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Are waiting times and length of stay connected? Theoretical underpinnings and empirical results

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Are waiting times and length of stay connected? Theoretical underpinnings and empirical results from the English NHS

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Abstract

The English Government implemented and stringently enforced maximum waiting time (MWT) targets to tackle long waiting times for elective surgery. We consider their impact on patient prioritisation for treatment based on expected hospital length of stay. We demonstrate that prioritisation based on expected length of stay can significantly decrease average waiting times. We test whether hospitals have adopted such behaviour using data for four large volume elective procedures and 1998 – 2011 period which saw the progressive tightening of targets and their subsequent relaxing after 2010. Our analysis suggests that, following the introduction of the MWT regulatory framework, patients with longer expected hospital stay waited longer for treatment. As coronary procedures were subject to explicit shorter waits from the start we uncover positive and statistically significant relationship for CABG and PCI patients in almost all years. For orthopaedic patients we find a positive and statistically significant association after 2004 when the 18-week referral to treatment (RTT) target was introduced. We find predominantly statistically insignificant results for the period prior. These findings raise safety and fairness concerns in the treatment of clinically complex and potentially urgent patients when the healthcare system is strapped with MWT targets.

Keywords: maximum waiting times, length of stay, prioritisation

JEL: H4, I1

1. Introduction

In response to widespread dissatisfaction with long waiting times for hospital care in the English National Health Service (NHS), the New Labour Government introduced a policy of increasingly tighter maximum waiting times. Hospital performance against the targets was monitored and publicly reported and there were strong sanctions for managers of poorly performing hospitals (Propper et al., 2008). The focus of this paper is on targets for elective procedures. In the English NHS patients can only gain access to elective surgery by being added to the waiting list by a hospital consultant. Although clinical guidelines are the principal influence on the decision regarding patient's waiting time for a surgery (Van Ackere and Smith, 1999), implementing any changes in practice designed to achieve hospital strategic objectives, including control of waiting times, will also likely filter through given the public reporting and managerial sanctions.

The success of the maximum waiting time targets regime in eliminating the long waits and decreasing the mean waiting times is well documented (Propper et al., 2010; Nikolova et al., 2015; Sinko et al., 2018). Reaction amongst health professionals is more ambiguous, with a widespread view that targets distorted clinical priorities and undermined professionalism (Smith and Sutton, 2013). Propper et al. (2010) found that targets in England were achieved without diverting activity from other less monitored aspects of health care and without decreasing patient health on exit from hospital. However, the National Audit Office (2001) reported that 20% of consultants surveyed in three specialties claimed that they changed the ordering of patients for treatment in order to meet the 18-month target in England. Using hospital administrative data covering all disease categories for the entire England Sinko et al. (2018) found that that the reform changed the way patients are prioritised for treatment with longer waiting patients benefitting at the expense of those who previously waited less. Nikolova et al. (2015), using administrative data for a different country, Scotland, where similar targets were implemented, found the same pattern of decrease in variability in waiting times across different patient groups within disease categories. This evidence suggests that the persistent anxiety that political targets undermine the essence of medical professionals work might not be unsubstantiated after all (Smith and Sutton, 2013).

Faced with maximum waiting time targets providers have incentives to abandon prioritisation based on clinical need and treat patients instead on "First come, first served" (FCFS) basis which reduces the probability of breaching the target. The literature on the topic of prioritisation in the context of queueing in general (Adan and Resin, 2015; Conway et al., 2003) and waiting lists and associated waiting times in particular (Gupta, 2013; Arnette and Hadorn, 2003) is vast. Sinko et al. (2018) and Nikolova et al. (2015) find evidence of switching to FCFS approach in England and Scotland respectively. Further reduction in maximum waiting time as well as in average waiting time can be achieved if hospitals assign lower priority to patients with higher expected length of stay who are likely to be sicker. Even though such an approach is associated with overall lower expected waits, this improvement will increase waiting time for patients who tend to stay in hospital longer. However, to implement this strategy, hospitals have to be able to predict reliably length of stay when scheduling patients for treatment.

As accurate predictions of patient length of stay help hospitals manage resources effectively (Khanna et al., 2012; Adamina et al., 2011) and increase efficiency of patient care (Rotter et al., 2010; Nicholson et al., 2014), this area is extensively studied. Predictions have been built for different types of elective admissions: colorectal surgery (Faiz et al., 2011); percutaneous coronary intervention (Negassa and Monrad, 2011), hip replacement (Elings et al., 2014; Abbas et al., 2011; Foote et al., 2009; Husted et al., 2008), knee replacement (Yasunaga et al., 2009; Jonas et al., 2013; Huang et al., 2012; Husted et al., 2008), spinal surgery (Sharma et al., 2013) among the most recent work in this area. The Department of Health in England uses age, gender, social deprivation, and presence of other medical conditions to produce a case-mix adjusted length of stay for benchmarking use for NHS Choices (NHS England, 2015) which is the primary NHS website providing comparative data about health providers. Research also points to the importance of admission method (Kulinskaya et al., 2005; Watkins et al., 1999), discharge destination (Abbas et al., 2011; Kulinskaya et al., 2005; Watkins et al., 1999), ethnicity (Carter and Potts, 2014), living arrangements (Husted et al., 2008), obesity (Kremers et al., 2014) and the presence of disease-specific health problems (Elings et al., 2014; Yasunaga et al., 2009; Sharma et al., 2013). Many of these data items can be collected throughout the patient's contact with a hospital. Thus, hospitals are in a position to incorporate this information in their decision regarding patient's waiting time for elective treatment.

Indirect evidence on the possible link between waiting time and length of stay comes from Farrar et al. (2009). In their evaluation of the impact of an English NHS reform, linking hospital activity to a national tariff (Payment by Results), on hospital length of stay, they found that other policies appear to have driven the decrease in hospital length of stay. Interviews with NHS managers reveal that pressures in the form of waiting times targets were driving these changes (Sussex and Farrar, 2009). The latter finding is consistent with the results of a qualitative study undertaken by the Audit Commission (Audit Commission, 2005).

The contribution of this paper is twofold. We first demonstrate theoretically that the lowest average waiting time among prioritisation disciplines based on length of stay is achieved if patient groups with shorter expected length of stay have higher priority in treatment. The relationship between expected length of stay and waiting times is then tested using administrative data for the English NHS for four large volume elective procedures (cardiac artery bypass surgery (CABG), percutaneous corononary intervention (PCI), hip replacement and knee replacement) and 14 financial years for 1998 – 2011 period. Our findings suggest that, following the introduction of the maximum waiting time regulatory framework, patients with longer expected hospital stays waited longer for treatment in the majority of cases.

In England maximum waiting time reforms were first introduced in 2000. Since then the targets against which organisations were performance managed have been progressively shortened and those for cardiac procedures have always been in advance of the more general targets. Maximum waiting times were successfully reduced from 18 months for general inpatient admissions and 12 months for cardiac revascularisation with cardiac artery bypass surgery (CABG) falling in this category in March 2001 to nine and six months respectively in March 2004. By the end of the same period the term revascularisation was widened to include all adult cardiac surgery with explicit inclusion of percutaneous corononary intervention (PCI). By March 2005 the target for revascularisation was reduced to 3 months while for the number of other inpatient admissions with waits longer than 6 months was limited to 20% of the 2003 level. The general target was then reduced to 18 weeks from referral to treatment (RTT) in December 2008. Our sample also covers the first 21 month after the Coalition government during which they briefly suspended the central management of the 18-week target, a policy it announced soon after it took office in June 2010 as part of organisational restructuring (Gregory et al., 2012) and financial stringency environment (Appleby, 2015).

2. Motivating Example

We develop a primitive example to motivate our empirical analysis. We start with a deterministic scenario for arrival and service times (Subsection 2.1) which is next generalised for the stochastic case. In the latter we focus on Poisson arrival and general service time processes (Subsection 2.2).

2.1. Deterministic Case

We assume there are two types of patients: type A and type B. Patients arrive to hospital following two types of deterministic cycles that repeat every 16 periods. Table 1 shows the way patients of each type arrive within a cycle. Four patients arrive per cycle, 2 of type A and 2 of type B. A hospital can treat only one patient at a time. The first panel of the table corresponds to the case when all patients arrive at the beginning of the cycle. The second panel corresponds to the case when patient arrivals are spread across sixteen period cycle. We assume that the patients are treated using non-preemptive[1] scheme. Further in the text we omit

[1] In this context non-preemptive means that once a lower priority patient begins their treatment, a higher priority patient arrived after the beginning of the treatment has to wait until the treatment is finished.

Table 1: ARRIVAL PROCESSES

Discipline\Period	0	...	4	...	7	...	15	16	...	20	...	23	...	31
						Process I								
Type A	2	0	0	0	0	0	0	2	0	0	0	0	0	0
Type B	2	0	0	0	0	0	0	2	0	0	0	0	0	0
						Process II								
Type A	1	0	1	0	0	0	0	1	0	1	0	0	0	0
Type B	1	0	0	0	1	0	0	1	0	0	0	1	0	0

"non-preemptive" for brevity. We compare three alternative schemes for processing patients: a prioritisation for patients of type A over type B, a prioritisation for patients of type B over type A, and FCFS with equal chances for each type of being treated first upon simultaneous arrival. In queuing literature an algorithm of how clients are processed is called a queuing discipline.

We further consider two different combinations of service times (S) for patients A and B. In the first one we assume that each patient type has a hospital length of stay (service time) of 4 periods, i.e $S_A = S_B = 4$. In the second one we assume that service time for type A patient is 2 periods and service time for type B patient is 6, i.e. $S_A = 2$ and $S_B = 6$.

Population characteristics of waiting time outcomes for different processing schedules are reported in Table 2. We present actual waiting times for patients of type A and B, mean waiting times, unconditional means and variances of waiting time for the entire patient population, maximum waiting times for each patient type, and probability to observe the maximum waiting time in population for two combinations of service times and two arrival schedules.

The first two panels of Table 2 demonstrate the case when service time is 4 periods for both types of patients for different arrival schedules. For arriving schedule I, when all patients arrive at the beginning of the cycle, results are symmetric as all characteristics of the patients are

[2] A_i, a member of set A, (see footnote below)

[3] $\{0, 4, 8, 12\} \setminus A_i$, where A – all possible combinations of assigning two patients of type A waiting times {0,4,8,12}

[4] First tuple from an element A' (see footnote below)

[5] Second tuple from an element of A' $A' = \{\{(0, 2), (4, 10)\}, \{(0, 8), (2, 10)\}, \{(0, 14), (2, 8)\}, \{(6, 14), (0, 8)\}, \{(6, 8), (0, 10)\}, \{(12, 14), (0, 6)\}\}$

Table 2: Population characteristics of waiting times outcomes

Discip.	WT^A	WT^B	$\overline{WT}_A$	$\overline{WT}_B$	$\overline{WT}$	$V(WT)$	WT_A^{max}	WT_B^{max}	$P[WT^{max}]$
		Process I, $S_A = S_B = 4$ periods							
Type A	$\{0,4\}$	$\{8,12\}$	2	10	6	20	4	12	1/4
FCFS	$\{wt_1^A, wt_2^A\}^2$	$\{wt_1^B, wt_2^B\}^3$	6	6	6	20	12	12	1/4
Type B	$\{8,12\}$	$\{0,4\}$	10	2	6	20	12	4	1/4
		Process II, $S_A = S_B = 4$ periods							
Type A	$\{0,0\}$	$\{8,5\}$	0	6.5	3.25	11.69	0	8	1/4
FCFS	$\{0,4\}$ $\{4,4\}$	$\{4,5\}$ $\{0,5\}$	3	3.5	3.25	3.69	4	5	1/4
Type B	$\{4,8\}$	$\{0,1\}$	6	0.5	3.25	9.69	8	1	1/4
		Process I, $S_A = 2,\ S_B = 6$ periods							
Type A	$\{0,2\}$	$\{4,10\}$	1	7	4	14	2	10	1/4
FCFS	$\{wt_1^A, wt_2^A\}^4$	$\{wt_1^B, wt_2^B\}^5$	7	5	6	23.33	14	10	1/8
Type B	$\{12,14\}$	$\{0,6\}$	13	3	8	30	14	6	1/4
		Process II, $S_A = 2,\ S_B = 6$ periods							
Type A	$\{0,4\}$	$\{2,3\}$	2	2.5	2.25	2.19	4	3	1/4
FCFS	$\{0,4\}$ $\{6,4\}$	$\{2,3\}$ $\{0,3\}$	3.5	2	2.75	3.69	6	3	1/8
Type B	$\{6,10\}$	$\{0,0\}$	8	0	4	18	10	0	1/4

identical. Waiting time for the lower priority patients is naturally longer, variances, maximum waiting times and associated probabilities are identical across the prioritisation disciplines.

Once symmetry breaks (Panel 2) results change significantly. Expected waiting times for the higher priority patients becomes 0 and 0.5, while for the lower priority patients – 6.5 and 6 correspondingly. Expected waiting time in population is 3.5 for all three disciplines. Variances differ as well. The smallest variance is associated with FCFS discipline (3.69). The second lowest variance demonstrates type B prioritisation (9.69). The largest variance is associated with type A prioritisation (11.69). Maximum waiting times are associated with prioritisations of type A and B (8 periods). The lowest maximum waiting type is associated with $FCFS$ (5 periods). Summarising, FCFS is associated with minimum variance and smallest maximum waits. Expected waiting time in population does not depend on queuing discipline.

Panels 3 and 4 are associated with the case when service time for patients A is 2 periods, while service time for patients B is 6 periods. For both processes population waiting time depends on prioritisation. The smallest average waiting time is associated with prioritisation A with shorter service time. The second best average waiting time is linked to FCFS, and the longest population waiting time is associated with Type B prioritisation. For these two processes $Var(Type\ A) < Var(FCFS) < Var(Type\ B)$. However patients with longer service time (usually sicker patients) have to wait more.

Summarising, for patient groups with similar service time, population waiting time does not depend on prioritisation, while variance reaches its minimum with FCFS queueing discipline. For patients with different service time, prioritisation changes not only variance of waiting time, but also population average. The smallest waiting time average is associated with Type A prioritisation, i.e. placing higher priority on patients with shorter service time. As service time is associated with patients' health status, under these conditions, sicker and, potentially, more complex patients have to wait longer.

2.2. Stochastic Case

In this section we demonstrate that section 2.1 deterministic findings regarding average waiting time extend to a stochastic set-up. Assume there are $k = 1, \ldots, K$ patient types. Patients of type k arrive to queue following independent Poisson process with λ_k intensity. Similarly to the previous scenario, there is only one server (hospital), and only one patient can be treated at a time. The queue is non-preemptive. Service time (S_k) distribution for patients of type k has first and second moments accordingly $\mathrm{E}\left(S_k\right)$ and $\mathrm{E}\left(S_k^2\right)$. Assuming that patients of type k, $k = 1, \ldots K-1$ are always of higher treatment priority comparing to patients of type $k+1$, expected waiting time for patients of type k is:

$$\mathrm{E}\left(W_k\right) = \frac{\omega_0}{(1 - \sum_{j=1}^{k} \rho_j)(1 - \sum_{j=1}^{k-1} \rho_j)} \tag{1}$$

where $\rho_j = \lambda_j \mathrm{E}(S_j)$, $\omega_0 = \sum_{j=1}^{K} \lambda_j \mathrm{E}\left(S_j^2\right)/2$. For details see, for example, Gupta (2013). The unconditional expected waiting time is:

$$\mathrm{E}(W) = \frac{\sum_{k=1}^{K} \lambda_k \mathrm{E}(W_k)}{\sum_{k=1}^{K} \lambda_k} \tag{2}$$

For K patient types $\mathrm{E}(W)$ for FCFS discipline is equivalent to $\mathrm{E}(W)$ for 1/M/G process with Poisson intensity $\lambda = \sum_{k=1}^{N} \lambda_k$ and service time distribution S which is a mixture of S_k with $\mathrm{E}(S) = \lambda^{-1} \sum_1^K \lambda_k \mathrm{E}(S_k)$, $\mathrm{E}(S^2) = \lambda^{-1} \sum_1^K \lambda_k \mathrm{E}(S_k^2)$, and $\rho = \lambda \mathrm{E}(S) = \sum_1^K \rho_k$.

$$\mathrm{E}\left(W^{FCFS}\right) = \frac{\lambda \mathrm{E}(S^2)}{2(1-\rho)} = \frac{\omega_0}{1 - \sum_{k=1}^{K} \rho_k} \tag{3}$$

For $K = 2$ we can easily rank expected waiting times. Assume that $\mathrm{E}(S_1) < \mathrm{E}(S_2)$. As in subsection 2.1 we consider three types of prioritisation: $(1,2)$, $FCFS$, and $(2,1)$. Corresponding expected waiting times are:

$$\begin{aligned}
\mathrm{E}\left(W^{(1,2)}\right) &= \frac{\omega_0 \left[\lambda_1(1-\rho_1-\rho_2) + \lambda_2\right]}{(1-\rho_1)(\lambda_1+\lambda_2)(1-\rho_1-\rho_2)} \\
\mathrm{E}\left(W^{(2,1)}\right) &= \frac{\omega_0 \left[\lambda_1 + \lambda_2(1-\rho_1-\rho_2)\right]}{(1-\rho_2)(\lambda_1+\lambda_2)(1-\rho_1-\rho_2)} \\
\mathrm{E}\left(W^{(FCFS)}\right) &= \frac{\omega_0}{1-\rho_1-\rho_2}
\end{aligned} \tag{4}$$

The differences $\mathrm{E}\left(W^{(2,1)}\right) - \mathrm{E}\left(W^{(FCFS)}\right)$ and $\mathrm{E}\left(W^{(FCFS)}\right) - \mathrm{E}\left(W^{(1,2)}\right)$ are accordingly:

$$\begin{aligned}
\mathrm{E}\left(W^{(2,1)}\right) - \mathrm{E}\left(W^{(FCFS)}\right) &= \frac{\omega_0 \lambda_1 \lambda_2 \left[\mathrm{E}(S_2) - \mathrm{E}(S_1)\right]}{(1-\rho_2)(\lambda_1+\lambda_2)(1-\rho_1-\rho_2)} \\
\mathrm{E}\left(W^{(FCFS)}\right) - \mathrm{E}\left(W^{(1,2)}\right) &= \frac{\omega_0 \lambda_1 \lambda_2 \left[\mathrm{E}(S_2) - \mathrm{E}(S_1)\right]}{(1-\rho_1)(\lambda_1+\lambda_2)(1-\rho_1-\rho_2)}
\end{aligned} \tag{5}$$

These differences are always positive as long as $\mathrm{E}(S_2) > \mathrm{E}(S_1)$ (by construction) and $\sum \rho_i < 1$ (capacity of the system is sufficient to handle patient inflow). Thus, $\mathrm{E}\left(W^{(2,1)}\right) > \mathrm{E}\left(W^{(FCFS)}\right) > \mathrm{E}\left(W^{(2,1)}\right)$ which resembles the deterministic results from the previous subsection. This result can be generalised in the following way:

Theorem 2.1. *Assume there are $k = 1, \ldots, K$ patients groups with the corresponding Poisson arrival intensity λ_k; only one patient can be treated at a time; queueing is non-preemptive; hospital has sufficient capacity i.e. $\sum_{k=1}^{K} \lambda_k E(S_k) = \sum_{k=1}^{K} \rho_k < 1$; hospital does not stay idle if there are patients in the queue; time of treatment is an arbitrary stochastic process with two first moments $E(S_k)$ and $E(S_k^2)$, s.t. $E(S_{k-1}) < E(S_k), \forall\ k$. Then for an arbitrary non-idling queuing discipline $\Pi = \{\pi_1, \ldots, \pi_k, \pi_{k+1}, \ldots \pi_K\}$ and pairwise-permutated queueing discipline $\Pi_{k,k+1} = \{\pi_1, \ldots, \pi_{k+1}, \pi_k, \ldots \pi_K\}$ where π_i patient group has higher priority than $\phi_{i+1} \forall i$, population waiting time $E(WT^{\Pi}) > E(WT^{\Pi_{k,k+1}})$ if and only if $E(S_k) < E(S_{k+1})$*

For proof see Appendix Appendix A ■

In summary, a prioritisation-based discipline can potentially decrease average waiting time. But such approach is not without caveats. First, if hospitals resort to prioritising based on expected length of stay, patients with longer stays, who are likely the more complex and sicker ones, will wait more. Moreover, under certain conditions, these patients can wait longer than the government-specified maximum. The last issue can be resolved by closely watching hospital performance against the target and assigning patients, who are about to breach the limit, the highest possible priority. Formally, the term for such prioritisation is "accumulating priority queues" and was introduced by Kleinrock and Finkelstein (1967). Although, the latter strategy may slightly increase expected waiting times in population, it leads to a decrease in maximum waiting times.

3. Data

We use data from the Hospital Episode Statistics (HES) for 14 financial years from 1998 to 2011[6]. HES is an administrative dataset covering all NHS-funded hospital admissions in England.

We extract a subset of patients who were admitted for elective procedures. We next restrict our attention only to admissions from waiting lists and booked admissions. We drop all cases with waiting times more than two years. We disregard observations with missing data on waiting

[6]Financial years run from 1st April to 31st March.

time.

Our sample includes patients admitted for four large volume elective procedures: two coronary revascularisation surgeries, CABG and PCI with patient volume 273,827 and 190,919 respectively, and two orthopaedic surgeries, hip replacement and knee replacement with 701,939 and 730,418 treatments [7] (Table A.3).

We merge the HES data set with the income domain of the Economic Deprivation Index (EDI)(Department for Communities and Local Governments, 2012) as a measure of economic deprivation. This index tracks levels of economic deprivation in the Lower-layer Super Output Areas (LSOAs) in England[8].

As the focus of our analysis is to explore waiting time prioritisation with respect to expected length of stay we, separately for each patient observation, construct a new waiting time measure as the difference between individual $WT_{i,j}$ and WT_j^m – trust average waiting time for a particular treatment for the month the patient is put on the waiting list. The aim is to capture hospital assessment of patient's length of stay relative to the pool of other patients as of the date when decision to treat is made. To address intra-weekly seasonality, waiting time is aggregated to weekly frequency (Sinko et al., 2018).

4. Methods

Our primary interest lies in the relationship between waiting times for surgery and expected hospital length of stay. Decisions regarding patients' waiting times are taken after seeing a consultant and reflects their perception of clinical need as well as pressures to achieve

[7]We use the following OPCS-4 codes for cardiac revascularisation: K40-K46 for CABG; K49, K50, K75 for PCI; excluding K25-K38 (heart valve procedure). For hip replacement patient records with OPCS-4 codes W37-W39 and W94-W95 in the main operation field were extracted. For knee replacement we retain patient records with W40-W42 codes.

[8]The EDI index is available for 1999–2009. Our HES data extract is larger; it covers also 1998/99, 2009/10, and 2010/11 financial years. To utilise this information we use the 1999 EDI index for 1998/99 financial years and the 2009 index for 2009/10 and 2010/11.

government-imposed maximum waiting time targets and any hospital established routine in processing patients off the waiting list. The goal of our empirical analysis is to check whether predicted length of stay (LoS) given the information available to the hospital at the point of entry has any impact on hospital's decision making within the framework discussed in Section 2.2. Positive relationship between expected LoS and WT implies that patients with longer expected length of stay have higher chances to stay in the queue longer. Negative relationship implies that hospitals prioritise patients with longer expected LoS over patients with shorter stays. Thus the relationship we are investigating is

$$WT_{i,j} = f_j\left(E(LoS_{i,j}|I_H), X_{i,j}\right) \tag{6}$$

where $f_j(.)$ – hospital's j response function, $E(LoS_{i,j}|I_H)$ – conditional expectation of LoS of patient i given information set I_H available to a hospital at the time of decision-making regarding waiting time, $X_{i,j}$ – additional variables that impact hospital's decision on waiting time.

We adopt a linear specification:

$$WT_{ij} = \alpha + \beta_1 E(LoS_{ij}|I_H) + X_{i,j}\beta + \nu_j + \varepsilon_{ij} \tag{7}$$

Vector $\hat{\beta}$ stores the estimates on all covariates in our estimation. ν_j is the hospital provider-specific error term and ε_{ij} is the patient-specific error term. We estimate Eq. 7 using generalised method of moments (GMM) with fixed effects allowing for additional covariance structure between instruments within a hospital trust[9]. This captures hospital provider idiosyncratic practices in processing patients off the waiting list. We run separate regressions across fourteen years of data. To take into account that maximum waiting time targets were changing over time, allow for arbitrary non-linear trend and changes in system capacity we run separate regressions

[9]STATA ivregress GMM, wmat

for each year. Year of data consists of all patients who *started* waiting during the year. As at the beginning of the sample average waiting time for CABG exceeds 200 days, people who started waiting in 1998 could end up being treated in 2000 – 2001.

Information available to the hospital in patient administrative records is captured by the inclusion of dummies for 17 Charlson conditions[10] (Charlson et al., 1987), six dummies for comorbidity count (0 – 5+), gender, dummy for each quintile of economic deprivation, dummy for being of white ethnic background, a third degree polynomial of age. Our length of stay prediction model builds on the model used by the Department of Health in England where age, gender, deprivation, and the presence of other health problems are the four variables used in the case-mix adjustment of length of stay (NHS England, 2015). We test the robustness of our results with respect to model specification by re-estimating the model without hospital fixed effects.

5. Results

5.1. Summary statistics

Table A.3 shows patient count, average waiting times and average length of stay for each year in our analysis for the four procedures of interest (PCI, CABG, hip replacement, and knee replacement). The first panel is for the number of patients in different years. The pattern for CABG procedures is not clear-cut. Their number peaked at 15538 in 2002; it declined slightly in subsequent years, but remained relatively stable until 2008 when it began decreasing; there were 10884 CABGs performed in 2011. The number of PCI treatments increased from 5569 in 1998 to 26368 in 2006 following which it declined to 22656 in 2011. The numbers of hip replacement and knee replacements grew throughout the entire period of our analysis.

[10]These are myocardial infarction, congestive cardiac failure, peripheral vascular disease, dementia, cerebrovascular disease, chronic lung disease, connective tissue disease, ulcer, chronic liver disease, hemiplegia, moderate or severe kidney disease, diabetes, diabetes with complications, cancer, moderate or severe liver disease, metastatic cancer and AIDS.

The second panel presents the average waiting times. The average waiting times for CABG surgeries peaked in 2000 at 220.64 days. Following that they decreased steadily until 2009 when CABG patients waited on average 51.85 days. The average CABG waits grew to 63.22 over the 2010–2011 period. PCI waiting times increased up until 2003 following which they experienced a steady decline from 92.22 days in 2003 to 36.9 days in 2008. The average PCI wait increased to 40.39 days in 2011. Average waiting times for hip replacement and knee replacement patients followed a similar pattern. Their lowest values in 2009 were 82.37 and 85.28 days respectively for hips and knees. These increased to 88.94 and 94.88 days in 2011.

The third panel in Table A.3 shows the averages for length of stay. The average length of hospital stay for PCI, hip replacement, and knee replacement declined over the 15-year period of our analysis. In 2011 the average length of stay was 0.73, 5.44, and 5.32 days respectively for PCI, hips, and knees. The average length of stay for CABG grew from 9.10 days in 1998 to 10.07 days in 2006. It declined over the next five years and was 9.38 days in 2011.

5.2. Estimation results

Table A.4 presents our main results of interest from the second stage of the GMM estimation for 1998–2011 period. There are four panels in each table, one for each of the procedures and 14 columns for every year. The first row of each panel shows coefficient estimates for the relationship between expected LoS and WT. The next four rows show estimates for third degree polynomial of age and constant. The sixth row presents p-values for the overidentification test which checks the joint validity of moment conditions. The bottom two rows show R^2 and number of observations. In all tables statistically significant coefficients at the 1% confidence level are in red and in blue at the 5%.

Tables A.5 – A.8 present coefficient estimates for predictors of length of stay for the four selected procedures. Each table has 14 rows, one for each year of our analysis. The first five rows show the coefficient estimates on dummies for 1 – 5+ co-morbidities. 0 co-morbidities dummy is the base category. The following 17 rows are for the Charlson dummies. Next four rows in each table are for quintiles of economic deprivation index. The most deprived quintile (1) is omitted. We also report estimates for being female, of white ethnic background, third polynomial of age, constant and observation count. Table A.9 presents results from two stage GMM estimation without fixed effects. The results are similar to Table A.4.

5.2.1. GMM results

The first panel of Table A.4 presents estimates from the GMM estimation for CABG. From 1999 onwards estimates for expected LoS are consistently positive and statistically significant. The coefficient magnitude peaks in 2000, fairly consistently declines up until 2009 and increases over 2010 – 2011 period. Recall that maximum waiting time targets for CABG were more aggressive than for general inpatient admissions and a three-month wait was implemented by the end of 2004 financial year. Thus, a patient who is expected to stay an extra day in hospital following a CABG surgery, on average, waits an additional one week ($\hat{\beta}_{E[LoS]} = 0.953$) in 2000 and one third of a day ($\hat{\beta}_{E[LoS]} = 0.054$) in 2009. Age polynomial estimates are statistically significant for most years. P-values for overidentification test that the moments are jointly relevant suggest that we accept the null in all years.

The second panel of Table A.4 shows GMM estimates for PCI. Expected length of stay coefficient estimates are positive and statistically significant except for 2000, 2006 and 2008. Coefficient magnitude is the highest in 2000 at 2.464 suggesting that an extra expected day in hospital is associated with two and a half weeks of additional wait. Similarly to CABG the coefficient estimate on expected length of stay declines until 2009 and goes up again in the last two years of our analysis. We accept the null that our moment conditions are jointly valid for all years of our analysis. Age polynomial estimates are mostly statistically significant.

The third panel presents the GMM results for hip replacement. For the first half of our study period results are statistically insignificant except for year 2000 when the relationship is negative and statistically significant. Following 2004, when the 18-week RTT was introduced, the expected LoS estimates are consistently positive and statistically significant with its magnitude the highest in 2005. Similarly to CABG and PCI the relationship is stronger in the last two years following a decrease over a period of several years. We reject the null regarding the joint validity of the moment conditions. Third degree polynomial of age is statistically significant in 2007 and 2009 only.

The last panel of table A.4 is for knee replacement. Results for expected LoS, except for year 1999, are statistically insignificant until 2003 including. In 1999 the relationship is positive and significant. Following 2004 coefficients on expected LoS are consistently positive and statistically significant. We accept the null regarding joint validity of moment conditions in 2006-2008 period and 2011. Age polynomial is statistically significant in all years starting 2004.

Predominantly negative and significant intercept of the regression may be attributed to the estimated age polynomial. Formally, this is the waiting time (in weeks) relative to the average in a particular month, for an average hospital and a particular procedure for patients with zero expected length of stay and zero age. Since the fraction of patients older than 40 years in all years is larger than 0.9965 and fraction of patients older than 30 is larger than 0.999, the intercept, on its own, does not carry any particular meaning.

Overall, the magnitude of the $E(LoS)$ coefficient across all the procedures tends to decrease over the years, reaches its minimum in $2008 - 2009$ and increases after that. This result supports the findings of Sinko et al. (2018) and Nikolova et al. (2015). One of the hospital responses to shrinking maximum waiting time targets is to reduce variance of waiting time around the population waiting time. This, by itself, will lead to a decrease in the coefficient of interest. After 2008, when monitoring was relaxed, the increase of the coefficient magnitude might be attributed to the corresponding increase in waiting times. Additional indication that variation of the coefficients over the years are not attributed to decrease in explanatory power of expected length of stay could be the fact that overall explanatory power of the regressions do not decrease with decrease of the coefficients, but rather has a tendency to increase over time.

To check validity of the models considered we are using Hansen's overidentification test (Hansen, 1982) which tests the joint validity of moment conditions. While the specification is adequate for CABG and PCI procedures, it is not supported for hip replacement in all years and knee replacement for 1998 – 2005 and 2009 – 2010. Failure to accept the null reflects the fact that some of the sample moments are not sufficiently close to 0 at the estimated parameter values.

5.2.2. Length of stay prediction results

Tables A.5 – A.8 present coefficient estimates for predictors of length of stay. Length of hospital stay for CABG patients (Table A.5) does not appear to be consistently linked to comorbidity count except for patients with 5 or more additional health problems where the association is positive and statistically significant. The pattern of association with area deprivation rank is mostly statistically insignificant and negative. From the 17 Charlson conditions cerebrovascular (CEVD), peptic ulcer (PU) and renal disease (RD) patients have longer stays in almost all years. Patients with congestive heart failure (CHF) and chronic obstructive pulmonary disease (COPD) stay in hospital longer from 2007 onwards. Patients with rheumatoid disease (RhD) and metastatic cancer are found to stay in hospital less in most years, while acute myocardial infarction (AMI) patients had shorter stays at the beginning of the study period and longer stays towards the end. Consistent with previous research women who undergo CABG surgery stay in hospital longer (Capdeville et al., 2001; Scott et al., 2003). There is no difference in terms of length of stay between patients of white and other ethnic background. Individual coefficients of age polynomial are not consistently significant over the years.

Table A.6 shows coefficient estimates for PCI model. Comorbidity dummies are found to be statistically significant predictors of LoS in most years. The magnitude of the effect increases with comorbidity count pointing to longer stays for more complex patients and decreases in magnitude over time for patients with 4+ comorbidities. Economic deprivation rank is not associated with different length of stay. The presence of renal disease is associated with longer hospital stays in all years, while patients with AMI, CHF, CEVD, PU and cancer are found to stay more in all/some years after 2004. Women with PCI stay in hospital longer (Thompson et al., 2006), while being of white ethnic background does not influence differently length of stay. Individual coefficients of age polynomial are not consistently significant over the years.

Coefficient estimates of predictors of hospital length of stay for hip replacement patients are presented in Table A.7. Comorbidity count is statistically significantly associated with length of stay in all years with the relationship being stronger for more complex patients; over time the magnitude of the coefficients decreases and the gradient becomes less pronounced. Economic deprivation rank is statistically significantly associated with decreasing length of stay, although the magnitude of this decrease gets smaller over time. This finding is consistent with Cookson and Laudicella (2011). Patients with dementia have longer stays in most years. Patients with CHF and RD have longer stays in the second half of our study period, while patients with RhD stay in hospital longer in the beginning. COPD and diabetes patients consistently stay in hospital shorter periods. Women stay longer in hospital (Abbas et al., 2011), while white ethnic background is associated with longer stays in 2004–2006 period. Age polynomial is statistically significantly associated with LoS in most years and link is stronger after 2004.

Table A.8 presents estimates of length of stay predictors for knee replacement. Comorbidity count is statistically significantly associated with length of stay. The relationship is consistently positive and increasing in number of comorbidities, although it weakens towards the end of our study period. Decrease in economic deprivation is associated with shorter length of stay, although, similarly to hip replacement, the magnitude of these effects gets smaller over time. In 2011 the rank dummies, except for the fourth deprivation quintile, are not statistically significant. Patients with CEVD, Dementia and RD have longer hospital stays in most years. Patients with RhD stay in hospital longer in the beginning of our study period, while patients with CHF have longer lengths of stay during the second half. COPD patients stay in hospital less in most years, while AMI and diabetes patients have shorter lengths of stay during the first half of the study period. In all years women stay in hospital longer (Carter and Potts, 2014). Length of stay for patients of white ethnic background does not differ from length of stay for patients of other ethnicities. Age polynomial coefficients are statistically significant for all years but 1999 and 2001.

5.2.3. Sensitivity check

The GMM results without fixed effects are reported in Table A.9. Failure to account for hospital provider idiosyncratic practices in processing patients off the waiting list results in rejecting the null that moments are jointly valid in every year and for all conditions. However, despite this fact the estimated coefficients structure resembles the one reported in Table A.4. Positive statistically significant coefficients are concentrated towards the end of the sample, local minimum of the estimated coefficients is concentrated around 2008.

6. Discussion

The New Labour Government, through a series of progressively tighter maximum waiting time targets, managed to eliminate long waiting times for elective surgery in the NHS and decrease average waits. This regulatory framework, however, created "motivation and opportunity" (Bevan and Hood, 2006) for hospitals to shift focus from managing patients based on clinical priorities to managing to the target. Our on-going study of hospital behaviour suggests that two distinct strategies were adopted to meet the maximum waiting time targets. The first strategy aims to minimise the probability of breaching the target when waiting time is independent from expected length of stay. The goal of the second is to minimise the average waiting time by prioritising patients based on their expected length of stay. The latter is the focus here.

We first show theoretically for both, deterministic and stochastic, cases that the lowest average waiting time is achieved if patient groups with shorter expected length of stay have priority with respect to treatment over the rest of the patient population. We also test whether expected length of stay impacts on waiting times using data for four large volume surgical procedures. To account for endogeneity of length of stay Generalised Method of Moments method is adopted. Our findings suggest that, following the introduction of the maximum waiting time regulatory framework, patients with longer expected hospital stay waited longer for treatment in the majority of cases. In particular, we find that coronary patients with longer expected lengths of stay waited longer for treatment since the start of the study period as coronary procedures were subject to explicit shorter waits from the very beginning. The 18-week RTT target was introduced in 2004. Its impact is reflected in the pattern of results for orthopaedic patients where we uncover a positive and statistically significant association between expected length of stay and waiting times in all years after 2004. We find predominantly statistically insignificant results for the period prior to the reform. The relationship is negative and statistically significant for hip replacement in 2000 and positive and significant for knee replacement in 1999. However, delaying treatment for clinically complex and potentially urgent patients is unfair and could be unsafe.

Over recent years the NHS has been faced with declining funding and growing waiting lists and times. Waiting times have been persistently above the 18-week RTT target since March 2016 (NHS England, 2018) The waiting list has grown to above 4 million from above 2.4 million in 2009 - its highest level since 2007 (Anandaciva and Thompson, 2017). These changes have happened against the backdrop of changing Government paradigm on waiting times. NHS leaders have acknowledged that the service cannot currently meet the standards for elective care. The 18-week RTT target has been demoted to an overall 2020 goal in “Next steps on the NHS five year forward view” 2017. The document also explicitly recognizes that average waiting times for elective treatment will rise. NHS England (2017) notes a shift in focus to urgent patients. This includes introducing a new standard to give patients a definitive cancer diagnosis within 28 days and expressing support for re-organising scheduling for treatment by splitting ’hot’ emergency and urgent care from ’cold’ planned surgery clinical facilities. This implies, in the absence of funding increase, the waiting times will further go up and making the

18-week RTT even more difficult to deliver.

In light of the results in this paper shifting focus to urgent patients is a welcome change in government priorities provided hospitals find a balance between clinically-justified prioritisation and long waits which are widely interpreted as a sign of poorly functioning public health care system.

Our results could be contemporaneously confounded by other events. In particular, it might be the case that waiting time and length of stay are endogenous as patient health could deteriorate while waiting which, in turn, leads to longer length of stay. Unfortunately, we cannot directly test this hypothesis as even the national PROMs data set, which is the richest in terms of patient health characteristics and frequency of data measurement, does not contain information on the health status of the patients at the time they enter the system. Previous research presents mixed evidence on health status deterioration for CABG and PCI (Sari et al., 2007; Légaré et al., 2005), while our results are consistent for both procedures. There is no evidence in the clinical trial literature of significant deterioration in health for patients with joint replacements (Hirvonen et al., 2007; Tuominen et al., 2010), while our results present consistent evidence of a positive and statistically significant relationship between waiting times and length of stay following the introduction of the maximum waiting time targets and lack of a clear link in the period prior.

It might be also that what we observe is the result of imminent long-waiters about to breach the target displacing urgent patients. In the absence of relevant data to evaluate empirically this hypothesis, we perform a thought experiment. Allowing for this new explanation raises the question as to why exactly urgent patients, of all patients about to be treated, are being moved down the queue? And if, this is simply the result of re-prioritisation based on expected waiting times, then why urgent patients are consistently assigned waiting times which are higher than average as suggested by the positive coefficient between expected length of stay and deviation from the average wait variable? We think this is unlikely as, otherwise, it will imply a moral failure of the NHS and we do not think this is the case.

Appendix A. Appendix A: Proof of Theorem 2.1

Using Equations 1 and 2 and assuming, for simplicity, that indices reflect the priority order associated with queuing discipline Π, i.e. in the further discussion only $\mathrm{E}(S_k) < \mathrm{E}(S_{k+1})$ is satisfied.

$$\mathrm{E}(W_k) = \frac{\omega_0}{(1-\sum_{j=1}^{k}\rho_j)(1-\sum_{j=1}^{k-1}\rho_j)}, \quad \mathrm{E}(W) = \frac{\sum_{k=1}^{K}\lambda_k \mathrm{E}(W_k)}{\sum_{k=1}^{K}\lambda_k}$$

where $\rho_j = \lambda_j \mathrm{E}(S_j)$, $\omega_0 = \sum_{j=1}^{K}\lambda_j \mathrm{E}\left(S_j^2\right)/2$. It can be noted that $E(W_j^{\Pi}) = E(W_j^{\Pi_{k,k+1}})$ for all but two categories: $E(W_k^{\Pi})$ and $E(W_{k+1}^{\Pi})$.

$$\mathrm{E}\left(W_k^{\Pi}\right) = \frac{\omega_0}{(A-\rho_k)A}, \quad \mathrm{E}\left(W_{k+1}^{\Pi}\right) = \frac{\omega_0}{(A-\rho_k-\rho_{k+1})(A-\rho_k)}$$
$$\mathrm{E}\left(W_k^{\Pi_{k,k+1}}\right) = \frac{\omega_0}{(A-\rho_{k+1})A}, \quad \mathrm{E}\left(W_{k+1}^{\Pi_{k,k+1}}\right) = \frac{\omega_0}{(A-\rho_k-\rho_{k+1})(A-\rho_{k+1})}$$

where $A = 1-\sum_{j=1}^{k-1}\rho_j$ and void indices reflect the priority position of a patient group . Thus,

$$E(W^{\Pi}) - E(W^{\Pi_{k,k+1}}) =$$
$$\frac{\omega_0}{(\sum_{k=1}^{K}\lambda_k)}\left[\frac{\lambda_k}{A(A-\rho_k)} + \frac{\lambda_{k+1}}{(A-\rho_k-\rho_{k+1})(A-\rho_k)} - \frac{\lambda_{k+1}}{A(A-\rho_{k+1})} - \frac{\lambda_k}{(A-\rho_k-\rho_{k+1})(A-\rho_{k+1})}\right] =$$
$$\frac{\omega_0}{(\sum_{k=1}^{K}\lambda_k)}\left[\frac{\lambda_k(A-\rho_k-\rho_{k+1})+A\lambda_{k+1}}{A(A-\rho_k-\rho_{k+1})(A-\rho_k)} - \frac{\lambda_{k+1}(A-\rho_k-\rho_{k+1})+A\lambda_k}{A(A-\rho_k-\rho_{k+1})(A-\rho_{k+1})}\right] =$$
$$\frac{\omega_0}{(\sum_{k=1}^{K}\lambda_k)}\left[\frac{\lambda_k(A-\rho_k-\rho_{k+1})+A\lambda_{k+1}}{A(A-\rho_k-\rho_{k+1})(A-\rho_k)} - \frac{\lambda_{k+1}(A-\rho_k-\rho_{k+1})+A\lambda_k}{A(A-\rho_k-\rho_{k+1})(A-\rho_{k+1})}\right] =$$
$$\frac{\omega_0}{(\sum_{k=1}^{K}\lambda_k)}\left[\frac{-A\lambda_k\rho_{k+1} - \lambda_k\rho_{k+1}(A-\rho_k-\rho_{k+1}) + A\lambda_{k+1}\rho_k + \lambda_{k+1}\rho_k(A-\rho_k-\rho_{k+1})}{A(A-\rho_k-\rho_{k+1})(A-\rho_{k+1})(A-\rho_k)}\right] =$$
$$\frac{\omega_0}{(\sum_{k=1}^{K}\lambda_k)}\left[\frac{-A\lambda_k\lambda_{k+1}(\mathrm{E}(S_{k+1})-\mathrm{E}(S_k)) - (A-\rho_k-\rho_{k+1})\lambda_k\lambda_{k+1}(\mathrm{E}(S_{k+1})-\mathrm{E}(S_k))}{A(A-\rho_k-\rho_{k+1})(A-\rho_{k+1})(A-\rho_k)}\right]$$

as $\rho_i = \lambda_i \mathrm{E}(S_i)$

$$E(W^{\Pi}) - E(W^{\Pi_{k,k+1}}) = \frac{\omega_0}{(\sum_{k=1}^{K} \lambda_k)} \left[\frac{\lambda_k \lambda_{k+1} (\mathrm{E}(S_k) - \mathrm{E}(S_{k+1}))(2A - \rho_k - \rho_{k+1})}{A(A - \rho_k - \rho_{k+1})(A - \rho_{k+1})(A - \rho_k)} \right]$$

Since $A = \sum_{i=1}^{K} \rho_i < 1,\ \rho_i > 0,\ \lambda_i > 0 \Rightarrow E(W^{\Pi}) - E(W^{\Pi_{k,k+1}}) < 0 \Leftrightarrow (\mathrm{E}(S_k) - \mathrm{E}(S_{k+1}))$. Thus, minimum unconditional expected waiting time is associated with a queuing discipline, for which $E(S_i) < E(S_{i+1}), \forall\ i$ ■

Appendix A.1. GMM Results

Table A.3: Patient count, average waiting times, and average length of stay by years

Number of patients (COUNT), average waiting times (WT) and average length of stay (LOS) for fourteen financial years and four elective medical procedures: cardiac artery bypass surgery (CABG), percutaneous corononary intervention (PCI), hip replacement (HIP) and knee replacement (KNEE).

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	1998–2011
							Number of Procedures								
CABG	13,661	12,601	13,566	14,804	15,538	15,189	15,483	13,802	13,451	14,473	14,131	12,245	11,091	10,884	190,919
PCI	8,569	9,212	10,871	14,180	15,875	19,903	23,971	25,253	26,368	25,131	25,007	23,451	23,380	22,656	273,827
HIP	36,295	36,115	37,608	39,945	43,125	48,261	48,354	49,346	51,998	57,365	60,470	60,724	64,343	67,990	701,939
KNEE	28,266	29,118	31,723	35,560	41,603	49,777	53,140	55,800	58,512	66,035	68,904	67,991	70,206	73,783	730,418
							Average Waiting Time								
CABG	202.97	206.91	220.64	188.78	154.35	105.86	99.02	67.35	68.10	66.59	60.27	51.85	52.61	63.22	116.67
PCI	75.44	73.78	85.89	83.74	89.24	92.22	83.31	56.06	52.15	44.00	36.90	38.41	38.94	40.39	59.31
HIP	226.23	228.97	238.11	239.33	234.76	215.56	181.88	160.08	143.66	112.83	82.70	82.37	83.32	88.78	153.23
KNEE	268.59	266.49	274.82	272.61	261.94	236.71	196.65	174.38	153.99	120.06	87.08	85.28	87.53	94.88	162.24
							Average Length of Stay								
CABG	9.10	9.21	9.28	9.55	9.61	9.68	9.83	9.99	10.07	9.59	9.46	9.60	9.42	9.38	9.57
PCI	1.92	1.82	1.68	1.54	1.51	1.47	1.41	1.36	1.19	1.00	0.94	0.86	0.77	0.73	1.20
HIP	12.43	11.91	11.38	10.98	10.52	9.78	9.21	8.59	7.82	7.11	6.68	6.39	5.89	5.44	8.40
KNEE	12.52	11.83	11.20	10.69	10.04	9.30	8.59	8.05	7.36	6.66	6.28	6.03	5.70	5.32	7.84

Table A.4: Generalised Method of Moments Estimation Results with Fixed Effects

Extract of GMM estimation results (Eq. 7) for fourteen financial years 1998 – 2011 and four medical elective procedures: cardiac artery bypass surgery (CABG), percutaneous corononary intervention (PCI), hip replacement (HIP) and knee replacement (KNEE). Each panel contains coefficient of interest, $E(LoS)$, third degree age polynomial, intercept, overidentification test result J_p, R^2 and number of observations. Coefficients in red are statistically significant at 1% CL, in blue - 5% CL, in black - statistically insignificant.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
							CABG							
E(LoS)	0.089	0.186	0.953	0.917	0.496	0.591	0.371	0.239	0.143	0.153	0.143	0.054	0.162	0.160
age	-0.426	-0.243	0.124	-0.995	0.192	-0.751	-0.044	0.276	0.333	0.125	0.082	-0.287	0.184	-0.094
age2	0.018	0.016	0.008	0.023	-0.001	0.018	0.005	-0.004	-0.005	-0.001	0.000	0.005	-0.004	0.001
age3	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000
Cons	-8.456	-14.804	-24.513	2.787	-11.576	2.956	-7.314	-8.232	-9.377	-5.710	-5.527	4.671	-4.925	-0.042
J_p	0.332	0.149	0.296	0.190	0.364	0.199	0.409	0.336	0.232	0.417	0.358	0.709	0.520	0.728
R^2	0.069	0.090	0.060	0.087	0.080	0.109	0.108	0.113	0.100	0.100	0.109	0.128	0.134	0.094
N	12115	12161	11899	12791	11714	8528	6587	6020	12273	13495	13357	11551	10931	9980
							PCI							
E(LoS)	1.610	2.464	0.156	0.584	1.584	0.664	0.359	0.454	-0.105	0.332	0.186	0.398	0.614	0.653
age	-0.701	-0.862	-0.410	-0.549	-0.236	0.216	-0.145	-0.577	-0.445	-0.234	-0.273	-0.056	-0.435	-0.437
age2	0.017	0.018	0.012	0.011	0.008	-0.001	0.004	0.010	0.007	0.004	0.004	0.001	0.007	0.007
age3	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
Cons	4.213	7.891	-0.051	6.911	-2.594	-8.655	-0.037	10.268	8.482	3.778	4.928	-0.024	7.968	7.701
J_p	0.441	0.502	0.241	0.238	0.283	0.310	0.372	0.297	0.399	0.155	0.135	0.152	0.103	0.033
R^2	0.052	0.035	0.048	0.040	0.033	0.037	0.026	0.030	0.029	0.033	0.046	0.045	0.045	0.045
N	7455	9401	10637	13887	15497	11735	11015	10636	23835	23934	24587	22967	22851	21921
							HIP							
E(LoS)	0.070	-0.065	-0.291	-0.108	0.018	0.129	0.116	0.653	0.184	0.139	0.200	0.196	0.364	0.276
age	0.557	0.175	-0.059	0.829	0.164	0.573	0.624	-0.091	0.112	0.317	0.134	0.198	0.049	0.025
age2	-0.004	0.003	0.004	-0.008	0.004	-0.007	-0.008	0.004	-0.001	-0.005	-0.003	-0.004	-0.002	-0.001
age3	-0.000	-0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000	-0.000	0.000	0.000	0.000	0.000	0.000
Cons	-14.599	-7.115	1.977	-19.715	-10.423	-14.568	-15.549	-4.353	-4.213	-6.158	-2.225	-2.413	-0.343	0.276
J_p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.004	0.007	0.001	0.006	0.000
R^2	0.115	0.118	0.116	0.112	0.112	0.112	0.104	0.123	0.119	0.127	0.142	0.142	0.130	0.134
N	34773	36006	37026	39084	34454	24286	20710	25043	47536	49791	57065	59676	63335	61304
							KNEE							
E(LoS)	0.043	0.597	-0.157	0.040	-0.001	0.212	0.535	0.641	0.325	0.278	0.191	0.263	0.403	0.357
age	0.063	0.514	0.966	0.579	0.712	0.742	2.123	1.082	0.728	0.744	0.410	0.408	0.442	0.892
age2	0.008	0.004	-0.008	-0.001	-0.005	-0.007	-0.028	-0.014	-0.009	-0.010	-0.006	-0.006	-0.007	-0.013
age3	-0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cons	-15.780	-34.435	-29.998	-24.154	-23.732	-23.756	-55.024	-29.682	-19.443	-18.141	-9.478	-8.503	-10.620	-19.988
J_p	0.000	0.000	0.006	0.001	0.002	0.000	0.001	0.000	0.052	0.466	0.442	0.019	0.003	0.157
R^2	0.076	0.088	0.089	0.094	0.089	0.104	0.086	0.104	0.100	0.104	0.106	0.117	0.118	0.110
N	27579	29866	31689	35909	33013	25050	23333	29087	53922	57226	65278	67074	70176	65931

Table A.5: OLS results for length of stay for elective cardiac artery bypass surgery (CABG) prediction

OLS regression results for predicting length of stay for elective cardiac artery bypass surgery (CABG) on number of comorbidities, seventeen Charlson conditions, quintile dummies for index of multiple deprivation (IMD), gender, white vs non-white race, third degree age polynomial, and intercept for every year from 1998 to 2011. Coefficients in red are statistically significant at 1% CL, in blue - 5% CL, in black - statistically insignificant.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Comorb 1	0.278	0.164	0.001	0.148	0.101	-0.057	0.585	-0.573	-0.057	-0.301	0.033	-0.363	0.564	1.910
Comorb 2	0.761	0.577	0.04	0.274	0.286	0.171	0.654	-0.402	-0.068	-0.471	0.14	0.321	0.62	1.863
Comorb 3	0.859	0.53	0.413	0.192	0.262	0.183	0.521	-0.146	0.2	-0.307	0.427	0.264	0.736	2.114
Comorb 4	1.738	1.087	0.626	0.54	0.667	0.609	1.017	0.038	0.24	-0.064	0.343	0.359	0.74	2.180
Comorb 5+	3.047	3.062	2.398	2.823	2.194	2.257	3.265	3.203	2.775	1.901	2.615	2.492	2.643	3.878
IMD 2	-0.324	-0.294	-0.495	-0.14	0.317	0.027	-0.335	-0.213	0.152	-0.013	-0.124	0.034	0.089	-0.146
IMD 3	-0.276	-0.603	-0.652	-0.152	-0.309	-0.191	-0.214	-0.929	-0.081	0.101	-0.347	-0.132	-0.27	-0.422
IMD 4	-0.213	-0.39	-0.992	-0.309	-0.206	-0.17	-0.381	-1.179	-0.387	-0.185	-0.465	-0.479	-0.313	-0.874
IMD 5	-0.334	-0.707	-0.712	-0.405	-0.171	-0.061	-0.493	-1.165	-0.417	-0.402	-0.621	-0.575	-0.382	-0.765
AMI	-0.869	-0.880	-0.603	0.022	0.687	-0.261	-0.168	-1.456	-0.37	0.447	0.716	2.988	3.237	1.200
CHF	0.572	0.019	0.73	0.099	0.039	0.544	0.989	0.659	1.264	1.638	2.089	2.555	2.195	2.594
PVD	-0.637	-0.192	0.395	-0.061	0.102	0.511	0.093	-0.766	-0.109	0.534	0.508	0.265	-0.001	0.443
CEVD	2.813	1.890	2.147	1.774	4.291	3.461	2.39	2.139	2.845	2.366	2.015	3.145	3.033	1.907
Dementia	-0.14	-3.170	0.238	18.264	17.141	-2.043	8.054	.	-0.426	6.554	2.804	-0.921	2.961	0.736
COPD	-0.085	-0.137	0.063	0.273	0.561	0.588	0.697	0.313	0.282	0.540	0.527	0.930	0.637	0.812
Rheumatoid	-1.056	0.422	0.194	-0.724	-0.982	-0.457	-1.346	-1.765	-1.223	-0.652	-0.807	-0.669	-0.946	0.059
Peptic ulcer	3.287	10.84	1.918	8.635	3.631	-1.299	4.270	-0.503	7.944	4.009	2.81	4.529	3.482	3.391
Mild LD	7.711	1.894	5.214	0.665	1.448	-0.248	-3.125	-0.485	0.993	4.719	1.332	0.341	2.951	2.209
Diabetes	0.063	0.068	0.267	-0.09	0.128	0.016	0.15	-0.374	0.203	-0.074	-0.014	-0.025	0.384	-0.134
Diabetes+Compl	-0.194	-2.348	0.757	1.424	3.658	3.363	1.126	2.067	2.820	0.516	1.636	0.162	1.364	2.627
HP/PAPL	2.149	1.573	6.267	3.322	1.12	-2.249	12.046	2.152	1.465	-0.686	0.261	5.798	5.422	0.785
Renal	2.442	6.185	3.845	2.358	3.801	5.152	4.424	7.133	4.331	3.429	2.951	3.713	3.362	1.983
Cancer	-0.326	1.038	-1.086	-0.372	0.475	-0.332	-0.448	-2.381	-0.99	-0.916	-0.606	-0.992	0.449	-0.209
Moderate/Severe LD	.	.	.	25.125	29.389	55.329	19.909	6.159	9.154	1.96	12.501	4.139	3.036	5.385
Metastatic Cancer	-3.198	-0.818	-1.799	-2.012	-3.827	.	-2.250	-6.160	-1.107	2.967	-0.098	-3.525	-2.963	-0.690
AIDS	.	.	-1.326	.	-3.279	.	3.543	.	24.806	-1.08	.	.	.	.
Female	0.716	0.511	0.414	0.620	0.568	1.184	0.766	1.440	1.145	0.772	0.707	0.699	0.881	0.641
White	-0.146	-0.06	0.018	0.253	0.141	-0.398	-0.659	0.093	-0.195	0.139	-0.304	-0.222	-0.082	0.087
age	0.217	0.510	0.257	0.266	0.385	0.451	0.262	-0.057	0.239	0.300	0.118	0.437	0.300	0.033
age2	-0.004	-0.009	-0.004	-0.006	-0.008	-0.01	-0.005	0	-0.005	-0.007	-0.005	-0.009	-0.007	-0.002
age3	0	0.000	0.000	0.000	0.000	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000
Cons	2.89	-2.499	1.368	2.512	0.116	-0.267	1.779	7.565	1.416	1.556	6.081	-1.467	0.212	3.804
N	12115	12161	11899	12791	11714	8528	6587	6020	12273	13495	13357	11551	10931	9980

Table A.6: OLS results for length of stay for elective percutaneous corononary intervention surgery (PCI) prediction

OLS regression results for predicting length of stay for elective percutaneous corononary intervention (PCI) on number of comorbidities, seventeen Charlson conditions, quintile dummies for index of multiple deprivation (IMD), gender, white vs non-white race, third degree age polynomial, and intercept for every year from 1998 to 2011. Coefficients in red are statistically significant at 1% CL, in blue - 5% CL, in black - statistically insignificant.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Comorb 1	0.157	0.263	0.328	0.136	0.051	0.009	0.054	0.121	0.146	0.129	0.120	0.1	0.237	0.221
Comorb 2	0.256	0.356	0.327	0.235	0.155	0.063	0.132	0.117	0.225	0.231	0.296	0.179	0.302	0.266
Comorb 3	0.317	0.339	0.432	0.294	0.210	0.176	0.157	0.128	0.257	0.261	0.301	0.248	0.361	0.310
Comorb 4	0.485	0.637	0.486	0.394	0.282	0.124	0.204	0.224	0.268	0.325	0.357	0.288	0.344	0.340
Comorb 5+	0.758	0.977	0.862	0.665	0.420	0.367	0.321	0.422	0.412	0.380	0.497	0.402	0.459	0.446
IMD 2	-0.051	-0.111	-0.068	0.028	-0.069	0.077	-0.099	0.033	0.05	0.003	-0.016	0.012	-0.03	0.053
IMD 3	-0.149	-0.186	-0.097	-0.02	-0.076	0.083	-0.169	0.037	0.065	0.016	-0.04	0.021	-0.01	0.051
IMD 4	-0.188	-0.218	-0.137	-0.003	-0.026	-0.005	-0.138	0.002	0.038	0.01	-0.02	0.006	-0.01	0.018
IMD 5	-0.258	-0.205	-0.174	-0.032	-0.119	-0.001	-0.183	-0.097	-0.008	-0.014	-0.05	-0.046	-0.047	0.001
AMI	-0.02	0.003	0.171	0.122	0.161	0.237	0.383	0.456	0.398	0.295	0.532	0.701	0.404	0.519
CHF	1.258	0.157	0.096	0.543	0.111	0.684	0.536	1.055	0.17	0.301	0.736	0.413	0.429	0.569
PVD	0.044	-0.290	-0.019	-0.113	0.360	0.254	-0.146	-0.148	0.127	0.067	0.004	0.051	0.135	0.077
CEVD	0.428	1.156	0.874	0.094	0.041	0.281	1.437	0.193	0.711	0.479	0.698	0.345	0.678	0.389
Dementia	.	.	.	0.013	-0.903	-1.307	.	1.009	2.049	0.159	-0.457	0.227	0.079	0.761
COPD	0.316	-0.13	0.214	0.011	0.097	0.131	0.008	-0.001	0.018	0.066	0.03	0.017	0.008	0.015
Rheumatoid	0.682	-0.356	0.473	0.107	-0.015	0.65	0.321	-0.058	0.018	-0.101	0.093	-0.08	0.088	0.052
Peptic ulcer	0.369	0.022	0.597	0.37	3	1.02	0.422	0.175	0.382	1.076	1.042	0.489	0.614	0.830
Mild LD	3.973	-0.054	-0.331	0.158	-0.011	0.658	1.861	0.239	0.297	0.469	0.108	-0.093	1.176	0.178
Diabetes	-0.046	-0.274	-0.103	-0.093	0.027	0.07	0.021	-0.032	0.003	-0.001	-0.044	-0.007	0.029	-0.013
Diabetes+Compl	1.296	-0.038	-0.750	0.073	0.431	0.307	0.144	0.09	0.352	-0.155	0.169	0.375	0.121	0.214
HP/PAPL	1.206	-0.255	-0.473	0.346	2.338	-0.403	1.03	0.598	0.216	0.481	-0.541	-0.037	-0.328	-0.235
Renal	-0.214	0.57	0.789	0.685	0.614	1.014	0.921	0.976	0.516	0.573	0.652	0.580	0.391	0.433
Cancer	0.227	-0.401	0.7	0.784	0.414	0.49	0.694	0.188	0.418	0.214	0.227	0.253	0.264	0.143
Moderate/Severe LD	-2.363	-0.304	1.582	.	.	2.914	0.542	-0.236	3.449	0.175	5.567	1.443	0.408	0.329
Metastatic Cancer	-0.114	-1.815	-0.07	-0.445	-0.028	-0.586	-0.064	0.269	0.353	-0.294	1.262	0.558	0.216	0.116
AIDS	.	0.195	.	.	0.727	4.204	2.021	-0.269	-0.235	1.097	0.103	.	.	.
Female	0.171	0.182	0.119	0.092	0.135	0.103	0.004	0.067	0.080	0.110	0.077	0.05	0.094	0.080
White	0.025	0.016	0.05	-0.039	-0.034	0.01	-0.045	0.004	-0.044	-0.005	-0.103	-0.117	-0.02	-0.075
age	0.068	0.035	-0.082	-0.018	0.032	-0.023	0.012	-0.066	0.021	0.027	-0.060	-0.042	0.004	0.027
age2	-0.002	-0.001	0.001	0	-0.001	0	0	0.001	0	-0.001	0.001	0	0	-0.001
age3	0.000	0.000	0	0	0	0	0	0	0	0.000	0	0	0	0.000
Cons	1.147	1.292	2.824	1.887	0.827	1.859	1.103	2.248	0.444	0.172	1.765	1.805	0.483	-0.076
N	7455	9401	10637	13887	15497	11735	11015	10636	23835	23934	24587	22967	22851	21921

Table A.7: OLS results for length of stay for elective Hip replacement(HIP) prediction

OLS regression results for predicting length of stay for elective hip replacement on number of comorbidities, seventeen Charlson conditions, quintile dummies for index of multiple deprivation (IMD), gender, white vs non-white race, third degree age polynomial, and intercept for every year from 1998 to 2011. Coefficients in red are statistically significant at 1% CL, in blue - 5% CL, in black - statistically insignificant.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Comorb 1	1.035	0.936	0.654	0.849	0.730	0.515	0.400	0.479	0.423	0.529	0.309	0.200	0.138	0.096
Comorb 2	2.049	1.916	1.657	1.688	1.613	1.374	1.012	0.850	0.912	0.950	0.808	0.628	0.414	0.400
Comorb 3	3.135	2.700	2.875	2.971	2.506	2.453	1.661	1.498	1.529	1.650	1.420	1.181	0.905	0.843
Comorb 4	4.921	4.061	3.739	4.047	3.537	3.715	3.091	2.346	2.502	2.558	2.132	1.946	1.269	1.310
Comorb 5+	7.843	6.630	6.469	7.309	7.190	6.627	5.041	4.799	5.363	5.377	4.874	4.597	3.431	3.268
IMD 2	-0.528	-0.601	-0.585	-0.491	-0.341	-0.497	-0.544	-0.406	-0.314	-0.337	-0.158	-0.142	-0.215	-0.094
IMD 3	-0.963	-0.992	-1.090	-1.067	-0.884	-1.041	-0.894	-0.776	-0.498	-0.350	-0.357	-0.296	-0.346	-0.239
IMD 4	-1.124	-1.298	-1.213	-1.258	-0.992	-1.138	-0.945	-0.794	-0.659	-0.557	-0.413	-0.412	-0.419	-0.290
IMD 5	-1.270	-1.348	-1.509	-1.396	-1.192	-1.140	-1.068	-0.862	-0.656	-0.614	-0.456	-0.456	-0.552	-0.371
AMI	-2.388	-1.649	-1.612	-1.346	-0.365	-0.941	-0.718	-0.901	-0.16	-0.039	-0.139	0.336	0.014	-0.039
CHF	1.456	1.545	1.364	-0.069	0.518	-0.378	0.925	1.189	0.895	0.994	1.126	1.339	1.580	1.676
PVD	-1.900	-0.684	-0.089	-0.75	-1.235	-1.241	-0.153	0.036	-0.394	-1.195	-0.600	-0.56	0.229	-0.671
CEVD	2.797	1.456	2.686	1.887	1.284	2.795	1.155	1.643	2.142	4.347	1.329	0.707	1.212	0.972
Dementia	3.737	11.567	3.355	1.223	4.382	2.39	4.867	2.064	3.936	7.023	6.221	3.434	3.680	2.758
COPD	-1.589	-1.259	-1.201	-1.228	-0.792	-0.949	-0.446	-0.391	-0.451	-0.459	-0.356	-0.376	-0.196	-0.168
Rheumatoid	0.795	0.764	1.004	0.859	0.467	0.095	0.507	-0.003	-0.039	0.245	0.115	0.239	0.165	0.341
Peptic ulcer	2.421	2.527	1.426	1.608	2.684	2.127	6.338	1.688	0.977	4.342	0.723	2.743	0.492	0.306
Mild LD	-2.449	1.702	0.193	1.556	0.029	-0.364	-1.470	0.662	2.163	2.314	-0.026	0.373	0.252	1.844
Diabetes	-0.826	-0.831	-0.656	-0.617	-0.675	-0.676	-0.529	-0.105	-0.393	-0.452	-0.273	-0.202	0.017	-0.147
Diabetes+Compl	-1.373	-0.371	1.121	2.917	-0.268	1.476	-1.811	1.449	-0.786	1.918	-0.681	-0.564	0.114	-0.239
HP/PAPL	5.463	3.962	0.067	-1.261	2.833	1.26	2.475	-0.307	1.385	1.53	4.132	3.419	1.121	4.224
Renal	0.775	-0.575	1.997	0.594	1.461	1.228	2.164	2.221	1.371	0.599	1.137	0.865	0.770	1.022
Cancer	-0.768	1.049	-0.611	1.433	0.101	0.989	0.48	-0.796	-0.008	-0.705	0.153	0.077	0.422	0.199
Moderate/Severe LD	-1.255	-0.98	9.068	-4.490	8.505	13.847	-3.439	-0.681	-2.576	-0.811	7.171	1.646	15.873	3.530
Metastatic Cancer	4.314	1.54	-1.740	1.62	0.897	0.128	-0.257	1.059	0.997	0.697	1.919	1.385	1.527	0.303
AIDS	-1.793	-5.450	-2.500	-2.702	0.302	-2.313	6.034	-2.496	-0.32	-1.035	0.571	.	.	.
Female	0.613	0.556	0.690	0.493	0.593	0.511	0.181	0.534	0.357	0.473	0.386	0.444	0.431	0.406
White	0.233	0.07	0.142	0.294	0.330	0.208	0.557	0.529	0.407	0.088	0.246	0.172	0.101	0.013
age	0.127	0.021	0.241	0.151	0.168	0.057	0.327	0.277	0.544	0.432	0.457	0.348	0.265	0.394
age2	-0.005	-0.003	-0.007	-0.005	-0.005	-0.004	-0.009	-0.007	-0.012	-0.010	-0.010	-0.008	-0.007	-0.009
age3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cons	9.822	11.071	6.617	7.667	6.411	9.493	4.971	3.283	-2.251	-0.377	-1.709	0.075	1.672	-1.256
N	34773	36006	37026	39084	34454	24286	20710	25043	47536	49791	57065	59676	63335	61304

Table A.8: OLS results for length of stay for elective knee replacement (KNEE) prediction

OLS regression results of predicting length of stay for elective knee replacement number of comorbidities, seventeen Charlson conditions, quintile dummies for index of multiple deprivation (IMD), gender, white vs non-white race, third degree age polynomial, and intercept for every year from 1998 to 2011. Coefficients in red are statistically significant at 1% CL, in blue - 5% CL, in black - statistically insignificant.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Comorb 1	0.617	0.612	0.612	0.575	0.504	0.389	0.155	0.324	0.318	0.343	0.098	0.005	0.031	0.119
Comorb 2	1.718	1.619	1.627	1.466	1.396	0.919	0.814	0.721	0.718	0.789	0.539	0.344	0.302	0.300
Comorb 3	2.542	2.548	2.540	2.370	2.568	1.640	1.378	1.453	1.239	1.335	0.975	0.718	0.597	0.628
Comorb 4	4.313	3.492	3.498	3.578	3.212	2.836	2.046	2.272	1.857	1.947	1.700	1.248	1.026	1.087
Comorb 5+	6.877	5.403	5.200	6.464	6.534	4.611	4.091	4.249	3.776	3.771	3.562	3.450	2.756	2.721
IMD 2	-0.736	-0.453	-0.407	-0.138	-0.328	-0.344	-0.397	-0.138	-0.175	-0.298	-0.206	-0.173	-0.208	-0.037
IMD 3	-0.890	-0.766	-0.849	-0.607	-0.745	-0.681	-0.567	-0.493	-0.374	-0.394	-0.279	-0.199	-0.313	-0.088
IMD 4	-1.115	-0.924	-1.183	-0.789	-0.908	-0.842	-0.712	-0.467	-0.539	-0.510	-0.472	-0.334	-0.419	-0.220
IMD 5	-1.336	-1.268	-1.508	-1.149	-1.019	-0.952	-0.728	-0.496	-0.549	-0.473	-0.388	-0.401	-0.454	-0.183
AMI	-1.530	-1.430	-1.901	-1.209	-1.144	-0.647	0.161	-0.739	0.22	-0.428	-0.251	-0.151	-0.021	-0.202
CHF	0.167	1.231	1.231	1.149	0.563	1.288	0.659	0.758	1.033	0.933	1.498	2.104	1.716	1.548
PVD	-1.575	-0.384	-1.229	-1.209	-1.085	-1.459	-1.208	-1.105	-0.774	-0.508	-0.082	-0.245	0.06	0.044
CEVD	2.636	1.825	2.579	3.102	1.259	0.934	2.171	0.619	1.163	2.706	0.273	0.863	1.346	0.709
Dementia	18.473	2.155	25.463	8.897	10.903	11.045	3.650	8.516	3.489	4.817	3.997	2.763	4.308	2.586
COPD	-1.503	-1.054	-1.143	-1.106	-0.694	-0.272	-0.235	-0.270	-0.105	-0.432	-0.261	-0.145	-0.161	-0.078
Rheumatoid	0.685	0.650	0.440	-0.014	0.620	0.351	0.196	-0.095	0.085	0.155	-0.081	0.185	0.149	-0.007
Peptic ulcer	-0.158	-0.18	-0.152	4.194	-0.134	8.543	1.864	-0.355	3.333	0.738	0.994	0.774	0.424	-0.448
Mild LD	0.886	0.953	3.104	-0.427	2.33	1.317	2.969	-0.005	0.794	0.16	1.136	0.367	0.715	0.618
Diabetes	-0.627	-0.589	-0.511	-0.546	-0.588	-0.255	0.002	-0.124	-0.195	-0.216	0.042	0.025	0.161	-0.057
Diabetes+Compl	-2.335	-1.142	-1.381	-3.059	-2.529	-1.229	-1.530	1.144	0.868	-0.034	-0.084	0.236	0.43	0.800
HP/PAPL	-2.766	0.737	-1.977	-1.29	-0.401	-0.687	2.13	1.535	1.611	2.054	1.978	0.9	0.671	1.769
Renal	0.537	0.377	0.907	1.603	3.456	2.204	3.982	2.140	2.022	1.326	0.879	1.171	0.880	1.163
Cancer	-1.16	-0.508	-1.135	-0.309	-0.626	0.013	-0.682	-0.296	-0.283	-0.204	0.524	0.026	0.707	-0.094
Moderate/Severe LD	3.120	6.255	8.109	.	-2.288	-4.691	.	1	-0.686	-1.209	-2.066	0.504	1.252	0.255
Metastatic Cancer	-1.264	-0.695	-1.854	-0.816	-2.001	-1.685	2.537	1.387	-0.623	0.911	-1.655	-0.3	0.477	0.335
AIDS	.	5.769	4.348	6.918	7.145	.	5.596	.	1.074	0.041	6.572	.	.	.
Female	0.788	0.659	0.514	0.631	0.535	0.474	0.470	0.404	0.373	0.376	0.284	0.280	0.347	0.296
White	-0.102	-0.108	-0.111	-0.215	-0.05	0.126	0.331	0.288	0.141	0.008	0.053	-0.147	-0.158	-0.249
age	-0.121	0.143	-0.466	0.378	0.198	0.512	0.098	0.531	0.454	0.423	0.388	0.522	0.633	0.548
age2	-0.001	-0.005	0.004	-0.010	-0.006	-0.011	-0.004	-0.011	-0.010	-0.009	-0.009	-0.011	-0.013	-0.011
age3	0	0.000	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cons	15.183	9.451	22.644	4.415	7.112	0.056	7.177	-2.106	-0.464	-0.906	0.151	-3.193	-5.230	-4.503
N	27579	29866	31689	35909	33013	25050	23333	29087	53922	57226	65278	67074	70176	65931

Table A.9: Generalised Method of Moments Estimation Results without Fixed Effects

Snippets of GMM estimation results (Eq. 7) for fourteen financial years 1998 – 2011 and four medical elective procedures: cardiac artery bypass surgery (CABG), percutaneous coronary intervention (PCI), hip replacement (HIP) and knee replacement (KNEE). Each panel contains the coefficient of interest, $E(LoS)$, third degree age polynomial, intercept, overidentification test J_p, R^2 and number of observations for fourteen years of data. Significance of the coefficients is colour-coded. In black there are coefficients that are statistically insignificant, in blue – significant with 5%, in red – significant with 1%.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
							CABG							
E(LoS)	0.155	0.206	1.074	0.944	0.619	0.876	0.368	0.260	0.182	0.161	0.093	0.011	0.227	0.204
age	-0.217	0.105	0.229	-1.295	0.088	-1.202	0.083	0.283	0.449	0.075	0.137	-0.240	0.152	0.092
age2	0.015	0.011	0.005	0.029	0.002	0.025	0.002	-0.005	-0.007	-0.000	-0.001	0.004	-0.003	-0.001
age3	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	0.000	-0.000	0.000	-0.000	0.000	0.000
Cons	-12.535	-21.779	-26.190	8.011	-11.546	10.517	-9.247	-8.626	-11.678	-4.967	-5.467	4.065	-5.463	-4.519
J_p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R^2	0.069	0.090	0.060	0.087	0.080	0.109	0.108	0.113	0.100	0.100	0.109	0.128	0.134	0.094
N	12115	12161	11899	12791	11714	8528	6587	6020	12273	13495	13357	11551	10931	9980
							PCI							
E(LoS)	1.569	2.151	0.374	0.430	1.970	0.283	0.190	0.719	-0.031	0.315	0.496	0.692	0.811	1.076
age	-0.979	-0.736	-0.461	-0.451	-0.322	-0.009	-0.036	-0.524	-0.369	-0.309	-0.188	-0.009	-0.215	-0.331
age2	0.021	0.016	0.013	0.009	0.009	0.004	0.003	0.009	0.006	0.005	0.003	0.001	0.004	0.006
age3	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
Cons	10.330	5.926	0.645	5.672	-1.470	-5.174	-2.263	8.756	6.748	5.261	3.455	-1.001	3.495	4.979
J_p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R^2	0.052	0.035	0.048	0.040	0.033	0.037	0.026	0.030	0.029	0.033	0.046	0.045	0.045	0.045
N	7455	9401	10637	13887	15497	11735	11015	10636	23835	23934	24587	22967	22851	21921
							Hip							
E(LoS)	0.255	0.351	-0.163	-0.009	0.018	0.172	0.225	0.655	0.285	0.251	0.249	0.311	0.416	0.273
age	0.683	0.377	0.225	0.920	0.276	0.233	0.606	0.173	0.097	0.246	0.122	0.134	0.022	0.117
age2	-0.006	0.001	0.000	-0.010	0.002	-0.000	-0.007	-0.000	0.000	-0.003	-0.002	-0.003	-0.001	-0.002
age3	-0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000	0.000	-0.000	0.000
Cons	-19.974	-17.200	-5.911	-22.452	-12.666	-8.533	-16.229	-9.904	-5.360	-6.234	-2.602	-2.408	-0.675	-1.710
J_p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R^2	0.115	0.118	0.116	0.112	0.112	0.112	0.104	0.123	0.119	0.127	0.142	0.142	0.130	0.134
N	34773	36006	37026	39084	34454	24286	20710	25043	47536	49791	57065	59676	63335	61304
							Knee							
E(LoS)	0.119	0.579	-0.184	-0.211	-0.070	0.417	0.477	0.690	0.484	0.393	0.272	0.401	0.403	0.344
age	0.451	0.985	1.148	0.328	0.899	0.931	2.282	0.744	0.637	0.749	0.487	0.418	0.433	0.629
age2	0.002	-0.004	-0.011	0.001	-0.007	-0.010	-0.031	-0.009	-0.008	-0.010	-0.007	-0.006	-0.006	-0.010
age3	-0.000	-0.000	0.000	-0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cons	-24.417	-43.527	-34.064	-14.959	-29.184	-28.861	-56.897	-23.903	-19.414	-19.249	-11.836	-10.179	-10.275	-13.666
J_p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R^2	0.076	0.088	0.089	0.094	0.089	0.104	0.086	0.104	0.100	0.104	0.106	0.117	0.118	0.110
N	27579	29866	31689	35909	33013	25050	23333	29087	53922	57226	65278	67074	70176	65931

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