	0.0627	0.1272***	0.1665***	0.0866***	0.3923***	0.0846***	0.1654***	0.1784***
July	0.0845*	-0.0083	0.0791**	0.1020***	0.0386	0.2831***	0.0513**	0.0465*	0.0761***
Aug	0.1131**	0.0233	0.1471***	0.0976***	0.0784***	0.2844***	0.0425	0.0901***	0.0974***
Sept	0.0919*	0.0454	0.1234***	0.1286***	0.0863***	0.2493***	0.1098***	0.1433***	0.1607***
Oct	0.0945**	0.0879**	0.0957***	0.0742***	0.0482*	0.1908***	-0.0365	0.0137	0.0895***
Nov	0.0140	0.0888**	0.0319	0.0834***	0.0311	0.1589***	0.0264	0.0700***	0.1206***
IMR0 - PCI	-0.7795*	0.5696	-0.1959	-0.1536	0.0035	0.1766	-0.2522	-0.5481***	-0.4976***
Constant	4.2005***	3.5923***	4.1968***	3.6976***	3.5055***	3.0236***	3.5466***	3.4960***	3.4379***
Hospital sites Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES

Panel C - 1st Stage Probit for Choice of procedure: CABG vs PCI – Equation (3)

	(1) 2002	(2) 2003	(3) 2004	(4) 2005	(5) 2006	(6) 2007	(7) 2008	(8) 2009	(9) 2010
Differential distance of first 3 hospitals by procedure	-0.0016***	0.0001	-0.0013***	-0.0008**	-0.0004	0.0009***	-0.0003	-0.0008**	-0.0020***
EDI income 1st quintile (most deprived)	0.1810***	0.0191	0.0173	0.0338	0.0295	-0.0008	-0.0030	-0.0087	-0.0053
EDI income 2nd quintile	0.1254***	0.0314	-0.0024	0.0543**	0.0077	0.0148	0.0281	0.0139	0.0104
EDI income 3rd quintile	0.0909***	0.0016	-0.0176	0.0314	-0.0171	0.0252	-0.0014	0.0039	-0.0300
EDI income 4th quintile	0.0636***	-0.0210	-0.0177	0.0612***	0.0017	-0.0050	-0.0284	0.0013	0.0282
Patient age	0.0096***	0.0091***	0.0102***	0.0094***	0.0094***	0.0005	0.0085***	0.0029	-0.0023
age range 0-39 years	-0.3061***	-0.3015***	-0.2823**	-0.0918	-0.2956**	-0.1060	-0.0210	-0.1426	-0.2199*
age range 40-49 years	-0.1636***	-0.1351**	-0.1334**	-0.1088*	-0.0825	-0.2347***	-0.0359	-0.1776***	-0.2276***
age range 50-59 years	-0.0861***	-0.0658**	-0.0578**	-0.0711**	-0.0701**	-0.1090***	-0.0546*	-0.1055***	-0.0717**
age range 70-79 years	0.0099	0.0389	-0.0149	0.0015	0.0198	0.0730**	-0.0302	0.0368	0.0237
age range over 80 years	-0.4070***	-0.3829***	-0.4832***	-0.4627***	-0.3756***	-0.2170***	-0.4207***	-0.3631***	-0.2711***
Female patient	-0.3128***	-0.3407***	-0.3598***	-0.3203***	-0.3436***	-0.2886***	-0.3388***	-0.3389***	-0.3068***
Number of Comorbidities	0.1192***	0.1102***	0.1179***	0.1146***	0.1364***	0.1424***	0.1585***	0.1627***	0.1825***
Past Year Emergency Admissions	-0.1505***	-0.1284***	-0.1145***	-0.1025***	-0.1258***	-0.1301***	-0.1373***	-0.1199***	-0.1901***
Congestive Heart Failure	0.7357***	0.6994***	0.6561***	0.6886***	0.3365***	0.2807***	0.2487***	-0.0469	-0.0245
Peripheral Vascular Disease	0.1660***	0.1429***	0.0671**	0.0399	0.0312	-0.0751**	-0.0165	0.0560*	-0.0043
Cerebrovascular Disease	0.6004***	0.5050***	0.6662***	0.6712***	0.3980***	0.4536***	0.4553***	0.3974***	0.2798***
Chronic Obstructive Pulmonary Disease (COPD)	-0.0492	-0.1334***	-0.0756***	-0.0586**	-0.0882***	-0.0653**	-0.1185***	-0.1476***	-0.1198***
Rheumatoid Disease	-0.0460	-0.0771	-0.1470*	-0.0314	-0.2366***	-0.0634	-0.0288	-0.0177	-0.1789***
Peptic Ulcer Disease	0.1149	0.0838	0.1864	0.3119**	0.1442	0.2019	0.0638	0.0650	0.3818***
Mild Liver Disease	-0.2714	0.2168	-0.2847	-0.2433	-0.2328	-0.1994	-0.1881	-0.0861	-0.3578**
Diabetes	0.0296	0.0619***	-0.0206	-0.0141	0.0177	-0.0420**	-0.0940***	-0.1141***	-0.1046***
Diabetes + Complications	-0.1639	0.0134	-0.1407	-0.0527	0.1056	-0.0912	-0.0885	-0.1153	-0.1557**
Renal Disease	0.0087	-0.1425***	-0.0434	-0.1127**	-0.1432***	-0.1507***	-0.1247***	-0.1004***	-0.1710***
Cancer	-0.1327	-0.2029**	-0.3627***	-0.1917**	-0.3282***	-0.1432*	-0.1341*	-0.0907	-0.2581***
Jan	0.0011	0.0359	0.0870**	0.0649*	0.0191	0.0380	-0.0091	0.0801**	0.0472
Feb	-0.0023	-0.0191	0.0230	-0.0249	-0.0051	-0.0182	0.0183	0.0011	0.0071
Mar	-0.0244	-0.0261	0.0774**	-0.0354	-0.0099	-0.0516	0.0021	-0.0347	0.0378
April	0.1100***	0.1770***	0.0413	-0.0352	0.0594	-0.0954**	-0.0161	-0.0066	0.1301***
May	0.0501	0.1459***	0.1645***	0.0883**	0.0361	-0.1696***	0.0395	0.0379	0.1868***
June	0.0601	0.0979***	0.1020***	0.0204	-0.0007	-0.1454***	0.0610*	0.0794**	0.1711***
July	0.0587	0.0347	0.0441	-0.0005	0.0762**	-0.1033***	0.0492	0.0142	0.1117***
Aug	0.0606	0.0589	0.0898**	-0.0001	0.0498	-0.0688*	0.1093***	0.0851**	0.2552***
Sept	0.0842**	0.1114***	0.0758**	-0.0408	-0.0005	-0.0481	0.0842**	0.0443	0.1607***
Oct	0.0054	-0.0101	0.0972***	0.0445	0.0378	-0.0136	0.0089	-0.0467	0.0972**
Nov	0.0098	-0.0087	-0.0069	-0.0504	0.0028	-0.0564	0.0394	-0.0301	0.1075***
Constant	-0.0714**	-0.1671***	-0.3132***	-0.4841***	-0.4246***	-0.2987***	-0.3746***	-0.4634***	-0.5697***

Notes. Sample: CABG and PCI patients. Controls include hospital fixed effects (in Eq.(4) and (5) only). * p<0.10, ** p<0.05, *** p<0.01