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Do maximum waiting times guarantees change clinical priorities? A Conditional Density Estimation approach

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Abstract

The level and distribution of patient waiting times for elective treatments is a major concern in publicly-funded health care systems. Strict targets, which have specified maximum waiting times, have been introduced in the NHS over the last decade and have been criticized for distorting existing clinical priorities in scheduling hospital treatment. We demonstrate the usefulness of Conditional Density Estimation (CDE) in the evaluation of the reform using data for Scotland for 2002 and 2007. The CDE approach allows for variation in the effects of patients' characteristics over ranges of the distribution and avoids restrictive assumptions about error distribution and functional form. We find that health providers achieved the target by reducing the waiting times for long-waiting patients at the expense of short-waiting patients. We also document a change in the prioritization between different patient groups with some patient groups benefiting at the cost of others.

Keywords: health care, waiting times, conditional density estimation

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1. Motivation

Waiting times are of public concern in State healthcare systems because they are a key determinant of satisfaction with public services (Sanmartin et al., 2007), a perceived indicator of public sector inefficiency (Cullis and Jones, 1983, 1985), and a source of discomfort and anxiety (Lindsay and Feigenbaum, 1984; Propper, 1995). It is possible also, though the evidence is very limited, that delays in treatment may have negative health consequences (Siciliani and Gravelle, 2008; Appleby et al., 2003). Also of concern are variations in waiting times across geographical areas and personal characteristics since such variations may represent a source of inequity (Dimakou et al., 2009). The focus of this paper is on waiting times for elective surgery in the NHS in Scotland and, in particular, on waiting-time that passes between a hospital doctors' decision that a patient requires treatment to when the treatment is actually administered.

The high profile, stringently enforced and monitored, use of escalating waiting times targets by the New Labour government in England between the years 2000 and 2010 were a unique experiment in how to alter the performance of a large State bureaucracy. Similar centralized and high profile guarantees were introduced in Scotland in 2003. They reduced the maximum amount of time a patient could wait for a planned specialist treatment from 12 months (52 weeks) in 2002 to 18 weeks (126 days) in 2007. Failure to meet these guarantees led to severe sanctions for managers including the dissolution of one Health Board. In addition, the Scottish Executive created the NHS National Waiting Time Centre[1]. During the first five years of its operation, the Centre dealt with over 100,000 procedures across NHS Scotland Boards [2] in an effort to meet the escalating targets.

There has been widespread concern that the policy of waiting time guarantees would result in fraudulent statistics and distortion of clinical priorities. 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. Given the similarity of reforms in England and Scotland, the behavior of the consultants is likely to be similar. Siciliani and Hurst (2005) suggested that maximum waiting time guarantees in theory may be effective in reducing long waiting times, but perverting the incentives for hospitals: "they are not very effective in reducing mean or median waiting times, if the provider simply gives higher priority to less severe patients (who have waited longest), as they approach the maximum" (p.212). Appleby et al. conducted "before-and-after" comparison of waiting times distributions for English trauma and orthopaedic patients to evaluate the implications of the reform on patient prioritization. They calculated that the number of admissions

[1]The NHS National Waiting Times Centre was created in 2002 when Scottish Executive bought the Golden Jubilee National Hospital at Clydebank with the specific objective of reducing waiting times in Scotland (Scottish Executive, 2003).

[2]http://www.nhsayrshireandarran.com/uploads/4121/5years.pdf

around the 15-month target at the time increased by 2.2% of all orthopaedic admissions in post-reform period. While they could not unambiguously establish whether additional admissions had lead to delayed treatment for other patients, there was no evidence that very short-wait patients suffered.

This paper examines whether the prioritization reform has changed the 2002 ordering of clinical priorities in scheduling hospital treatment. Characteristics of patient's healthiness (age, co-morbidities, disease type) influence doctors' perception of urgency for treatment (Cullis et al., 2000). The impact of these patient characteristics are likely to vary over the range of waiting times. For example, having an additional co-morbidity might not reduce the waiting times for elderly patients older than 85 years who already have several health problems, but speed up treatment for younger adults with the same number of co-morbidities. The conditional density estimation (CDE) allows for such variations in covariate effects. In addition, its flexible specification of conditional probability functions and, hence, conditional expectations of the outcome of interest avoids restrictive assumptions about error distribution and relationship functional form.

2. Literature Review

The purpose of this section is twofold; namely the comparison of the different methods used in prioritization policy analysis and review of the results in related literature. The section compares different methods that have been applied to the analysis of the prioritization reform and contrasts the ability of these methods to incorporate skewness and point masses in the data. The section also reviews the contributions of Donald et al. (2001) and Gilleskie and Mroz (2004) to analyzing outcomes characterized by skewed, multi-peaked distributions.

The ultimate goal of waiting times modeling has been to recover a functional relationship between waiting time Y and relevant covariates X and construct correct statistical inference. Janulevicuite et al. (2011) studied the change in waiting times in Scotland and Norway using ordinary least squares (OLS) of the logarithm of waiting time on a set of covariates with matching to risk adjust the groups of individuals before and after the reform. Their results show that the aggressive waiting time targets in Scotland contributed to shorter waiting times for patients in low-priority disease categories while leaving patients in the high-priority groups unaffected. Assuming the model specification is correct, logarithmic transformation of the dependent variable can overcome skewness in some cases. However this approach is likely to face a new set of problems if the effect of interest is the level of the outcome variable. Moreover, when the the error term u is heteroscedastic in covariates X, the retransformation procedure to consistently recover $\hat{Y}|X$ becomes significantly more complicated (Manning, 1998; Mullahy, 1998).

Propper et al. (2010) adopted a difference-in-difference approach. They considered only a limited range of

possible distributional consequences of the waiting times targets. The authors compared various points in the waiting times distributions of England and Scotland using a difference-in-differences method. They found a small increase in waiting times at the lower end of the distribution. They also addressed possible patient reprioritization concerns by examining urgent cases and complication rates. However, their analysis did not satisfy the difference-in-differences assumption of no difference in trends prior to the reform and the findings were therefore inconclusive.

One approach that deals with skewed, multi-peaked distributions is based on survival or failure time models. Dimakou et al. (2009) used the Kaplan-Meier estimator to study the distributional changes in waiting times in the English NHS. They showed that the introduction of waiting time targets produced shifting spikes in the hazard rate just below the waiting time limit. They also showed that there was wide variation in waiting times distribution by hospital, specialty, and procedure. Using parametric Proportional Hazard (PH) and Accelerated Failure Time (AFT) models they evaluated covariate effects on the respective dependent variable[3] and find no statistically significant difference in characteristics such as age and sex.

An alternative approach to recover conditional expectations is to estimate a conditional probability density function itself. Efron (1988) proposed approximating unconditional distributions by a sequence of hazard rates. It was extended to conditional cases by Donald, Green and Paarsch (2001) and Gilleskie and Mroz (2004). The former approximates conditional density as a continuous function with structural shifts to allow for varying dependence of the covariates, while the latter uses sequences of logit hazard rates to reconstruct a discrete approximation of the density function. Gilleskie and Mroz refer to it as conditional density estimation (CDE) approach. These two approaches are very similar. They use flexible functional forms when defining sequences of conditional probabilities. This means that we have flexible representations of the conditional density functions, and consequently flexible representations of the expected value of the outcome conditional on covariates. These features make them appropriate for modeling waiting time distributions. Since they model conditional distribution function directly, they avoid the well-known issues of transformation and subsequent retransformation of a dependent variable with strictly positive and possibly multi-peaked distribution. In addition, the CDE naturally extends to a priori known discrete mass points. We adopt the CDE procedure due to the existence of a mass point in the waiting time distribution at time 0.

3. Conditional Density Estimation (CDE) method

[3]For the AFT models, the dependent variable is waiting time until admission; for the PH model it is the hazard rate

As described in Gilleskie and Mroz (2004) paper, the implementation of the CDE model involves several steps. We first divide the range of the dependent y into K bins with corresponding boundaries: $y_0, y_1, \ldots, y_K$. The probability that the random variable Y falls in the first interval is given by

$$\lambda(1,x) = p\left[y_0 \leq Y < y_1 | x, Y \geq 0\right] = \int_{y_0}^{y_1} f(y|x)dy$$

The probability that the random variable Y falls in the k-th interval is given by

$$p\left[y_{k-1} \leq Y < y_k | x\right] = \int_{y_{k-1}}^{y_k} f(y|x)dy$$

And the probability that the random variable falls in the k interval given that it did not fall in the first $k-1$ intervals or the discrete time hazard $\lambda(k,x)$ is

$$\lambda(k,x) = p[y_{k-1} \leq Y < y_k | x, Y \geq y_{k-1}] = \frac{\int_{y_{k-1}}^{y_k} f(y|x)dy}{1 - \int_{y_0}^{y_{k-1}} f(y|x)dy}$$

$$p[y_{k-1} \leq Y < y_k | x] = \lambda(k,x) \prod_{j=1}^{k-1} [1 - \lambda(j,x)]$$

The function $p\left[y_{k-1} \leq Y < y_k | x\right]$ defines the probability that the random variable Y falls in the k-th interval.

The conditional expectation of a function $h(\cdot)$ of a random variable Y, given x, is

$$E\left(h(Y)|x\right) = \int_{-\infty}^{\infty} h(y) f(y|x)dy$$

Given the partitioning of the support of Y, the approximation of $E\left(h(y)|x\right)$ in the k-th interval is

$$\hat{E}(h(y)|x) = \sum_{k=1}^{K} h^*(k|K)\lambda(k,x) \prod_{j=1}^{k-1} [1 - \lambda(j,x)] \tag{3.1}$$

In the formula above it is implicitly assumed that $h^*(k|K)$ does not depend on x.

Once we estimate sequences of $\hat{\lambda}(k,x)$ and $\hat{h}(k|K)$, we can construct an estimate of $\hat{E}(h(y)|x)$. To construct $\hat{h}(k|K)$, we compute:

$$h^*(k|K) = \frac{\sum_{y \in [y_{k-1}, y_k)} h(y)}{\sum_{y \in [y_{k-1}, y_k)} 1} \tag{3.2}$$

We use logit function to model the hazard rate $\hat{\lambda}(k,x)$. In the most restricted case, when $\lambda = f(k)$, each

observation in the sample is equally possible and the number of observations in the kth bin $[y_{k-1}\ y_k)$ is N_k:

$$\lambda_k = P(Y \in [y_{k-1}, y_k) | Y \geq y_{k-1}) = \frac{N_k / \sum_{l=1}^{K} N_l}{\sum_{s=k}^{K} N_s / \sum_{l=1}^{K} N_l} = \frac{N_k}{\sum_{s=k}^{K} N_s}$$

which, for the case of logit, gives an intercept

$$\alpha_k = \log\left(\frac{\lambda_k}{1-\lambda_k}\right)$$

This intercept would fit the unconditional discrete distribution function perfectly if it is the only covariate. Conversely, independent estimation of each "hazard" of falling within each bin would have an excessively large number of parameters to estimate. The CDE method, depending on specification, incorporates a wide range of models including the two extreme cases discussed above. It estimates a single logit model for all hazard rates simultaneously. The model depends on interactions of α_k polynomial with polynomials of the covariates x. The polynomial degree of α_k determines the flexibility of the response function across bins. The polynomial degree of x determines the flexibility of the response function in a particular bin.

4. Data

4.1. Scottish Morbidity Record 01 (SMR01)

We use the Scottish Morbidity Record 01 (SMR01) data set. This rich database records detailed information on all admissions to acute hospitals including patient characteristics such as age, number of co-morbidity conditions, and disease type. These are our main covariates. We compare the waiting times distributions before the implementation of the political waiting time guarantees (2002) with distribution after its implementation (2007).

We extract a subset of patients from the full-year population who were admitted for elective procedure. We next restrict our attention to only the first hospital stay for each patient in each year. This omits from the analysis all planned cases which cover treatment carried out on a cyclical basis (a course of chemotherapy) or where a clinically necessary delay occurs (the treatment of a second eye cataract or second hip repair). We lose, respectively, 33.3% and 35% of the sample for years 2002 and 2007. We also exclude observations where the waiting time is longer than two years. This results in additionally constricting the sample by 2.3% and 0.4% for years 2002 and 2007. We exclude from analysis pregnancy and conditions originating in the perinatal period (ICD-10 chapters 15 and 16) because of small number of observations. We have omitted as well external causes of morbidity and mortality and codes for special purposes (ICD-10 chapters 20 and 22) because the same ICD-10 code can be used to describe more than one medical condition with different severity and, hence, priority for

treatment[4]. Finally, we disregard observations with missing data on waiting times. This omits 2.2% and 2.6% from the original 2002 and 2007 samples. As a result, our analytical sample has 657,443 observations in total with 321,929 patient observation for 2002 and 335,514 for 2007. In preparing our data for analysis we follow Janulevicuite et al. (2011).

The data shows that patients do not leave the waiting list monotonically (Figure 1). We observe peaks at the 63rd and 126th days in 2007 data, the 365th day in both years, the 1st and 7th days in 2002 data. Moreover, we are able to observe a strong weekly seasonality pattern (Figure 2)[5]. In particular, the number of people who are accepted for treatment on the same day they see a specialist at the hospital is significantly smaller than the number of people who spend approximately between 1 and 65 days on the waiting list. The first and most pronounced peak in the data occurs on the first day. It is followed by peaks at 7, 14, 21, etc. days. Minimums, respectively, are around the 3rd, 10th, 17th, etc days. It might be explained by the fact that consultant visits and surgeries usually take place in the middle of the week. As a result, weekends fall on the third/fourth day following the appointment. The majority of patients are treated relatively quickly, but there is a small group of patients who wait, for example, 730 days.

4.2. Institutional Background

The setting for this paper is Scotland where high-profile, political guarantees on waiting times for elective hospital admissions were introduced in 2003. Our method takes a "before-and-after" approach, comparing waiting times distributions before the implementation of the political guarantees (2002) with distribution after its implementation (2007). The waiting times studied in this paper reflect the time that elapses between the hospital specialist's decision that a patient needs treatment to the date at which this treatment episode begins. This is only part, and sometimes less than a majority, of the total delay between when a patient initially seeks and receives treatment. The NHS operates a gatekeeping system under which, for elective treatments, patients must first seek the advice of a General Practitioner (GP) (with a trivial wait), second receive a referral from the GP to a hospital specialist (often a more substantial wait, that may involve waiting for diagnostic test results), and third a decision by the specialist that hospital treatment is necessary (which may also involve waiting for diagnostic test results). Direct access by patients to hospital specialists is only possible for emergency care through hospital Accident and Emergency departments. Elective patients are those that are pre-booked for treatment and thus we only consider a part of the time spent waiting along the whole patient pathway, from the initial point of contact when treatment is sought to discharge.

[4]Cullis et al. (2000) argue that one of the criteria for determining waiting times should be severity of the condition.
[5]Both, Figures 1 and 2, are on the log scale

4.3. Method Implementation

To implement the method, we have to[6]:

1. choose the number of intervals and their width;
2. estimate a set of constants $\hat{h}^*(1|K), \hat{h}^*(2|K), \ldots, \hat{h}^*(K|K)$ to use in Eq. 3.1;
3. calculate changes of the expectation of the function of the outcome of interest.

To eliminate seasonality discussed in Subsection 4.1 and make the number of patients in every bin comparable we introduce the following partitioning: the first bin consists of people that are treated on the same day, the second to 27th bin are for patients who are treated, respectively, during the first, second, ..., 26th week, bins 28 – 57 are constructed on a bi-weekly basis, bins 58–62 are constructed on a four-week basis. Our choice of partitioning is summarized below:

	Bin number			
	1	2–27	28–57	58–62
Number of days	same day	weekly	bi-weekly	six-weekly
Period covered (up to)	0	6 months	18 months	24 months

We estimate the set of constants as follows:

$$\hat{h}^*(k|K) = \bar{y}_k = \frac{1}{N_k} \sum_{\forall y_j \in (y_{k-1}, y_k]} y_j$$

In our estimation of the "hazard" function that conditions on covariates we include a polynomial of the third order in α_k in addition to the polynomials in the observed covariates. Our set of covariates X consists of all cross-products up to the fourth power of age category and number of comorbidities. These are interacted with 18 dummies for disease chapters and polynomials of α_k.

We next calculate an approximation of the conditional expectation for a particular set of covariates as in Equation 3.1. We calculate finite difference approximations of the derivatives which are our main effects of interest. For the purposes of statistical inference we bootstrap the standard errors.

[6] We use Norton (2010) to code the algorithm. All implementation errors are ours.

5. Results and Model Fit

This section covers (i) descriptive analysis, (2) model fit, and (3) main results. The main results subsection explores the changes in prioritization patters for changes over time, age category, number of comorbidity conditions for three disease chapters. The subsection concludes with a summary of reprioritization findings for all patient groups.

5.1. Descriptive Analysis

We first discuss the features of the unconditional and marginal waiting times distributions based on observed data in 2002 and 2007 (Table 1). The table consists of three panels: percentiles, patient characteristics, and type of disease. The first panel reports percentiles in bins, (see page 7). Since probabilities are estimated using these units, there is no formal way to return to daily frequency. The second panel shows estimated and observed average waiting times for two marginal distributions: age category and number of comorbidities. The third panel presents the observed and estimated averages for different disease categories.

For the rest of this subsection we compare summary statistics for pre- and post- reform years. The first panel shows that patients below the median, on average, waited longer in 2007. Given that there are fewer patients in 2002 than in 2007, results are inconclusive for weekly frequency. However, based on Figure 1, we can still conclude that the number of patients treated in 2002 within, at least, the first two weeks is larger than in 2007. For patients above the median waiting times declined dramatically with patients at the 75th and 90th percentiles waiting, respectively, 2 and 12 weeks less[7]. Average waiting time decreased from 10.77 to 9.04 bin units. The finding is consistent with Janulevicuite et al. (2011).

Panel 2 of Table 1 presents the pre- and post-reform marginal means of waiting times and counts for different patient groups depending on patient's age category and number of co-morbidity conditions. The mean waiting times declined for all age groups except for children aged 0–6 years. The patient count for all categories below 40 years is larger in 2002. This clearly shows that waiting times for children aged under 6 are smaller in 2002 in relative as well as in absolute terms. The mean waiting time for different comorbidity groups declined uniformly. The number of patients increased for all but patients with no long-term conditions.

Panel 3 of Table 1 presents the pre- and post-reform marginal means of waiting times and counts for different ICD-10 disease chapters. It shows that mean waiting times declined for the majority of disease types except for

[7] The 29^{th} time unit corresponds to two weeks of data

patients with metabolic diseases, mental health patients[8] and diseases of the nervous system (Ch. IV, V, VI). The table shows that less patients with cancer or heart problems were added to the waiting lists for elective treatment in 2007.

To further investigate our results in panel 1 of Table 1, we plot the unconditional distribution y_t in bin units. We define y_t as

$$y_t = CDF_t^{2007} - CDF_t^{2002}$$

where CDF is constructed using real data.

The upper left graph in Figure 3 shows the difference in the share of all patients treated up to a certain day between 2002 and 2007[9]. The share of patients treated within the first 8 weeks was larger in 2002. The dynamics change for waiting times above 8 weeks. For any time period longer than 8 weeks, the probability of treatment is larger in 2007. The shape of the graph can be best understood by analyzing Figure 1. The rate of taking patients off the waiting lists between weeks 9 and 18 decays at a lower rate in 2007 compared to 2002. After the 18th week we observe a significant decay in the number of patients treated. This results in a kink at week 9, increase in the difference between shares of patients treated in 2007 between week 9 and week 18, and a monotonic decline afterwards.

The graph maps the summary statistics in Table 1 showing that the waiting times for people who waited less than the median increased in 2007, while for people above the median waiting time decreased. The spike in the probability of treatment in Scotland at 18 weeks is consistent with the findings of Dimakou et al. (2009); Appleby et al. (2003) who find increases in the probability of treatment before the maximum waiting times targets using data for the English NHS. In contrast, Janulevicuite et al. (2011) find no similar pattern using Scottish data for August 2002/July 2003 and August 2005/July 2006 periods.

Exploring the cumulative difference for each disease category largely supports the observations based on all disease chapters[10] (the rest of Figure 3). Even though the pattern is the same across different ICD-10 groups, the magnitude of the effect is very different across disease categories. We are able to identify three sets of disease categories based on the difference in the magnitude of the effects. The first group comprises cancer (chapter 2), eye (chapter 7), and cardiovascular (chapter 9) patients. The common feature is that the initial decline in the share of treated patients is small ($\sim 2\%$). In addition, these three categories were subject to explicit 9-week waiting time target in 2007. The second group includes respiratory conditions (chapter 10), skin

[8] These patients are excluded if in psychiatric care.
[9] Please note that the absolute number of patients is different in 2002 and 2007.
[10] The results for all disease categories are available upon request

(chapter 12), congenital (chapter 17), abnormalities not diagnosed elsewhere (chapter 18), health status factors (chapter 21), external sources injuries (chapter 19), genitourinary (chapter 14), musculoskeletal (chapter 13), digestive (chapter 11), and infections (chapter 1). The common characteristic between the conditions in this big group is that the magnitude of the initial decline is between 3-7%. The third group includes disease categories for which the initial decline in the share of treated patients was 10% or larger. These are blood (chapter 3), endocrine and metabolic (chapter 4) diseases, mental (chapter 5), nervous system (chapter 6), and ear (chapter 8) diseases. We focus on circulatory system diseases, digestive system diseases, and diseases of the nervous system. These are large disease categories selected to represent each group described above.

The mean waiting time for diseases of the circulatory system declined from 88.2 to 56.1 days. There were approximately 24,000 patients on the waiting lists in both years. The plot for the marginal distribution of y_t for cardiovascular patients (lower left part of Figure 3) shows that a smaller fraction of cardiovascular patients were treated within the first 3 weeks. The initial decline was 2%. However, the share of patients treated within the first 9 weeks in 2007 is 10.7 percentage points larger than in 2002. The difference in cumulative distributions peaks at the 18-week target within which 92.5% of all patients on the waiting list in 2007 and 78.6% of the patients in 2002 were accepted for treatment. This indicates a 13.9% difference in the share of treated patients.

The mean waiting time for diseases of the digestive system declined from 69.5 to 54.5 days. The number of patients on the waiting list remained approximately the same. The marginal distribution plot (upper right part of Figure 3) shows that a slightly larger share (0.003%) of patients were treated with zero wait in 2007. The share of patients waiting between 1 and 42 days was larger in 2002. In particular, there were 7.5 percentage points more patients treated within the first 7 days in 2002. However, by the end of the 9th week, the share of patients treated in 2007 exceeds by 4.8 percentage points. 93.5% and 84.6% of all patients were treated respectively in 2007 and 2002 within the 18-week target.

The mean waiting times for diseases of the nervous system declined slightly from 65.9 to 64.7 days. The number of patients added to the waiting list increased from 6823 to 8444. Plotting the difference between the CDFs for the two years of our analysis (lower right part of Figure 3) shows that a 10% smaller share of patients were treated around the time of the 9th week. However, by the end of the 18-week target, the share of patients accepted for treatment in 2007 increased to 5.2%. 87% and 90% of all patients were treated within the 18-week target respectively in 2002 and 2007.

5.2. Model Fit

In this subsection we compare summary statistics based on original data with the summary statistics implied by the model. Our first results are reported in Table 1.

The structure of the table is described in Subsection 5.1. The first panel (percentiles) are reported in bin units described on page 7. The model captures the data quite well. It slightly underestimates the 25% of the 2002 distribution, and it overpredicts the 90% for 2007. In 2002 means differ by 0.1. In 2007 means differ by 0.03. The second panel demonstrates the estimated and observed average waiting times for two marginal distributions: age category and number of comorbidities. The model provides good fit for both distributions for the two years of our analysis. Most of the model results are within 3 days of the observed values. The model successfully captures the increase in the average waiting times for children aged 0–6 years. The third panel presents the observed and estimated averages across different disease categories. The difference between the two averages, except for ICD-10 chapter 5 for mental diseases, is within 3 days. The mental problems disease category has a very small size, which, we think, affects the precision of the model estimates. The model captures all increases in waiting times between 2002 and 2007, i.e. for infectious diseases, metabolic diseases, and mental problems. Moreover, the model correctly captures the signs of all changes in average waiting times between 2002 and 2007 for all categories considered.

We observe an increase in precision between 2002 and 2007. The average difference between the data and model estimates across disease categories, are, respectively, -2.4 for 2002 and -1.8 for 2007 with standard deviations of 2.1 and 1.2. We find similar results for the other marginal comparisons.

5.3. Main results

The next step is to fit the data in our model and compare prioritization schemes before and after the introduction of the waiting time targets. Results in Tables 2–10 come from the estimation of the conditional density using all disease categories, patient's age and number of co-morbidity conditions. Standard errors for all estimation procedures come from the standard deviation of 1000 bootstrap replications. We assume independence between individual admissions. Since we construct the sample by including only the first admission for each patient in 2002 and 2007 and individual admissions over time are not traced, the standard errors reflect only patient-level variation. Standard errors are not reported and available upon request. Statistically significant results for the 95% two-sided confidence interval are in underlined font and in bold for the 99% two-sided confidence interval.

5.3.1. Conditional means and their change between 2002–2007

We study how the change of the conditional mean estimates of waiting times vary across different subsets of individuals. Table 2 shows that the mean waiting times for all cardiac patients declined. Our estimates point to statistically significant declines for most groups. All children aged 0–6 years, children aged 7–17 years with 3, 4, or 5 comorbidity conditions, young adults aged 18–40 years with 5 comorbidities, 75-84 years old with 5 comorbidities, and patients older than 85 years with more than 2 comorbidities experience no statistically significant change in the time they wait for treatment[11].

Table 3 presents the mean waiting time estimates and their change for patients with diseases of the digestive system. We find that the waiting times for most groups declined. The waiting times for children aged 0–6 years with 0 and 1 comorbidities increased. They wait, respectively, 12.71 and 5.52 days more. These are statistically significant estimates. The rest of the children in this age group, children 7–17 years old with 0, 4 or 5 co-morbidity conditions, young adults with 5 comorbidities, and elderly aged 85+ years with 2 and 3 additional health problems experience no statistically significant change in their waiting times.

The conditional means and their changes over time for diseases of the nervous system in Table 4 show that the conditional waiting times significantly increased for all children and young adults with 4–5 co-morbidities. It also increased for elderly older than 75 years with 4 or 5 co-morbidities. We observe that the mean waiting times for patients with no comorbidities aged 40–74 years declined. The remaining groups of patients did not experience any change in their waiting times.

5.3.2. Effects for changes in age

We next explore how the reform impacted the order of clinical priorities. Despite the fact that the reform towards reduction in waiting times was carried out over the course of the previous decade, there is no quantitative answer regarding the extent to which it led to changes in the way patients were taken off the waiting lists. To address this question we study how the waiting times estimates change when one of the explanatory variables changes by one unit and compare the patterns for 2002 and 2007. An important dimension is to explore whether priorities for treatment changed between 2002 and 2007.

The order of prioritizing cardiovascular patients based on their age was changed in 2007 (Table 5). We find that all patient groups who waited more compared to the previous age group in 2002 experience no statistically significant change in their waiting times in 2007. The longest waiting age groups in 2002 are children aged 7-17

[11]For brevity, in the rest of this subsection, we use "increase/decrease" for "statistically significant increase/decrease", "no change" for "no statistically significant change for 5% confidence level".

years (0 comorbidities), adults aged 18-39 years (1 comorbidity), and adults aged 40-54 with more than one comorbidity. In 2007 all these groups were shifted one age category down, i.e. children below 7 years, children aged 7-17 years, adults aged 18-39 years with more than 1 comorbidity. In 2007 children aged 7–17 years are found to have not waited longer for treatment compared to young children aged 0–6 years. The same holds for adults aged 18–39 years with more than 2 co-morbidities. The rest of the cardiac patients wait less for treatment in both years.

The next set of marginal effects for age is for the group of patients with diseases of the digestive system (Table 6). Overall, the pattern of prioritization was preserved in 2007. We observe difference in patient ordering for treatment only for the group of patients older than 85 years. In 2002 patients with 0–2 co-morbidities waited shorter periods, while, in 2007, patients 1-2 additional health conditions experience no change. Our estimates point to statistically significant longer waits for the 85+ group with 4 and 5 co-morbidities in 2007. In comparison, only patients with 5 co-morbidity conditions in the 85+ age group wait more in 2002.

The patterns of prioritization for treatment based on patient's age in the two years of our analysis were largely different for nervous system patients (Table 7). In 2002 all patients up to the age of 54 wait longer for treatment. Elderly patients age 65–74 with no co-morbidities, patients age 75–84 with up to 3 co-morbidities, and the majority of patients age 85+ wait shorter periods. In other words, the age group that waited the most is 55-64 for any number of comorbidities. In contrast most patients with diseases of the nervous system wait approximately the same in 2007. Only young adults age 18–39 and 40–54 experience small increases (3.29 and 2.13 days respectively) in their waiting times.

5.3.3. Effects for changes in the number of co-morbidity conditions

We consider the effects of the number of co-morbidity conditions. We focus on cardiovascular patients first (Table 8). The results show that the overall reduction in waiting times is accompanied by several changes in the pattern for treatment. In particular, in 2007 most patients (up to 75 years) with one additional health problem waited less compared to patients with no co-morbidities. No similar pattern is observed in 2002. In 2007 patients older than 75 years do not experience any change in their waiting times as their co-morbidities increase. No similar pattern is observed in 2002. Further, in 2007, patients with 5 co-morbidities, regardless of their age, wait about the same as patients with 4 co-morbidities, while, in 2002, they are assigned shorter waits. All other age groups wait less if they have larger number of co-morbidities .

We next study the marginal effect estimates for patient with diseases of the digestive system (Table 9). We see no clear pattern in patient ordering for treatment based on their number of co-morbidities. We uncover two

changes in the ordering of priorities depending on patient's number of co-morbidity conditions. First, patients with 1 co-morbidity, with the exception of children aged 0–6 years, wait less for treatment than patients with no co-morbidities and these are statistically significant declines. Second, adults 40-64 years old, with 3 and 4 health problems do not experience any changes in the time spent waiting for treatment in 2007. In comparison, in 2002, the same patients waited less. The pattern for the other patient groups is preserved in 2007.

For patients with diseases of the nervous system we observe a different pattern of prioritization in 2007 compared to 2002 (Table 10). Before the implementation of the waiting time targets most patients with large number of co-morbidities (3–5) were assigned significantly shorter waiting times. The only exception is children aged 0–17 years who did not experience a significant decline in their waiting times compared to children in the same age group with 4 conditions. Patients with 0–2 co-morbidities waited insignificantly less. Half of these patients, in 2007, waited shorter periods. The waits for patients with 3–5 additional health problems did not decrease for patients who had more health conditions.

5.3.4. Re-prioritization results. Aggregate evidence.

The push to reduce the maximum waiting times to 18 weeks in 2007 could have been achieved in three ways. It could have been done through faster processing of all patients on the waiting lists. Such approach to meeting the target implies that the number of patients treated per day should unambiguously increase. Alternatively, providers could decide to reduce the number of patients that used to be treated within the first several weeks and instead treat faster patients who waited longer applying exactly the same scheme to each disease category. In this case reprioritization occurs between patients within the same group defined by age category and number of co-morbidities. Finally, providers could substitute short-wait patients from one group with long-wait patients from another. Our results supports the third scenario.

To extend the results reported in Figure 3 to conditional model-implied CDFs we adopt the following approach. Using the model output we compute conditional cumulative distribution functions (CDF) for each patient category i before and after the reform. There are 864 such groups for each year. Next, we take a difference between them over time and count the number of times when it is larger than a threshold level δ, i.e.:

$$\begin{aligned} n^{\delta}_{2002}(t) &= \sum_{i=1}^{N} I((CDF_i^{2002}(t) - CDF_i^{2007}(t)) > \delta) \\ n^{\delta}_{2007}(t) &= \sum_{i=1}^{N} I((CDF_i^{2007}(t) - CDF_i^{2002}(t)) > \delta) \end{aligned} \tag{5.3}$$

where n (later referred to as count) is the variable of interest, δ – threshold level, N – total number of categories.

In other words, 2002 count with threshold level δ at a particular point in time t corresponds to the number of patient groups, for which the cumulative probability of treatment exceeds $\delta\%$ compared to the same patient groups at the same t in 2007.

Results are reported in Figure 4 for $\delta = 1\%, 5\%, 10\%, 20\%$. We restrict our analysis to patient groups with at least 50 patients in at least one period to reduce noise caused by small groups. This eliminates 379 groups out of 864. We observe that across all threshold levels for short waiting time the number of groups that have a larger proportion of patients treated in 2002, or 2002 count (red line) constitute a significant part of the sample. The 2007 count (blue line) for short waiting times is very close/identical to 0. The pattern changes with time. At the 9th week target, the 2002 count is smaller compared to the 2007 count. By week 18, the 2002 count is virtually 0, while the 2007 count reaches its maximum over all patient categories. The fact that, for short waiting times, different groups react differently to the prioritization reform implies that re-prioritization, at least partially, follows the third scenario.

Cross-sectional results for count variable are reported in Table 11. The table consists of three panels. Each panel corresponds to a different point in time, 1 week, 9 weeks, and 18 weeks. For all panels we observe two very similar patterns: (i) mean age category for 2002 count is almost always smaller than for 2007 count and corresponding standard deviations are usually larger; (ii) Average number of co-morbidities along with their standard deviations are smaller for 2002 count.

6. Conclusions

The paper compares patient prioritization for treatment before and after the maximum waiting times reform in Scotland. The paper analyzes two aspects of patient waiting time prioritization. First, it describes a mechanism of how providers achieve the waiting times target. Second, the paper documents a change in the prioritization between different patient groups. While the former has been covered in previous literature (Propper et al., 2008; Dimakou et al., 2009; Janulevicuite et al., 2011), the latter, to the best of our knowledge, is a novel result.

We adopt the CDE method (Gilleskie and Mroz, 2004) to analyze patient prioritization. The procedure allows us to estimate directly a discrete approximation of conditional densities of waiting times for different patient categories. We use the model to analyze patient category likelihood of being treated before and after the reform in waiting times.

To analyze how providers meet the waiting time target, we studied (i) marginal distributions directly derived from the data, and (ii) model-implied discrete conditional density approximations. Both approaches provide

support for the fact that the waiting time target is achieved at the cost of increasing waiting times for patients who used to wait less.

We find that re-prioritization for treatment affected some patient groups more than others. In particular, for the three disease chapters we consider, we find several changes in treatment patterns. For diseases of the nervous system we observe in 2002: (i) children were treated with the shortest waiting time, and (ii) waiting times for all patients decreased significantly as the number of co-morbidities increased. In 2007 children were not given priority in treatment. There was no decrease in waiting time as the number of co-morbidities increased. We also find a statistically significant increase in waiting times for the two children categories along with decreases in waiting times for two adult categories with 0 co-morbidities. For diseases of the digestive system we find an increase in waiting times for children with 0 and 1 co-morbidities. Finally, for heart diseases, we observe that patients age 75+ waited less as their number of co-morbidities increased. This pattern is not present in 2007.

Our findings raise the issue of whether other factors could explain the change in patient prioritization that we document. Since there is a five-year distance between the two samples, it is possible that the observed change in prioritization patterns is the result of factors other than the reform. We explore the possible validity behind this claim by comparing the difference between unconditional distributions for years 1998-2006 and year 2007. We observe that the distributions for years 1998/2002 were relatively stable and they started to shift significantly following the waiting times reform in 2003. However, in the absence of data on confounding factors, any interpretation of the observed shifts in distributions is speculative.

While we register change in prioritization patterns for treatment, we do not know how these changes have affected patient health. Further data and more analysis are needed to answer this question properly. Another limitation of our analysis is that the only way patients could leave the waiting lists is through admission. Exits due to death, relocation, change in patient condition are not recorded. We also do not directly control for the severity of patient's condition and instead we use number of co-morbidities to proxy.

References

Appleby, J., Boyle, S., Devlin, N., Harley, M., Harrison, A., Locock, L., 2003. Sustaining reduction in waiting times: identifying successful strategies. Report commissioned by the Department of Health Policy Directorate. King's Fund. London.

Cullis, J., Jones, P., 1983. Impatient waiting: a discussion and policy proposal. British Medical Journal 287, 1483–1486.

Cullis, J., Jones, P., 1985. National health service waiting lists: a discussion of competing explanations and a policy proposal. Journal of Health Ecoomics , 119–135.

Cullis, J., Jones, P., Propper, C., 2000. Waiting Lists and Medical Treatment: Analysis and Policies, Handbook of Health Economics. Elsevier Science.

Dimakou, S., Parkin, D., Devlin, N., Appleby, J., 2009. Identifying the impact of government targets on waiting times in the NHS. Health Care Management Science 12, 1–10.

Donald, S., Green, D., Paarsch, H., 2001. Differences in wage distributions between Canada and the United States: an application of a flexible estimator of distribution functions in the presence of covariates. Review of Economic Studies 67, 609–633.

Efron, B., 1988. Logistic regression, survival analysis, and the Kaplan – Meier curve. Journal of American Statistical Association 83, 414–425.

Gilleskie, D., Mroz, T., 2004. A flexible approach for estimating the effects of covariates on health expenditures. Journal of Health Economics 23, 391–418.

Janulevicuite, J., Askildsen, E., Kaarboe, O., Holmas, T., Sutton, M., 2011. The impact of different prioritization policies on waiting times: A comparative analysis for Norway and Scotland. Working Paper.

Lindsay, C., Feigenbaum, B., 1984. Rationing by waiting lists. The American Economic Review 74, 404–17.

Manning, W., 1998. The logged dependent variable, heteroscedasticity, and the retransformation problem. Journal of Health Economics 17, 283–295.

Mullahy, J., 1998. Much ado about two: Reconsidering retransformation and the two-part model in health econometrics. Journal of Health Economics 17, 247–281.

National Audit Office, 2001. Impatient and outpatient waiting in the NHS. report by comptroller and auditor general. hc 221 session 2001 - 2002: 26 July 2001. National Audit Office: TSO, London .

Norton, E., 2010. Conditional density estimation, in: Modeling Health Care Costs and Counts, ASHEcon, Cornell University. Pre-conference course.

Propper, C., 1995. The disutility of time spent on the United Kingdom's National Health Service waiting list. The Journal of Human Resources 30, 667–700.

Propper, C., Sutton, M., Whitnall, C., Windmeijer, F., 2008. Did 'targets and terror' reduce waiting times in england for hospital care. The B.E. Journal of Economic Analysis and Policy 8. Article 5.

Propper, C., Sutton, M., Whitnall, C., Windmeijer, F., 2010. Incentives and targets in hospital care: Evidence from a natural experiment. Journal of Public Economics 94, 318–335.

Sanmartin, C., Berthelot, J.M., Mcintosh, C., 2007. Determinants of unacceptable waiting times for specialized services in Canada. Healthcare Policy 2, 140–154.

Siciliani, L., Gravelle, H., 2008. Ramsey waits: Allocating public health services resources when there is rationing by waiting. Journal of Health Economics 27, 1143–1154.

Siciliani, L., Hurst, J., 2005. Tackling excessive waiting times for elective surgery: a comparative analysis of policies in 12 OECD countries. Health Policy 72, 201–215.

Figure 1: Waiting times frequency

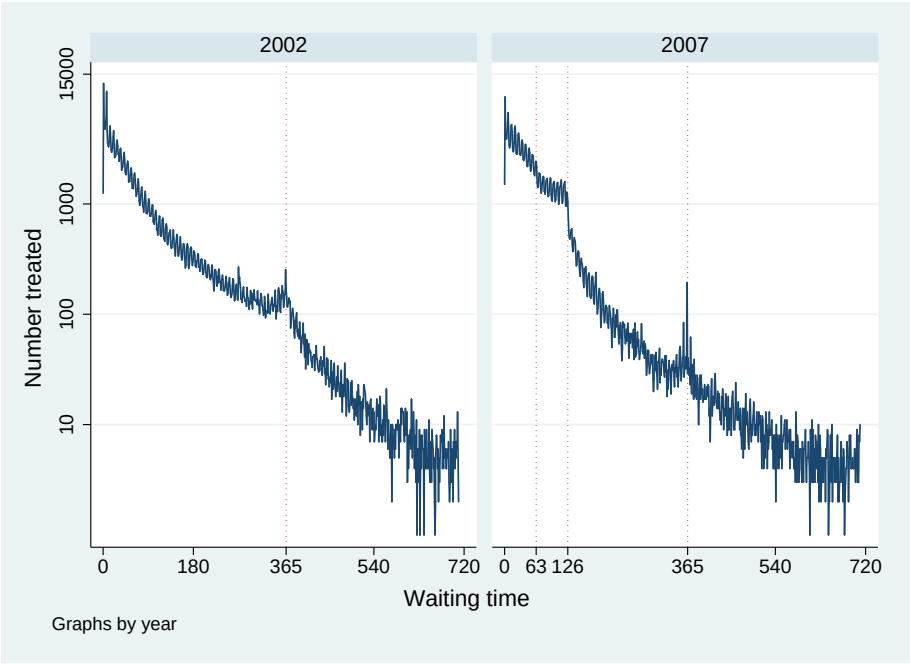

Figure 2: Waiting times frequency less than 63 days

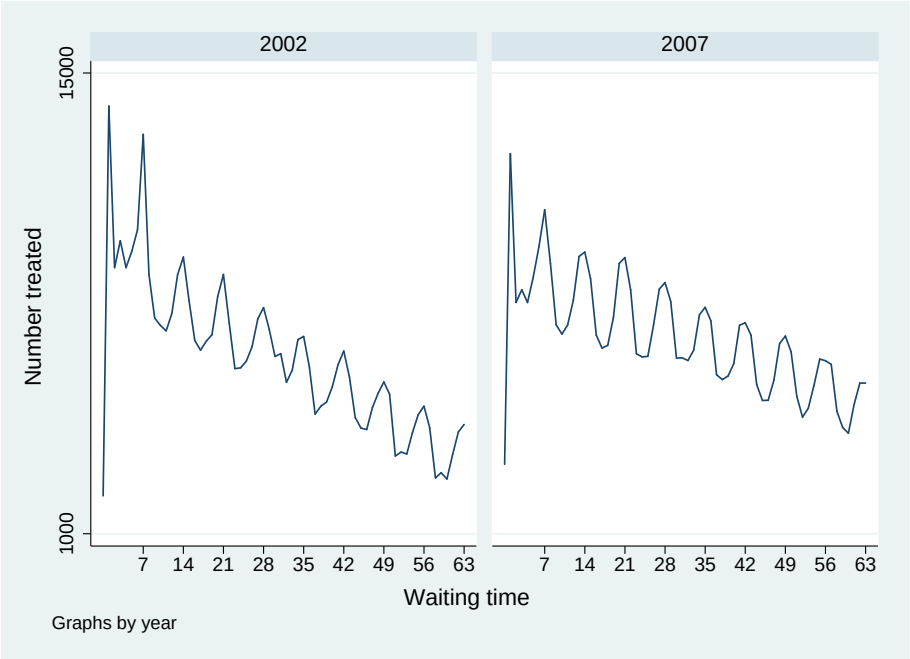

Figure 3: Dependence of $CDF_t^{2007} - CDF_t^{2002}$ on waiting time. Unconditional and marginal distributions for cardiovascular, digestive, and nervous diseases.

Dependence of $CDF_t^{2007} - CDF_t^{2002}$ on waiting time for unconditional and marginal distribution for cardiovascular, digestive, and nervous system diseases (ICD-10 Chapter 9, Chapter 11, and Chapter 6). Results are constructed using real data. The two vertical red lines correspond to 63 days (9 weeks) and 126 days (18 weeks). These are the waiting time targets in 2007.

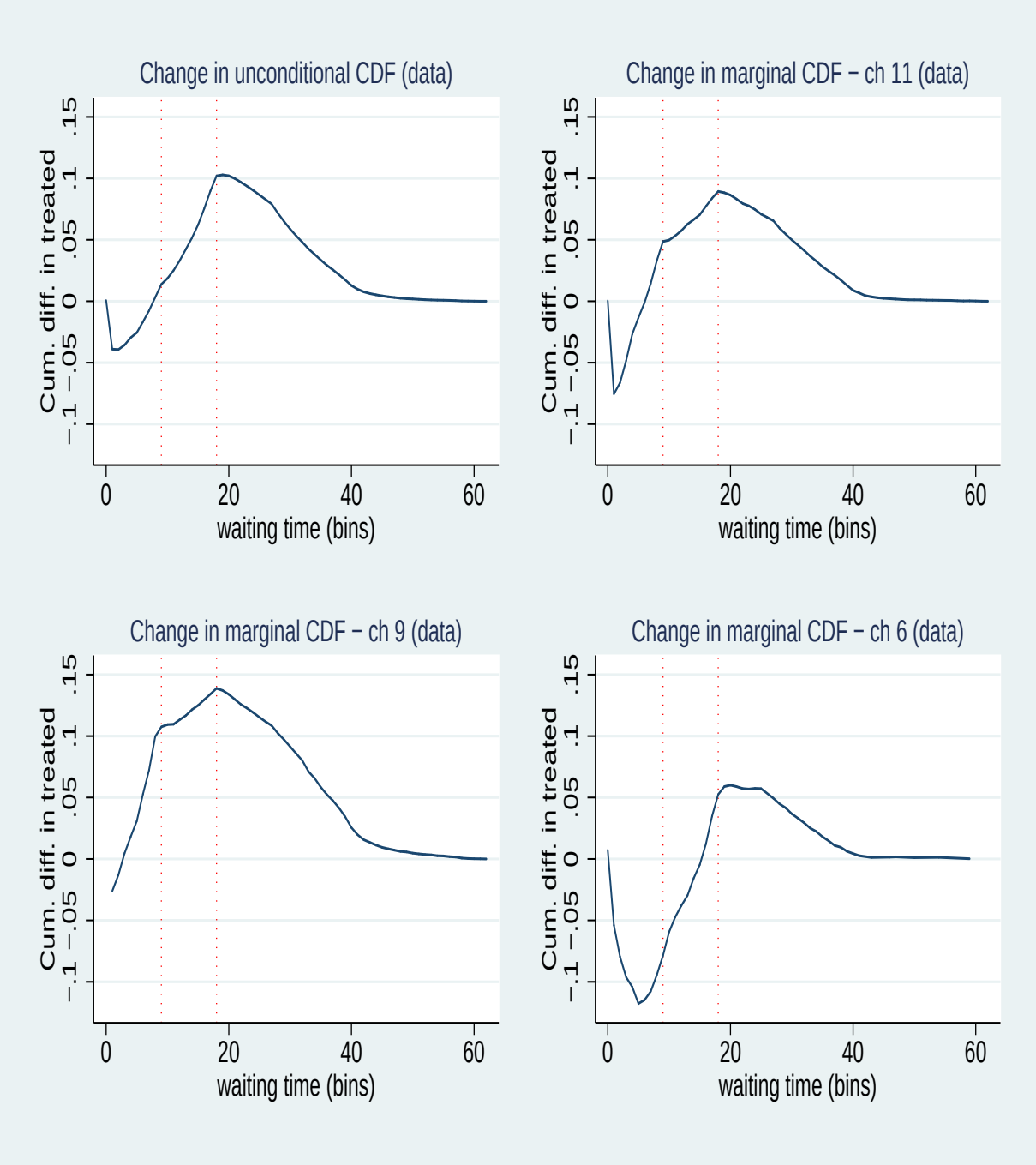

Figure 4: Group count for different threshold level

Number of groups of patients where $CDF_t^{2002} - CDF_t^{2007} > \delta$ (red line) and $CDF_t^{2007} - CDF_t^{2002} > \delta$ (blue line), t–number of adjusted time units. Vertical red dotted lines are at the 9th and 18th week of the sample.

Table 1: Actual and implied average waiting times.

Comparison between average waiting times computed directly from the data and implied by the model. Note: For the first part of the table, waiting times are reported in adjusted units (see p. 7).

	Pre-reform			Post-reform		
	Avg Wait	**Avg Wait (est.)**	**N**	**Avg Wait**	**Avg Wait (est.)**	**N**
10th	1	1	32193	1	1	33552
25th	3	2	80483	3	3	83878
50th	6	6	160965	7	7	167756
75th	15	15	241447	13	13	251633
90th	29	29	289737	18	19	301960
Mean	10.77	10.67	321,929	9.04	9.01	335,510
Patient Characteristics						
Age 0 – 6	61.5	61.9	18374	64.1	65.7	15268
Age 7 – 17	77.3	84.8	18720	64.2	69.6	17674
Age 18 – 39	86.8	86.3	65571	70.5	71.7	58451
Age 40 – 54	81.2	85.0	69747	66	68.7	74279
Age 55 – 64	78	82.9	52535	61.8	64.6	59156
Age 65 – 74	78.7	79.3	53020	58.2	60.2	59056
Age 75 – 84	77.3	77.6	35361	57.1	57.7	41496
Age 85 +	73	76.5	8601	54.2	57.1	10132
Co-morbidities 0	83	85.2	193251	66.1	68.6	187606
Co-morbidities 1	75.6	78.1	72728	61.1	63.0	75784
Co-morbidities 2	73.9	75.7	30361	59.6	60.7	35602
Co-morbidities 3	70.9	72.9	13257	55.7	58.4	17953
Co-morbidities 4	70	71.4	6329	55.2	56.4	9615
Co-morbidities 5	65.6	67.5	6003	52.3	53.3	8952
ICD-10 Disease Chapters						
I.Infections	46.1	48.4	1136	46.3	49.3	911
II. Cancer	43.5	45.8	35199	37.3	39.6	33709
III. Blood	36.8	40.2	3498	33	34.4	4322
IV. Metabolic	48.7	50.3	2603	55.3	55.4	2072
V. Mental	35.6	45.6	382	53.5	51.4	262
VI. Nervous	65.9	68.4	6823	64.7	66.3	8444
VII. Eye	110.9	113.6	21689	66.6	69.0	26988
VIII. Ear	89.7	90.8	4806	84.8	85.8	4254
IX. Cardiovascular	88.2	90.6	24460	56.1	59.1	23716
X. Respiratory	121.3	123.3	11307	82.8	84.4	11588
XI. Digestive	69.5	71.8	71213	54.5	56.5	71542
XII. Skin	75.3	77.1	10842	62.1	65.3	8874
XIII. Musculoskeletal	139.6	142.3	27595	98.1	99.8	37753
XIV. Genitourinary	69.3	70.9	34690	62.8	64.9	35545
XVII. Congenital	127.3	126.0	4135	98.1	100.5	4609
XVIII. Undiagnosed	48.4	51.3	23101	39.1	41.3	23641
XIX. External Injury	52.4	53.1	4980	41.8	44.0	6529
XXI. Health status factor	88.7	90.7	33470	82.6	85.3	30755

Table 2: Conditional means for diseases of the circulatory system and their change b/n 2002–07

CDE-implied conditional mean waiting times for different patient groups that vary by age category and number of co-morbidity conditions in 2002 and 2007 (first panel). Change in conditional mean waiting times between years 2007 and 2002 (second panel). Statistically significant results for the 95% two-sided confidence interval are underlined. Statistically significant results for the 99% two-sided confidence interval are in bold font.

	2002						**2007**					
	Number of co-morbidities						**Number of co-morbidities**					
Age	**0**	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
0-6	**121.22**	**77.05**	**52.37**	**38.26**	**29.32**	**23.13**	**103.54**	**61.30**	**45.09**	**36.73**	**30.72**	21.82
7-17	**139.12**	**93.84**	**69.23**	**54.90**	**44.40**	**35.31**	**102.34**	**65.53**	**49.95**	**42.32**	**38.22**	**33.29**
18-39	**134.74**	**98.24**	**79.20**	**68.17**	**58.71**	**47.71**	**92.45**	**65.34**	**52.29**	**45.57**	**42.16**	**40.13**
40-54	**119.38**	**92.49**	**79.96**	**73.24**	**66.27**	**55.46**	**78.55**	**60.69**	**51.28**	**46.20**	**43.68**	**42.65**
55-64	**99.30**	**80.73**	**73.53**	**70.34**	**65.85**	**56.39**	**64.00**	**53.54**	**47.69**	**44.48**	**42.95**	**42.51**
65-74	**79.06**	**66.97**	**63.37**	**62.31**	**59.40**	**51.19**	**50.85**	**45.77**	**42.91**	**41.46**	**40.91**	**40.87**
75-84	**61.62**	**54.04**	**52.28**	**51.80**	**49.03**	**41.02**	**40.00**	**38.52**	**37.89**	**37.83**	**38.03**	**38.11**
85+	**47.31**	**42.31**	**40.85**	**39.52**	**35.38**	**26.80**	**31.39**	**32.11**	**32.95**	**33.80**	**34.39**	**34.44**
	Change in conditional means between 2002 and 2007											
0-6							-17.66	-15.75	-7.28	-1.52	1.38	-1.29
7-17							**-36.82**	**-28.31**	**-19.28**	-12.58	-6.18	-2.02
18-39							**-42.28**	**-32.90**	**-26.91**	**-22.60**	**-16.55**	-7.58
40-54							**-40.82**	**-31.79**	**-28.68**	**-27.04**	**-22.58**	**-12.81**
55-64							**-35.30**	**-27.19**	**-25.83**	**-25.86**	**-22.90**	**-13.88**
65-74							**-28.21**	**-21.21**	**-20.45**	**-20.85**	**-18.49**	**-10.32**
75-84							**-21.62**	**-15.52**	**-14.38**	**-13.97**	**-11.00**	-2.92
85+							**-15.92**	**-10.20**	-7.90	-5.71	-0.99	7.64

Table 3: Conditional means for diseases of the digestive system and their change b/n 2002–07

CDE results for diseases of the digestive system. See description of Table 2 for details.

	2002 Number of co-morbidities						2007 Number of co-morbidities					
Age	**0**	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
0-6	**21.71**	**28.06**	**35.19**	**41.41**	**44.01**	**40.37**	**34.42**	**33.58**	**35.67**	**38.94**	**41.00**	**38.36**
7-17	**52.48**	**54.39**	**58.44**	**61.95**	**61.61**	**54.33**	**52.44**	**48.65**	**49.61**	**52.25**	**53.34**	**49.07**
18-39	**78.24**	**72.37**	**71.86**	**72.40**	**69.94**	**60.89**	**64.23**	**57.02**	**56.31**	**57.87**	**57.90**	**52.53**
40-54	**91.55**	**78.99**	**74.81**	**73.39**	**70.25**	**61.56**	**67.21**	**57.82**	**55.87**	**56.48**	**55.90**	**50.46**
55-64	**92.06**	**75.59**	**69.47**	**67.49**	**65.24**	**58.90**	**63.36**	**53.71**	**51.36**	**51.59**	**50.98**	**46.29**
65-74	**83.57**	**66.28**	**60.17**	**59.05**	**58.95**	**56.20**	**56.88**	**48.33**	**46.31**	**46.69**	**46.51**	**42.83**
75-84	**71.94**	**56.16**	**51.49**	**52.25**	**55.13**	**56.64**	**51.34**	**44.31**	**43.02**	**44.02**	**44.68**	**42.14**
85+	**62.36**	**49.24**	**46.71**	**50.03**	**56.63**	**63.03**	**48.84**	**43.28**	**43.05**	**45.26**	**47.44**	**46.41**

Change in conditional means between 2002 and 2007

0-6	**12.71**	**5.52**	0.49	-2.47	-3.01	-2.03
7-17	-0.04	**-5.74**	**-8.83**	**-9.70**	-8.28	-5.28
18-39	**-14.01**	**-15.35**	**-15.55**	**-14.53**	**-12.04**	-8.38
40-54	**-24.34**	**-21.17**	**-18.94**	**-16.90**	**-14.35**	**-11.10**
55-64	**-28.69**	**-21.88**	**-18.10**	**-15.89**	**-14.26**	**-12.61**
65-74	**-26.68**	**-17.95**	**-13.86**	**-12.36**	**-12.43**	**-13.36**
75-84	**-20.60**	**-11.86**	**-8.47**	**-8.23**	**-10.44**	**-14.51**
85+	**-13.53**	**-5.97**	-3.67	-4.78	-9.20	**-16.63**

Table 4: Conditional means for diseases of the nervous system and their change b/n 2002–07

CDE results for diseases of the nervous system. See description of Table 2 for details

	2002 Number of co-morbidities						2007 Number of co-morbidities					
Age	**0**	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
0-6	**46.48**	**39.74**	**33.91**	**28.07**	**23.76**	**19.73**	**57.79**	**55.24**	**55.00**	**56.81**	**59.58**	**59.64**
7-17	**57.75**	**51.47**	**45.25**	**39.36**	**33.20**	**27.02**	**62.73**	**58.77**	**57.17**	**57.40**	**58.24**	**57.28**
18-39	**66.89**	**61.11**	**54.76**	**48.32**	**41.28**	**33.67**	**66.02**	**60.70**	**57.80**	**56.60**	**56.12**	**54.80**
40-54	**73.07**	**67.21**	**60.89**	**53.98**	**46.36**	**38.00**	**68.15**	**61.85**	**57.83**	**55.39**	**53.98**	**52.61**
55-64	**74.94**	**69.07**	**62.57**	**55.44**	**47.57**	**39.22**	**68.98**	**62.28**	**57.75**	**54.64**	**52.61**	**51.45**
65-74	**71.80**	**66.39**	**59.55**	**52.36**	**44.63**	**36.97**	**68.40**	**61.85**	**57.42**	**54.52**	**52.60**	**51.48**
, 75-84	**64.37**	**59.44**	**52.81**	**45.05**	**38.37**	**32.02**	**66.37**	**60.30**	**56.45**	**54.33**	**53.07**	**52.16**
85+	54.30	**49.88**	**43.27**	**35.71**	**30.15**	**25.87**	**62.54**	**57.23**	**54.31**	**53.12**	**52.76**	**52.27**

Change in conditional means between 2002 and 2007

0-6	11.32	**15.49**	**21.09**	**28.75**	**35.81**	**39.94**
7-17	4.97	7.30	11.92	**18.04**	**25.03**	**30.25**
18-39	-0.87	-0.42	3.04	8.29	14.84	21.16
40-54	**-4.92**	-5.36	-3.06	1.41	7.62	14.60
55-64	**-5.96**	-6.80	-4.82	-0.79	5.04	12.22
65-74	-3.40	-4.54	-2.13	2.17	7.97	14.50
75-84	1.99	0.86	3.64	9.28	14.70	20.14
85+	8.24	7.35	11.04	17.39	22.60	26.4

Table 5: Marginal effects for age: circulatory system

CDE results for circulatory system diseases. Each number is the difference b/w two consecutive age groups. See Table 2 for details.

	2002 Number of co-morbidities						2007 Number of co-morbidities					
Age	**0**	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
0-6												
7-17	17.88	16.79	**16.86**	**16.64**	**15.08**	**12.21**	-1.50	4.20	4.86	5.59	7.50	12.30
18-39	-4.39	4.40	9.97	**13.28**	**14.31**	**12.40**	-9.83	-0.19	2.34	3.25	3.94	6.84
40-54	**-15.36**	**-5.75**	0.76	5.06	7.56	**7.75**	**-14.04**	**-4.65**	-1.01	0.63	1.52	2.52
55-64	**-20.08**	**-11.76**	**-6.43**	-2.90	-0.42	0.93	**-14.55**	**-7.15**	**-3.58**	-1.73	-0.74	-0.14
65-74	**-20.24**	**-13.75**	**-10.16**	**-8.03**	**-6.45**	**-5.19**	**-13.15**	**-7.78**	**-4.78**	**-3.02**	**-2.04**	-1.64
75-84	**-17.44**	**-12.93**	**-11.09**	**-10.51**	**-10.37**	**-10.17**	**-10.85**	**-7.24**	**-5.02**	**-3.63**	**-2.89**	-2.76
85+	**-14.31**	**-11.73**	**-11.43**	**-12.29**	**-13.65**	**-14.22**	**-8.60**	**-6.41**	**-4.94**	**-4.03**	**-3.63**	-3.67

Table 6: Marginal effects for age: digestive system

CDE results for digestive system diseases. Each number is the difference b/w two consecutive age groups. See Table 2 for details.

	2002 Number of co-morbidities						2007 Number of co-morbidities					
Age	**0**	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
0-6												
7-17	**30.77**	**26.33**	**23.25**	**20.54**	**17.60**	**13.96**	**18.02**	**15.07**	**13.93**	**13.31**	**12.34**	**10.71**
18-39	**25.76**	**17.98**	**13.43**	**10.45**	**8.32**	**6.56**	**11.79**	**8.36**	**6.70**	**5.61**	**4.56**	3.46
40-54	**13.31**	**6.62**	**2.94**	0.99	0.31	0.67	**2.98**	0.81	-0.45	-1.38	-2.01	-2.07
55-64	0.51	**-3.40**	**-5.34**	**-5.90**	**-5.01**	-2.66	**-3.85**	**-4.11**	**-4.50**	**-4.90**	**-4.92**	**-4.17**
65-74	**-8.49**	**-9.32**	**-9.30**	**-8.43**	**-6.29**	-2.71	**-6.48**	**-5.39**	**-5.05**	**-4.90**	**-4.47**	**-3.45**
75-84	**-11.63**	**-10.11**	**-8.68**	**-6.81**	**-3.82**	0.45	**-5.54**	**-4.02**	**-3.29**	**-2.67**	**-1.83**	-0.70
85+	**-9.58**	**-6.93**	**-4.78**	-2.22	1.51	6.39	-2.50	-1.03	0.03	1.24	2.76	**4.27**

Table 7: Marginal effects for age: nervous system

CDE results for nervous system diseases. Each number is the difference b/w two consecutive age groups. See Table 2 for details.

	2002 Number of co-morbidities						2007 Number of co-morbidities					
Age	**0**	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
0-6												
7-17	**11.28**	**11.73**	**11.34**	**11.29**	**9.44**	7.36	4.93	3.54	2.17	0.59	-1.39	-2.50
18-39	**9.14**	**9.64**	**9.50**	**8.96**	**8.07**	6.65	3.29	1.93	0.63	-0.79	-2.12	-2.59
40-54	**6.18**	**6.10**	**6.13**	**5.66**	5.09	4.33	2.13	1.15	0.03	-1.21	-2.16	-2.17
55-64	1.86	1.86	1.68	1.46	1.21	1.21	0.83	0.43	-0.08	-0.76	-1.37	-1.25
65-74	-3.13	-2.68	-3.01	-3.08	-2.94	-2.24	-0.58	-0.43	-0.33	-0.11	-0.01	0.02
75-84	**-7.43**	**-6.95**	-6.75	-7.31	-6.26	-4.96	-2.04	-1.55	-0.97	-0.20	0.47	0.67
85+	-10.07	**-9.55**	**-9.54**	**-9.34**	-8.23	-6.15	-3.83	-3.06	-2.14	-1.19	-0.26	0.11

Table 8: Marginal effects for number of co-morbidity conditions: circulatory system

CDE results for circulatory system diseases. Each number is the difference b/w consecutive comorbidities. See Table 2 for details.

	2002 Number of co-morbidities						2007 Number of co-morbidities					
Age	**0**	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
0-6		-44.19	**-24.68**	**-14.11**	**-8.93**	**-6.22**		**-42.33**	**-16.46**	**-8.35**	-6.01	-9.47
7-17		-45.29	**-24.61**	**-14.33**	**-10.50**	**-9.09**		**-36.84**	**-15.59**	**-7.63**	-4.10	-4.93
18-39		-36.50	**-19.04**	**-11.02**	**-9.47**	**-11.00**		**-27.13**	**-13.05**	**-6.72**	**-3.41**	-2.03
40-54		-26.89	**-12.53**	**-6.72**	**-6.97**	**-10.81**		**-17.86**	**-9.42**	**-5.07**	**-2.52**	-1.04
55-64		-18.57	**-7.20**	**-3.19**	-4.49	**-9.46**		**-10.46**	**-5.85**	**-3.22**	**-1.53**	-0.44
65-74		-12.08	**-3.61**	**-1.06**	-2.91	**-8.20**		**-5.08**	**-2.85**	-1.45	-0.55	-0.04
75-84		-7.58	**-1.76**	-0.48	-2.78	-8.00		-1.47	-0.63	-0.06	0.20	0.08
85+		-5.00	-1.46	-1.34	-4.13	**-8.58**		0.72	0.84	0.85	0.59	0.05

Table 9: Marginal effects for number of co-morbidity conditions: digestive system

CDE results for digestive system diseases. Each number is the difference b/w consecutive comorbidities. See Table 2 for details.

	2002 Number of co-morbidities						2007 Number of co-morbidities					
Age	**0**	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
0-6		6.35	**7.13**	**6.23**	**2.60**	-3.64		-0.84	**2.10**	**3.27**	2.06	-2.65
7-17		1.91	4.05	**3.51**	**-0.34**	-7.29		**-3.78**	0.96	**2.64**	1.09	-4.27
18-39		-5.87	**-0.50**	0.53	-2.46	-9.04		**-7.21**	-0.70	1.55	0.04	**-5.38**
40-54		-12.56	**-4.18**	**-1.42**	-3.14	-8.69		**-9.39**	**-1.96**	0.62	-0.58	**-5.44**
55-64		-16.47	**-6.12**	**-1.98**	-2.24	-6.34		**-9.65**	**-2.35**	0.22	-0.61	**-4.69**
65-74		-17.29	**-6.10**	**-1.12**	-0.10	-2.75		**-8.55**	**-2.02**	0.38	-0.18	**-3.68**
75-84		-15.77	**-4.68**	**0.76**	2.88	**1.52**		**-7.03**	**-1.29**	0.99	0.67	-2.55
85+		-13.12	**-2.53**	**3.32**	**6.60**	**6.40**		**-5.56**	-0.23	**2.21**	2.18	-1.03

Table 10: Marginal effects for number of co-morbidity conditions: nervous system

CDE results for nervous system diseases. Each number is the difference b/w consecutive comorbidities. See Table 2 for details.

	2002					2007				
	Number of co-morbidities					Number of co-morbidities				
Age	**0**	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
0-6		-6.73	-5.83	-5.84	-4.31	-4.07		-2.56	-0.23	1.81	2.82	0.24
7-17		-6.28	-6.22	-5.89	-6.16	-6.18		-3.95	-1.60	0.23	0.86	-0.92
18-39		-5.78	-6.36	-6.44	-7.05	-7.61		-5.32	-2.90	-1.19	-0.47	-1.33
40-54		-5.86	-6.32	-6.91	-7.62	**-8.36**		**-6.30**	-4.02	-2.44	-1.41	-1.33
55-64		-5.86	-6.51	-7.13	-7.86	**-8.36**		**-6.70**	**-4.53**	-3.11	-2.03	-1.15
65-74		-5.41	-6.84	-7.19	-7.73	-7.66		**-6.55**	**-4.43**	-2.89	-1.93	-1.12
75-84		-4.93	-6.63	-7.76	-6.68	-6.35		-6.07	-3.85	-2.12	-1.26	-0.90
85+		-4.42	-6.62	-7.56	-5.56	-4.31		-5.31	-2.92	-1.16	-0.34	-0.49

Table 11: A cross-section distribution of count variables.

The table reports a cross-section of patient characteristics for Figure 4. Means, standard deviations of age categories and number of co-morbidities, and number patient groups are reported. Results are reported for 3 time points: 1 week, 9 weeks and 18 weeks.

	2002 count					2007 count				
		Age Cat.		Comorbs			Age Cat.		Comorbs	
%	**Count**	**mean**	**st.d**	**mean**	**st.d**	**Count**	**mean**	**st.d**	**mean**	**st.d**
					Week 1					
1 %	304	4.65	2.08	1.63	1.50	62	5.16	1.57	2.52	1.71
5 %	118	4.88	2.41	1.82	1.47	14	4.79	1.31	2.14	1.83
10 %	44	4.57	2.74	1.77	1.38	2	5.00	0.00	1.00	1.41
20 %	5	2.80	2.95	0.80	0.84	0				
					Week 9					
1 %	175	4.22	2.01	1.65	1.53	206	5.16	1.92	1.85	1.58
5 %	120	4.02	1.94	1.48	1.43	126	5.22	1.69	1.97	1.61
10 %	46	3.48	1.87	1.63	1.50	50	5.52	1.49	2.52	1.61
20 %	2	1.50	0.71	0.50	0.71	20	6.80	1.01	2.55	1.70
					Week 18					
1 %	19	4.37	2.48	1.32	1.67	373	4.73	1.97	1.71	1.51
5 %	5	4.00	2.55	1.20	1.10	262	4.66	1.97	1.57	1.48
10 %	1	1		0		132	4.65	2.07	1.59	1.51
20 %	0					56	5.41	2.02	2.11	1.69