A Work Project, presented as part of the requirements for the Award of a Master´s Degree in Economics from the NOVA – School of Business and Economics

PRACTICE VARIATIONS IN THE PRODUCTION OF HEALTH

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A project carried out under the supervision of
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JANUARY 2016

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Abstract

This study investigates three questions related to medical practice variation. First, it tests whether average length of stay across Portuguese National Health Service hospitals varies when controlling for differences in patients' characteristics. Second, it looks at hospital-level characteristics in order to find out whether these are able to explain differences in average length of stay across hospitals. Finally, it proposes a best practice average length of stay for each of the six episodes of care analyzed. To perform the analysis, administrative data from the Diagnosis-Related groups' data set for the year of 2012 was used. A replication of a hierarchical two-stage model with hospital fixed effects was carried out. The results show that after taking patients' characteristics into account, variation in average length of stay across hospitals exists. This variation cannot be explained by hospital-level characteristics.

Keywords: average length of stay, episodes of care, hierarchical two-stage model, practice variation

Acknowledgements

The author would like to thank to Professor Pedro Pita Barros, her grandfather, parents, sister, Sara Ribeirinho Machado and Sascha Christian Müller.

1. Introduction

Medical practice variation means that there are different procedures, which can be chosen to treat the same medical condition. Consequently, the choice of the treatment and the duration of hospital stay will depend on many factors such as the patient's needs and illness, the information that is available to the physician, the availability of resources, among others. The literature has documented that wide variations across hospitals and geographical areas exist. However, Smits (1986, p.92) identified three cases in which practice variation is not problematic, namely "when uncertainties in the science of medicine lead to acceptable alternate practice patterns; when an innovation in diagnostic or treatment modality is in a phase of active dissemination; and where the variation reflects underlying differences in the population's health status". If concluded that the patients' characteristics and treatment-related factors explain variation in length of stay (LoS), this variation will be regarded as acceptable. However, if these sources do not explain variation across providers, practice variation can be related to inefficiency. Therefore, in order to be cautious whilst drawing conclusions about inefficiency across hospitals, in a first step, patient-level variables need to be taken into account when analyzing variation.

This study is concerned with three questions related to variation in medical practice. First, does the average length of stay across Portuguese National Health Service (NHS) hospitals vary much when adjusting for patients' case mix? Second, what explains these differences in average length of stay? Third, what would be the average length of stay if all hospitals would have an average length of stay equal to that of the benchmark hospitals? The study will focus on the year of 2012 and on six medical conditions using administrative data from hospital episodes in Portugal.

To carry out the analysis a replication of a regression model was performed, using a hierarchical, two-stage model with hospital fixed effects (Street, Conrad, Thomas, & Josselin,

2012). In the first stage, the models predict hospital length of stay as a function of Diagnosis-Related Groups' (DRG) dummy variables, patients' characteristics and treatment-specific variables. For each medical condition a graph with the average hospital fixed effects is provided. These graphs report the average hospital effects of each hospital compared to the national average by taking into account the influence of the variables included in the first stage. In the second stage, the estimated hospital fixed effects are regressed against a set of hospital characteristics in order to find out if these can explain differences in average length of stay across hospitals.

The results show that a large part of the variation in average length of stay is not due to the fact that different hospitals serve different populations. The study indicates that, after adjusting for patient-level variables, some hospitals exhibit an average length of stay that is around 20% to 50% below or above the national average length of stay. With just one exception (appendectomy), hospital characteristics do not account for this variation. These findings are in line with previous studies.[1] The unexplained variation may be related to hospitals' inefficiency, physicians' practice or hospitals' policies as well as to patients' characteristics, which were not included in the models. The results suggest that there is room for hospitals to improve efficiency. If all hospitals were able to meet the standards of the benchmark hospitals, a decrease in average length of stay would be possible and more patients could be treated.

The study is organized as follows. Section 2 provides a literature review on the topic. Section 3 justifies the choice of the medical conditions analyzed, designated as "episodes of care". Section 4 presents the data set and explains the methodological approach as well as the variables' choice. Section 5 discusses the results and Section 6 draws the main conclusions of the study.

[1] Gaughan, Mason, Street, & Ward, 2012; Häkkinen, Chiarello, Cots, Peltola, & Rättö, 2012; Mason, et al., 2012; O' Reilly, Serden, Talback, & McCarthy, 2012; Paat-Ahi, Swiderek, Sakowski, Saluse, & Aaviksoo, 2012; Scheller-Kreinsen, 2012

2. Literature Review

The literature on medical practice variation includes analyzing mainly variation in hospital admissions and readmissions, length of stay, the frequency of procedures as well as variation in the supply of health care resources per capita (Corallo, et al., 2014). The creation of the Dartmouth research group, which documented that there is "no standard of practice throughout the United States" (Wennberg, 2008, p. 10), has increased research in this area.

The authors, who analyzed practice variation, agree that there is variation across providers or geographical areas. However, the conclusions about the causes of variation are diverse. The amount of variation explained by some factors is also debatable and subject to the method used. Bernstein, Reschovsky and White (2011, p.3-4) noticed that "as research methods have improved, less geographic variation in health care appears to be unexplained" and that "geographical variation is extremely sensitive to how comprehensively health status is measured". By comparing some studies, these authors reported that the study with less indicators explained 18% of geographic spending variation, whereas the one which included many measures found that health status explained about 30% of variation.

Lu *et al.* (2015, p. 362) concluded that the literature incorporates many determinants that affect hospital length of stay such as "patient characteristics; hospital characteristics; clinical caregiver characteristics; and social/family environment characteristics". However, the authors draw attention to the fact that many studies are able to explain roughly 50% of length of stay variation when they just control patient characteristics (Lu, Sajobi, Lucyk, Cameron, & Quan, 2015).

Besides the commonly used demographic variables (namely age and gender) some studies introduced disease groupers and/or comorbidity indexes as risk adjustors to test for their ability to explain LoS (Lu, Sajobi, Lucyk, Cameron, & Quan, 2015). The most frequently used disease grouper and comorbidity index is the Diagnosis-related Group and the Charlson

index, respectively. These are also the ones that perform best (Lu, Sajobi, Lucyk, Cameron, & Quan, 2015). The articles of the second phase of the EuroDRG project, for instance, used both.[2]

Regarding hospital characteristics, previous studies have focused much of their attention on ownership status. For instance, Siciliani *et al.* (2011, p. 234) concluded that private and public treatment centers "have on average respectively 40% and 18% shorter length of stay compared to NHS public hospitals, even after controlling for differences in age, gender, number and type of diagnosis, deprivation and geographical variation". In this case, these differences were interpreted "as due to efficiency as opposed to selection (treatment of less complex cases)" (Siciliani, Sivey, & Street, 2013, p. 234).

Using duration of hospital stay as a measure of variations in hospital medical practice, Westert, Nieboer and Groenewegen (1993) came to the conclusion that variation in length of stay within hospitals was smaller than the length of stay variation between different hospitals. This means that "doctors conform to local standards with regard to length of stay decisions" (Westert, Nieboer, & Groenewegen, 1993, p. 838). Jong *et al.* (2006, p. 374) did a similar analysis by testing and confirming "the hypothesis that physicians who work in different hospitals adapt their length of stay decisions to what is usual in the hospital under consideration".

Moreover, an important and common feature found is that variation in length of stay remains unexplained after controlling for one or more of the following factors: demographic factors, patient characteristics, hospital characteristics, risk factors, diagnosis and procedures. For instance, a study found that "59% of the overall variation in length of stay remained unexplained after adjustment for discharge-level disease status, illness-severity, regional

[2] Cots, Chiarello, Salvador, & Castells, 2012; Gaughan, et al., 2012; Geissler, Scheller-Kreinsen, & Quentin, 2012; Häkkinen, Chiarello, Cots, Peltola, & Rättö, 2012; Mason, et al., 2012; Peltola, 2012; O' Reilly, Serden, Talback, & McCarthy, 2012; Or, Renaud, Thuilliez, & Lebreton, 2012; Paat-Ahi, Swiderek, Sakowski, Saluse, & Aaviksoo, 2012; Scheller-Kreinsen, 2012

poverty, hospital-level contextual factors", whereas "77% of the explainable variation was due to differences between hospitals" (Walsh, Onega, & Mackenzie, 2014, p. 53). By looking at different procedures, another study by Gaughan, Mason *et al.* (2012) concluded that patients' characteristics, treatment-specific variables, the Charlson comorbidity index and the Healthcare Resource Groups[3] explained between 28% and 63% of variation in length of stay. Interestingly, both this study and the articles of the second phase of the EuroDRG project found that hospital characteristics, in almost every episode of care analysed, were not able to explain variation in LoS across hospitals when taking patients' characteristics into account.

The admission method and discharge destination seem also relevant when explaining LoS (Gaughan, Mason, Street, & Ward, 2012; Kulinskaya, Kornbrot, & Gao, 2005). One study came to the conclusion that "LoS is at least 25% longer for patients transferred from other hospitals rather than admitted as an emergency; and LoS for patients discharged to private institutions is more than twice that for patients discharged to NHS institutions or their own home" (Kulinskaya, Kornbrot, & Gao, 2005, p. 369).

Finally, according to Corallo, Ashley *et al.* (2014), the medical conditions studied most intensively when analyzing practice variation are cancer, cardiovascular, gynecological, musculoskeletal, and respiratory conditions. Regarding the studies, which look at surgical conditions, the focus is on cardiovascular surgeries and cancer surgeries.

First, this study will test whether (1) patient-level characteristics can explain variation in length of stay; (2) differences in average length of stay across hospitals exist when differences in the patients' population are taken into account; (3) a set of hospital characteristics is able to explain differences in average length of stay across hospitals. Second, it is interesting to look for a best practice length of stay for each medical condition studied, since the literature does not focus on this aspect, although it seems relevant at least for the Portuguese case.

[3] This disease grouper is the English version of the Diagnosis-related groups.

The literature indicates that wide variation in LoS across providers exists. It is expectable to find variation in average hospital LoS even when controlling the influence of patients' characteristics. Since this study is based on a method used in a series of articles, which concluded that only in some cases hospital characteristics are able to explain differences in hospitals' average LoS, it is expectable to find the same effect.

3. The Choice of the Episodes of Care

In order to perform the analysis six medical conditions, commonly designated as "episodes of care" (EoC) in the literature, were selected.[4] The choice of the EoC took into account what was pointed out by Corallo *et al.* (2014, p.12): "In studying medical practice variations, it is important to focus on conditions and procedures that are clinically important, policy relevant, resource intensive (…) and/or have high level of public awareness". Therefore, the episodes of care which represent main causes of hospitalization and/or main causes of death in Portugal were investigated. Surgical treatments were privileged over medical conditions, since the former seem more important, according to the facts listed below, in terms of policy relevance.

In Portugal, the main causes of hospitalization among young people are respiratory and digestive diseases, whereas among adults are diseases of the circulatory system and cancer (Ministério da Saúde, 2011). These diseases also count as the main causes of death. However, respiratory diseases stand out as the dominant cause of death (Direcção Geral da Saúde, 2015). Looking at cardiovascular diseases, in the European Union 28 countries the mortality rate for cerebrovascular diseases is higher than that of ischemic heart disease (*e.g.* acute myocardial infarction) (Direcção Geral da Saúde, 2015). Comparing Portugal with the other 27 European countries, the inverse case is the norm. Portugal is the second European country with the lowest mortality rate for ischemic heart disease and its rate for cerebral vascular

[4] An episode of care is "an NHS term of art for a care episode of an inpatient, outpatient, day case, day patient, or for haemodialysis. Each episode is initiated by a referral (or re-referral) or admission, and is ended by a discharge"(Segen's Medical Dictionary, 2011).

accident is above the European Union 28 Member States average (Direcção Geral da Saúde, 2015). Thus, it is interesting to analyze the LoS of acute myocardial infarction (AMI) since it stands out when comparing to the other European countries. Besides it is in the category of diseases of the circulatory system. Appendectomy is analyzed since it is a common disease of the digestive system and breast cancer surgery is representative of the cancer category. Inguinal hernia surgery and cholecystectomy were also chosen as two more examples of gastrointestinal diseases. Pneumonia was also included because it is the main cause of hospitalization among respiratory diseases (Direcção-Geral de Saúde, 2014).

The study will analyze the following six episodes of care, namely two medical conditions and four surgical treatments, acute myocardial infarction, appendectomy, breast cancer surgery, cholecystectomy, inguinal hernia surgery and pneumonia.[5]

4. Data and Methodology

The data used is taken from the Diagnostic Related Groups' data set of *Administração Central do Sistema de Saúde* (ACSS). The year under analysis is 2012 as it is the most recent year with available (and not provisional) data.

Variation in length of stay may be due to patients' characteristics and needs as well as due to other factors such as hospital characteristics. Accordingly, we specify a hierarchical two-stage model. In the first stage, the focus will be on the patient-level variables and their ability to explain variation in length of stay. The first-stage model includes DRGs' dummy variables, individual characteristics and treatment-specific variables. After the estimation of stage 1, we present graphically the average hospital effects for each hospital purged of the influence of the patients' population. Hospitals were ordered from left to right from those with the lowest

[5] It would be interesting to analyze the case of coronary artery bypass graft as a further case representing circulatory diseases. However, there were few observations (six observations) for the hospital characteristics and a minimum number of hospital observations is required to perform the analysis using the selected approach (Street, Conrad, Thomas, & Josselin, 2012).

mean effects to the highest. This means that patients who were treated in hospitals in the left-hand side of the graph had a lower LoS compared to the ones more to the right. As a consequence, hospitals positioned more to the left are more efficient. The purpose of stage 2 is to determine whether the identified differences in average length of stay across hospitals can be explained by hospital characteristics. The second stage will have as dependent variable the estimated hospital effects and will test which hospital characteristics are able to explain differences in the average length of stay across providers.[7] The estimation method procedure proposed by Street *et al.* (2012) is adopted. As mentioned by the authors, their method is "of general interest to researchers evaluating variation in [costs or length of stay] among patients and across healthcare providers" (Street, Conrad, Thomas, & Josselin, 2012, p. 16).

As shown by Lu *et al.* (2015) many studies use the OLS model to predict LoS. However, LoS is a count variable, which is normally characterized by its skewed distribution. The adopted model in this study is a generalized linear model (a Poisson model or a negative binomial model) instead of OLS. In the presence of a skewed dependent variable, the use of an OLS model would violate its normality assumption.

The choice between a Poisson and a negative binomial model will depend on the existence of overdispersion (Cameron & Trivedi, 2005). In the presence of overdispersion, a negative binomial model is required in order to relax the assumption of "equidispersion" and to avoid underestimation of standard errors, which results in overconfidence in the results (namely rejecting the null hypothesis when, in fact, it should not be rejected). Dummy variables for each hospital were included in the first-stage regression so that the estimation of hospital fixed effects was possible. The estimated hospital effects can be interpreted as a "measure of relative hospital performance" (Street, Conrad, Thomas, & Josselin, 2012, p. 9).

[7] Hospital fixed effects are an estimated dependent variables and, thus, "suffer both sampling and random errors" (Street, Conrad, Thomas, & Josselin, 2012, p. 10). As in Street *et al.* (2012, p. 10), these sources of errors were accounted for by computing a "GLS regression with weights proportional to the inverse of the squared standard errors and Efron robust standard errors to correct for potential heteroscedasticity".

Regressions presented and discussed are poisson models in all cases, except in the cases of AMI and pneumonia, where negative binomial models are applied, since overdispersion was identified in length of stay of these episodes of care.[8]

Since we focus on six EoC, patients that fall under the EoC in question had to be identified either through diagnostics or procedures, depending on the case. With the exception of pneumonia, which was not analyzed in the EuroDRG project, the detailed definition of eligible patients and the choice of the treatment-specific variables for each EoC can be found in the respective EuroDRG project articles.[9] The definition of pneumonia eligible patients was based on Aronsky and Haug (2000): eligible patients were identified by a primary diagnosis code of pneumonia or a primary diagnosis of respiratory failure with a secondary diagnosis code of pneumonia.

In all EoC patients aged less than one year are excluded (Street, Conrad, Thomas, & Josselin, 2012) as well as patients identified in the data set as having an undetermined gender and patients attending ambulatory production line "as different classification systems are used to describe this activity" (Street, Conrad, Thomas, & Josselin, 2012, p. 8). In addition, hospitals with less than 10 eligible patients for the EoC in question were excluded in order to avoid inclusion of outlier hospitals.

Length of stay outliers were dropped from the analysis. As LoS distributions are skewed, "only right-tailed length of stay outliers are identified on a log-transformation of LoS with an upper trim based on three times the standard deviation threshold" (Street, Conrad, Thomas, & Josselin, 2012, p. 9).[10]

Table 1 summarizes the explanatory variables.

[8] Appendix 1 includes the test for overdispersion for each EoC.

[9] Häkkinen, Chiarello, Cots, Peltola, & Rättö, 2012; Mason, et al., 2012; O' Reilly, Serden, Talback, & McCarthy, 2012; Paat-Ahi, Swiderek, Sakowski, Saluse, & Aaviksoo, 2012; Peltola, 2012; Scheller-Kreinsen, 2012

[10] Appendix 2A and 2B show that the LoS distributions are skewed. Appendix 3 demonstrates how the LoS outliers were defined.

Table 1- Explanatory variables

	Variables' explanation	Abbreviation
Patient variables	– Diagnosis Related Groups dummy variables	– DRG 1, 2, 3, 4, 5, 6, 7, 8, 9
	– Other Diagnosis Related Groups dummy variable	– OtherDRGs
	– Age in quintiles	– Agecat1, agecat2, agecat3, agecat4, agecat5
	– Gender (=1 if male, =0 if female)	– Gender
	– Emergency admission dummy variable	– Emergency
	– Transferred in (=1 if dsp=2, =0 otherwise)	– Transin
	– Transferred out (=1 if cause of transference=1 or =2 or =3 or =4, =0 otherwise)	– Transout
	– Number of total diagnostics (=1, =2 or =3)	– Totaldiag
	– Number of total procedures (=0, =1, =2 or =3)	– Totalproc
	– No charlson comorbidity (=1 if patient has no charlson comorbidity, =0 otherwise)	– Charlson_0
	– One non-severe Charlson comorbidity dummy variable	– Charlson_1
	– At least one severe or two non-severe Charlson comorbidities dummy variable	– Charlson_2
	– Treatment specific dummy variables	– Defined in Appendix 4
	– Deceased (=1 if the patient died in hospital, =0 otherwise)	– Deceased
	– Urinary tract infection (=1 if the patient suffered this infection during the stay in hospital, =0 otherwise)	– Urinary tract infection
	– Postoperative surgical infection (=1 if the patient suffered this infection during the stay in hospital, =0 otherwise)	– Postoperative surgical infection
	– Adverse events dummy variable	– Adverse events
Hospital variables	– Number of patients treated annually in thousands	– Totalvol1000
	– The share of the hospital's patients that fall under the EoC in question (in percent)	– EoC percent
	– Specialization index	– Spec_index
	– Rate per 1000 of infections for all patients of the hospital	– Rate infections
	– Rate per 1000 of adverse events for all patients of the hospital	– Rate adverse events
	– University hospital dummy variable	– University hospital

dsp=2- destination of the patient after discharge: to another institution with internment; cause of the transference =1- to perform medical exams; =2- to follow; =3- for lack of resources; =4- for the treatment of an associated condition

In general, the variables were computed as in Street *et al.* (2012). All patient-level variables are dummies. The number of treatment-specific or related comorbidities' variables depends on the EoC in question and ranges from one to six and their choice was based on the articles of the second phase of the EuroDRG project. The choice of the treatment-specific variables to include in the first-stage pneumonia regression was based on Menéndez, Ferrando, Vallés, Martínez, and Perpiña (2001) and Suter-Widmer *et al.* (2012). To increase the explanatory power of the first-stage pneumonia model, frequently used procedures were looked for (*i.e.*, injection of antibiotic, injection or infusion of electrolytes or other therapeutic or prophylactic substance) and included in the model. Pneumonia-related variables such as fever, blood

pressure and others suggested by the literature (Menéndez, Ferrando, Vallés, Martínez, & Perpiña, 2001) could not be included because these were not available in the data set.[11]

DRGs' dummy variables were included in the first-stage regression. The DRGs have no specific ordering. Only DRGs with at least one percent of the total patients assigned to it were singled out by a dummy variable (Street, Conrad, Thomas, & Josselin, 2012). The *other DRGs* represent a range of DRGs that did not fulfill this requisite. Since all patients were allocated to one DRG dummy variable, a reference DRG was created. The reference group is the one with the highest percentage of patients in that EoC.[12]

Other variables were incorporated in the first-stage in order to control for demographic characteristics. Age categories were built instead of just using one variable capturing age in years. Diagnosis-related groups are good predictors of LoS and these include, in some cases, specific ages as a split variable (*e.g.* DRG 772 "Simple Pneumonia and/or Pleurisy, Age <18, with complications and comorbidities"). To control for cases where including age is relevant for explaining LoS but is not included in any of the DRGs' dummy variables, the first-stage models incorporate age categories. The age categories were "based on quintiles and chosen according to the observed distribution of age for the EoC in question" (Street, Conrad, Thomas, & Josselin, 2012, p. 12). In all cases, five age categories were defined. The justification for including an age reference group is the same as in the DRGs' dummy variables. The reference age category is the one with the highest percentage of patients in that EoC. With just two exception (appendectomy and pneumonia), the first age category is the reference.[13] A dummy variable indicates whether the patient was male.

The impact of the admission type and the destination of the patient after discharge were also considered. The variable *emergency* indicates whether a patient was admitted as an

[11] Appendix 4 includes a summary with the definition of the eligible patients, the treatment-specific variables used in each episode of care and the respective International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes used.

[12] Appendix 5 indicates the number of the DRG used in each DRG dummy variable.

[13] Appendix 6 shows how the age categories were defined for each episode of care.

emergency. On the one hand, *transferred in* indicates whether the destination of the patient after discharge is to another institution with internment. On the other hand, *transferred out* indicates whether the patient was transferred to another institution by looking at the underlying cause of transference. This variable assumes a value equal to one if the patient was transferred to perform medical exams, to be followed, because of lack of resources or to treat an associated condition. The variable *deceased* captures the cases in which the patient died during hospitalization.

The total number of diagnosis and procedures by episode was also accounted for. The total number of diagnosis ranges from one to three, whereas the total number of procedures ranges from zero to three.

As in Street *et al.* (2012, p.12), the Charlson comorbidities were divided in three: no Charlson comorbidity (the reference), non-severe comorbidity (Myocardial infarction, Congestive heart failure, Peripheral vascular Disease, Cerebrovascular disease, Dementia, Chronic pulmonary disease, Rheumatic disease, Peptic ulcer disease, Mild liver disease, Diabetes without chronic complication, Diabetes with chronic complication) and severe comorbidity ("hemiplegia/paraplegia, renal disease, cancer, moderate or severe liver disease, metastatic solid tumour and AIDS/HIV"). The variable *charlson 1* indicates whether the patient suffers from one non-severe Charlson comorbidity. The variable *charlson 2* indicates whether the patient suffered from at least one severe or two non-severe Charlson comorbidities. It is necessary to exclude the Charlson comorbidities whenever they are directly related to the EoC. Myocardial infarction is excluded in the case of AMI and cancer and metastic solid tumor in the case of breast cancer surgery (Street, Conrad, Thomas, & Josselin, 2012).

The variables *urinary tract infection* and *postoperative surgical infection* indicate whether the patient suffered the type of infection in question during hospitalization. Adverse events indicate whether "any of the following events occurred: foreign body left in during procedure,

infection and inflammatory reaction due to other vascular device, implant, etc., pulmonary embolism/deep vein thrombosis, sepsis and accidental cut, puncture, perforation or haemorrhage during medical care" (Street, Conrad, Thomas, & Josselin, 2012, p. 12).

Hospital-level characteristics include "the number of patients treated annually in thousands, the share of the hospital's patients that fall under the health condition in question in percent, a specialization index and the both the rate per 1000 of infections [,the reference,] and of [adverse events] for all patients of the hospital" (Street, Conrad, Thomas, & Josselin, 2012, p. 13).[14] The specialization index was based on Daidone and D'Amico (2009) definition. A dummy variable indicates whether the hospital is a university hospital. There are seven university hospitals: Santo António, Coimbra, Cova da Beira, São João, São José and Santa Maria. Although ownership status is commonly used when referring to hospital characteristics, it could not be included since all hospitals that are present in the data set are NHS public hospitals. Appendix 7 contains the descriptive statistics of all variables for all episodes of care.

5. Results

Table 2 exhibits an overview of the first-stage results of the six estimated models. Table A 1 presents the detailed regression results of stage 1 with the coefficients, standard errors and the significance level of each variable used. The explanatory power of the models ranges from 11.9% (pneumonia) to 48.3% (breast cancer surgery).

Almost every DRG is statistically significant in explaining LoS. The *other DRGs* are all statistically significant and being assigned to one of the *other DRGs* increases hospital stay. In almost every EoC being older (being in the fifth age category) means having a higher length of stay when compared to the youngest age category (age category 1). Being a man is just

[14] Following Street *et al.* approach (p.9) "hospital-level variables have been calculated on the full data set (before dropping any outlier)".

statistically significant in two cases (cholecystectomy and inguinal hernia). It increases length of stay in the case of cholecystectomy and decreases hospital stay in the case of inguinal hernia surgery.

Table 2- Overview of **r**egression results of Stage 1 for all Episodes of Care

Stage1	AMI	Appendectomy	Breast Cancer Surgery	Cholecystectomy	Inguinal Hernia Surgery	Pneumonia
DRGs	+/Nsig.	+/Nsig.	+	+	-/+/nsig.	-/+/Nsig.
otherDRGs	+	+	+	+	+	+
Age categories	+	-/+/Nsig.	Nsig.	+/Nsig.	+	-/Nsig.
Gender	Nsig.	Nsig.	NA	+	-	Nsig.
Transout	Nsig.	-	Nsig.	Nsig.	Nsig.	-
Transin	-	-	NA	Nsig.	NA	-
Totaldiag	+	+	Nsig.	+	+	+
Totalproc	+	+	+	+	+	+
Emergency	+	Nsig.	Nsig.	+	+	Nsig.
Deceased	-	Nsig.	NA	Nsig.	Nsig.	-
charlson_1	Nsig.	Nsig.	Nsig.	Nsig.	Nsig.	Nsig.
Charlson_2	Nsig.	Nsig.	Nsig.	Nsig.	Nsig.	Nsig.
Urinary tract infection	Nsig.	-	NA	Nsig.	Nsig.	+
Postoperative surgical infection	NA	+	NA	+	+	-
Adverse events	Nsig.	NA	NA	NA	NA	Nsig.
Treatment specific variables	Nsig.	Nsig.	-/+/Nsig.	Nsig.	+/Nsig.	-
Comorbidities	NA	Nsig.	NA	NA	Nsig.	-/+/Nsig.
N	10744	7591	2573	11479	7738	33219
adjusted Deviance R^2	0.186	0.241	0.461	0.426	0.273	0.119
Regression model	Nbreg	poisson	poisson	Poisson	poisson	Nbreg

Note: All regressions used a negative binomial model. + : the variable increases LoS; - : the variable decreases LoS; nsig.: the variable is not significant (significance was assessed at the 1% level); NA: not applicable; Nbreg: negative binomial

The variables, which indicate whether a patient was transferred to another institution after discharged or transferred to another institution during hospitalization are in the majority of the episodes not significant. Patients who were transferred to another institution during hospitalization (*transout*) have a lower LoS in the cases of AMI, appendectomy and pneumonia. In the case of appendectomy and pneumonia, patients whose destination after discharge was to another institution with internment (*transin*) also have a lower length of stay. The total number of procedures is always statistically significant. The total number of diagnosis is also significant for all EoC except for the case of breast cancer surgery. Both a higher number of procedures and diagnosis increase LoS. A patient that is admitted as an emergency has also a higher length of stay, although it is not statistically significant in three

EoC (breast cancer surgery, cholecystectomy and pneumonia). For the cases of appendectomy and pneumonia, patients who died whilst in hospital had a lower hospital stay.

In all EoC analyzed, having one non-severe charlson comorbidity or a severe or two non-severe charlson comorbidities is not statistically significant. The effect on LoS of having a urinary tract infection during hospitalization is mixed. In case of appendectomy it decreases length of stay and in the case of pneumonia increases LoS. A postoperative surgical infection also yields mixed effects. In three episodes (AMI, cholecystectomy and inguinal hernia surgery) it increases the length of stay and in one episode (pneumonia) it decreases hospital stay, which is biologically not expectable.[15] An adverse event is not statistically significant.

Finally, regarding the treatment specific variables, these are only significant in some cases. In the case of AMI they are not statistically significant. Having a laparoscopic surgery (appendectomy, cholecystectomy and inguinal hernia surgery) is never statistically significant. In the case of appendectomy and inguinal hernia surgery, suffering from essential hypertension was not statistically significant. In the case of breast cancer surgery all treatment variables are statistically significant, with the exception of plastic operation and total mastectomy. When analyzing the case of inguinal hernia surgery, just one treatment variable (bilateral inguinal hernia) is statistically significant and increases hospital stay when compared to having a unilateral inguinal hernia. Finally, in the case of pneumonia, having a principal diagnosis of respiratory failure and pneumonia as a secondary diagnosis decreases LoS in comparison to having pneumonia as a principal diagnosis. In this EoC all co-existing comorbidities, except chronic pulmonary disease, are statistically significant. Having diabetes decreases hospital LoS, which is not expectable. Patients, who suffer from congestive heart

[15] To test whether the unexpected effects are due to the type of model used, the first-stage regression was run using OLS (Appendix 8). The OLS gives an intuition for the expected sign of the variables. The OLS regressions do not contradict the signs of the negative binomial regressions (with just some exceptions in the appendectomy case). Therefore, the unexpected effects are not due to the chosen functional form.

failure, have higher hospital stays. Moreover, antibiotic administration, injection or infusion of electrolytes or other therapeutic or prophylactic substance decreases LoS.

Figure 1 shows the variation in average LoS for each EoC across hospitals purged of the influence of the variables included in the first-stage. The horizontal line in the graphs represents the national average LoS for each episode. Hospitals are ordered from the left to the right from the hospitals with the lowest LoS to the ones with the highest. Hospitals with wide confidence intervals were excluded.[16] This happened in two episodes, namely cholecystectomy and inguinal hernia. The wide confidence intervals reflect uncertainty around the average LoS. This uncertainty arises because a share of patients had long stays, which the variables included in the first-stage model did not explain (Gaughan, Mason, Street, & Ward, 2012).

With just the exception of the first left-hand sided hospital in the case of breast cancer surgery and the first hospital on the left side of the inguinal hernia surgery graph, the deviation from the national average length of stay does not exceed 50%. Pneumonia represents the episode with hospitals that diverge less from the national average. In contrast, breast cancer surgery and inguinal hernia surgery are the episodes that have many hospitals with lower and higher average length of stay when compared to the national average, respectively. Appendix 10 shows for each episode the ranking of the hospitals. It is not possible to identify a pattern of the hospitals that are frequently on the top or bottom of the ranking.

Table 3 reports the results of stage 2. The second stage regressions show that hospital characteristics are not able to explain differences in average LoS. However, in the case of appendectomy, the rate of adverse events for all patients in the hospital is statistically significant at a 1% level. When compared to the rate of infection, the rate of adverse events decreases average length of stay. Therefore, the unexplained variation in average hospital

[16] Appendix 9 includes the graphs with the hospital effects before excluding hospitals with wide confidence intervals.

length of stay may be attributed to various reasons: hospital inefficiency, hospitals' policy, physicians' practices or patient-level characteristics, which were not included in the first-stage model.

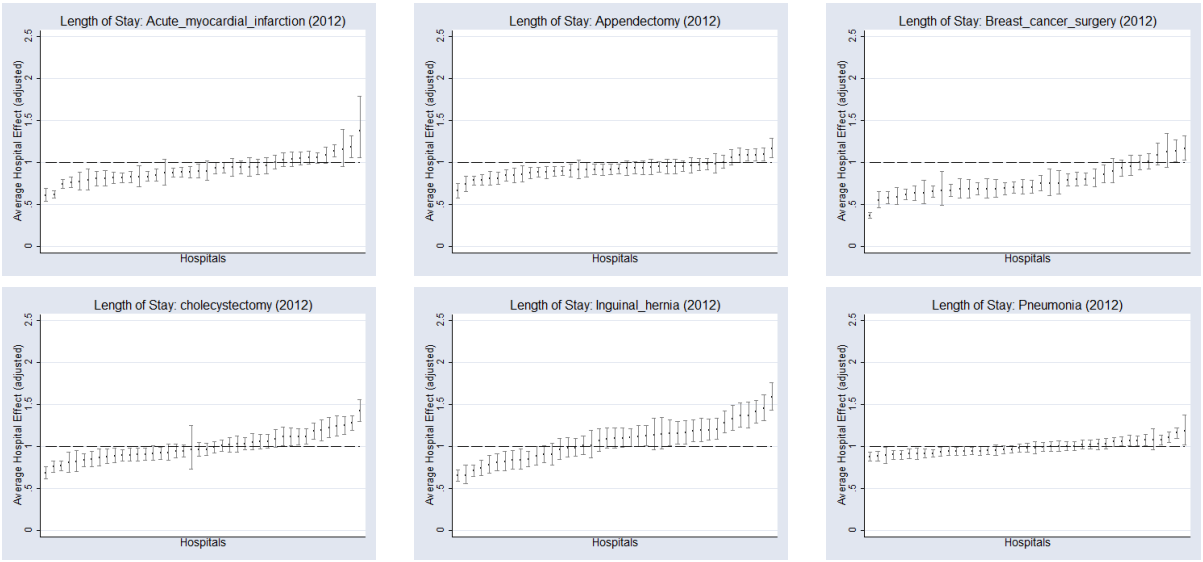

Figure 1- Average hospital effect for all episodes of care after excluding hospitals with wide confidence intervals

Table 3- Regression Results of Stage 2 for all Episodes of Care before removing the outliers

Stage 2	AMI	Appendectomy	Breast Cancer Surgery	Cholecystectomy	Inguinal hernia Surgery	Pneumonia
University hospital	-0.063 (0.113)	-0.015 (0.036)	0.161 (0.152)	-0.064 (0.053)	-0.044 (0.125)	-0.008 (0.047)
totvol1000	-0.001 (0.001)	-0.000 (0.001)	-0.003 (0.002)	-0.000 (0.001)	-0.000 (0.001)	-0.001 (0.000)
EoC percent	-0.021 (0.019)	-0.008 (0.108)	-0.059 (0.168)	-0.013 (0.018)	-0.017 (0.038)	-0.002 (0.009)
spec_index	-0.286 (0.380)	-0.187 (0.280)	-0.325 (0.638)	-0.277 (0.396)	0.117 (0.479)	0.090 (0.170)
Rate infections	Ref	Ref	Ref	Ref	Ref	Ref
Rate adverse events	-0.110 (0.234)	0.360** (0.117)	0.165 (0.445)	-0.043 (0.222)	-0.075 (0.536)	-0.083 (0.114)
_cons	-0.247 (0.220)	0.852*** (0.206)	1.129** (0.390)	0.688* (0.260)	0.366 (0.363)	1.345*** (0.126)
N	38	40	36	42	41	41
adjusted R^2	0.107	0.121	0.237	0.074	0.085	0.168

Efron robust standard errors are presented in parentheses. Ref: reference category
* p<0.05, ** p<0.01, ***p<0.001

5.1. Best practice average length of stay

Table 4 identifies the best practice average length of stay, *i.e.* the average length of stay that would be desirable if all hospitals would have an average length of stay equal to that of the benchmark hospitals. The best practice average length of stay for each episode is based on the average length of stay of the top 10% hospitals. The percentage reduction in average length of

stay ranges from 11,21% (pneumonia) to 47,65% (breast cancer surgery). With the implementation of a best practice average length of stay for each episode, a reduction in the total number of hospital days would be possible. Consequently less resources would be used, savings in costs would potentially occur and more patients could be treated.

Table 4- definition of best practice average length of stay

	National average LoS	Average fixed effects of the top 10% hospitals	Best practice average LoS	Percentage change in average LoS	Decrease in the total number of hospital days per 100 patients
AMI	5.22	0.68	3.56	-31.71%	-165
Appendectomy	2.92	0.74	2.17	-25.51%	-74
Breast cancer surgery	2.59	0.52	1.36	-47.65%	-123
Cholecystectomy	3.01	0.75	2.27	-24.66%	-74
Inguinal hernia surgery	1.93	0.95	1.32	-31.52%	-61
pneumonia	6.55	0.89	5.82	-11.21%	-73

Note: Best practice average LoS= national average LoS*[1-(1-average fixed effects of the top 10% hospitals)]

Table 5 reports the estimated savings in terms of average hospital days for each episode of care. The reduction in the total average number of days ranges from 3174 (breast cancer surgery) to 24408 (pneumonia). The highest reduction in average hospital days would be possible in the case of AMI, namely a reduction of 1.65 days.

Table 5- estimated reduction in average number of days with the reduction of inpatient average hospital days

	AMI	appendectomy	Breast cancer surgery	cholecystectomy	Inguinal hernia surgery	pneumonia
Total number of hospital days in 2012	10744	7591	2573	13105	7738	33219
reduction in average hospital days	1.653597	0.744352	1.233857	0.74265	0.609626	0.734767
reduction in the total number of hospital days with reduced inpatient average LoS	17766.25	5650.376	3174.714	9732.428	4717.286	24408.22

Note: reduction in the total number of hospital days with reduced inpatient average LoS= Total number of hospital days in 2012* reduction of average hospital days

6. Conclusions

This study focused on medical practice variation by analyzing average length of stay across Portuguese NHS hospitals for the year of 2012. The aim of this work was to find out (1) whether average length of stay across Portuguese NHS hospitals varies much when adjusting

for patients' case mix; (2) whether hospital characteristics explain the differences in average hospital stay and (3) what the average length of stay would be if all hospitals would have an average length of stay equal to that of the benchmark hospitals. It analyzed six different episodes of care, namely AMI, appendectomy, breast cancer surgery, cholecystectomy, inguinal hernia surgery and pneumonia.

The results are in line with previous studies. From the results, it is clear that a high proportion of the variation is not due to the fact that different hospitals serve different populations (patients' characteristics explained between 11% - pneumonia- and 46% -breast cancer surgery- of length of stay). When adjusting for differences in patients' characteristics, average length of stay across hospitals varies not more than 50% when compared to the national average. Regarding the explanations for the differences in average length of stay, the results show that hospital-level characteristics are not able to explain these differences. With just the exception of appendectomy, the rate of adverse events for all patients in the hospital is statistically significant at a 1% level. Therefore, the explanation for the differences in average length of stay across Portuguese NHS hospitals may be due to hospitals' inefficiency, hospitals' policies, physicians' practices or patient-level characteristics which were not included in the models.

The study shows that some hospitals could improve their performance. If a best practice LoS was implemented by looking at the LoS of the top 10% hospitals for each EoC, a decrease of 11% to 46% in average length of stay could be achieved. This would mean a saving in the total average number of hospital days. For instance, a reduction of 3174 average days in the case of breast cancer surgery and 24408 average days in the case of pneumonia. This would potentially imply savings in terms of costs and the treatment of more patients.

One limitation of this study is related to the patient-level characteristics. It was not possible to control for sociodemographic variables because these are not available in the data set.

Including this type of explanatory variables as well as more measures of health status could increase the explanatory power of the first-stage model. Therefore, ACSS should collect more information to incorporate in the DRGs' data set so that researchers were able to take these aspects into account when analyzing medical practice variation.

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Appendix

Table A 1- Regression Results of Stage 1 for all Episodes of Care

Stage1	AMI		Appendectomy		Breast Cancer Surgery		Cholecystectomy		Inguinal Hernia Surgery		Pneumonia	
DRG1	1.195***	(0.019)	1.440***	(0.020)	1.089**	(0.032)	1.533***	(0.079)	1.088*	(0.039)	1.242***	(0.021)
DRG2	Ref		1.193***	(0.044)	Ref		1.436***	(0.065)	1.175***	(0.027)	1.151***	(0.034)
DRG3	1.013	(0.084)	Ref				1.338***	(0.027)	Ref		Ref	
DRG4	1.106	(0.061)	0.953	(0.090)			Ref		0.701***	(0.036)	0.924***	(0.008)
DRG5	1.217***	(0.031)					1.692***	(0.066)			1.323***	(0.031)
DRG6	0.980	(0.017)									1.059***	(0.007)
DRG7	0.975	(0.016)									0.745***	(0.017)
DRG8											0.722***	(0.015)
DRG9											1.010	(0.043)
otherDRGs	1.340***	(0.041)	1.348***	(0.053)	1.275***	(0.077)	2.204***	(0.096)	1.370***	(0.067)	1.230***	(0.029)
agecat1	Ref		1.113***	(0.017)	Ref		Ref		Ref		0.938***	(0.009)
agecat2	1.050**	(0.016)	Ref		1.003	(0.020)	1.036*	(0.017)	1.051**	(0.019)	Ref	
agecat3	1.159***	(0.019)	0.955**	(0.015)	1.020	(0.021)	1.065***	(0.017)	1.101***	(0.020)	0.996	(0.008)
agecat4	1.240***	(0.021)	1.024	(0.016)	1.030	(0.023)	1.154***	(0.020)	1.104***	(0.021)	1.003	(0.008)
agecat5	1.230***	(0.023)	1.145***	(0.018)	1.020	(0.023)	1.299***	(0.022)	1.207***	(0.023)	0.992	(0.009)
Gender	0.988	(0.012)	1.006	(0.010)			1.029***	(0.011)	0.948**	(0.018)	0.999	(0.006)
Transout	0.799*	(0.076)	0.696***	(0.024)	1.055	(0.052)	0.541	(0.243)	0.500	(0.231)	0.860**	(0.046)
Transin	0.752**	(0.069)	0.318***	(0.042)			1.154	(0.466)			0.603***	(0.033)
Totaldiag	1.207***	(0.025)	1.034***	(0.009)	1.014	(0.009)	1.030***	(0.008)	1.037***	(0.010)	1.141***	(0.011)
Totalproc	1.531***	(0.068)	1.040***	(0.009)	1.074***	(0.015)	1.141***	(0.010)	1.064***	(0.009)	1.106***	(0.011)
emergency	1.266***	(0.025)	1.102*	(0.048)	0.899	(0.086)	1.571***	(0.022)	1.197***	(0.026)	1.007	(0.017)
Deceased	0.511***	(0.036)	0.498*	(0.167)			0.793*	(0.081)	0.794	(0.334)	0.595***	(0.006)
charlson_1	1.034*	(0.014)	1.014	(0.025)	1.020	(0.021)	0.972	(0.015)	0.956*	(0.018)	1.000	(0.007)
charlson_2	1.071*	(0.035)	1.117	(0.093)	1.106	(0.102)	0.991	(0.041)	0.964	(0.047)	1.005	(0.009)
Urinary tract infection	1.091	(0.055)	0.636**	(0.096)			1.049	(0.213)	1.421*	(0.247)	1.053***	(0.014)
Postoperative surgical infection			1.533***	(0.080)			1.616***	(0.148)	1.651***	(0.103)	0.417***	(0.007)

(continues)

(continued)

Stage1	AMI	Appendectomy	Breast Cancer Surgery	Cholecystectomy	Inguinal Hernia Surgery	Pneumonia
Adverse events	1.484 (0.844)					1.117 (0.327)
ST-elevated MI	1.057 (0.040)					
Non-ST elevated MI	1.066 (0.040)					
Subsequent MI	0.898 (0.068)					
Unspecified AMI	Ref					
Laparoscopy		1.040 (0.097)		0.906* (0.039)	0.927 (0.054)	
maindiagnosis_carcinomabreast			0.916*** (0.024)			
secondarydiag_maligneoplasm			1.221*** (0.048)			
Partialexcision_mammarygland			Ref			
Lympnode resection			1.120** (0.041)			
Plastic operation			1.015 (0.064)			
Total mastectomy			1.113 (0.129)			
Essential hypertension		1.005 (0.024)			0.998 (0.016)	
Unilateral IH					Ref	
Bilateral IH					1.127*** (0.018)	
Implants					0.999 (0.015)	
pneumonia						Ref
Respiratory failure						0.683*** (0.022)
diabetes						0.969*** (0.009)
Chronic pulmonary disease						0.964 (0.023)
Congestive heart failure						1.035*** (0.010)
Antibiotic						0.961*** (0.007)
Injection or infusion of electrolytes						0.931*** (0.007)
Injection or Infusion NEC						0.919*** (0.010)
N	10744	7591	2573	11479	7738	33219
Intercept	0.123*** (0.005)	2.285*** (0.125)	2.854*** (0.162)	1.610*** (0.089)	1.388*** (0.075)	3.884*** (0.192)
adjusted Deviance R^2	0.186	0.241	0.461	0.426	0.273	0.119
Regression model	Negative binomial	poisson	poisson	poisson	Poisson	Negative binomial

Note: The coefficients are exponentiated. Robust standard errors are presented in parentheses. Ref: reference category
* p<0.05, ** p<0.01, ***p<0.001

A Work Project, presented as part of the requirements for the Award of a Master´s Degree in Economics from the NOVA – School of Business and Economics

PRACTICE VARIATIONS IN THE PRODUCTION OF HEALTH

Complementary Appendix

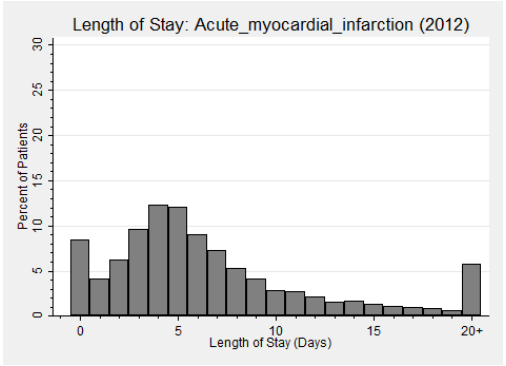
JOANA RIBEIRINHO SAMAGAIO 755

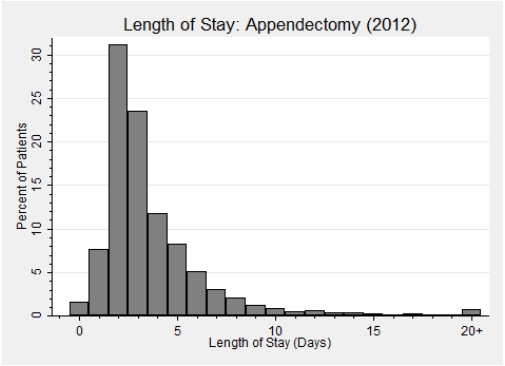
JANUARY 2016

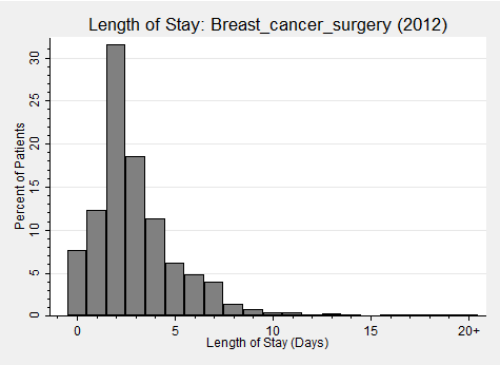
Appendix 1- test for overdispersion

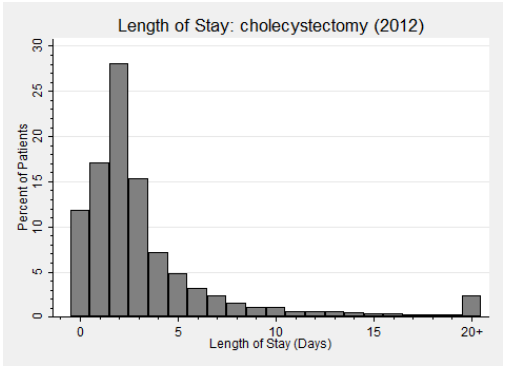
	likelihood ratio test of alpha=0		Model
AMI	Alpha=0.0798124	chibar2(01) = 637.01 Prob>=chibar2 = 0	Negative Binomial
Appendectomy	Alpha=1.23e-27	chibar2(01) = 0.00 Prob>=chibar2 = 1	Poisson
Breast Cancer Surgery	Alpha=1.33e-14	chibar2(01) = 0.00 Prob>=chibar2 = 1	Poisson
Cholecystectomy	Alpha= 7.60e-08	chibar2(01) = 0.0e+00 Prob>=chibar2 = 0	Poisson
Inguinal Hernia Surgery	Alpha=2.47e-12	chibar2(01) = 0.00 Prob>=chibar2 = 1	Poisson
Pneumonia	Alpha=0.092959	chibar2(01) = 3268.11 Prob>chibar2 = 0	Negative Binomial

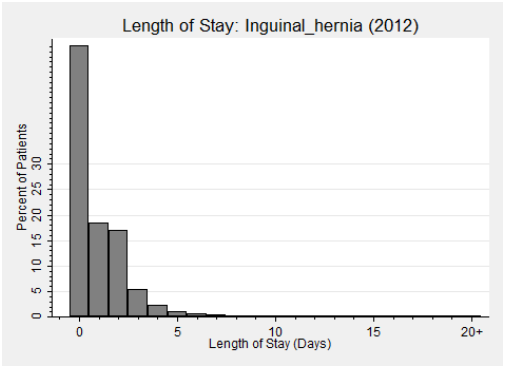
Appendix 2 A- Length of stay distribution (before dropping any outlier) for all Episodes of care

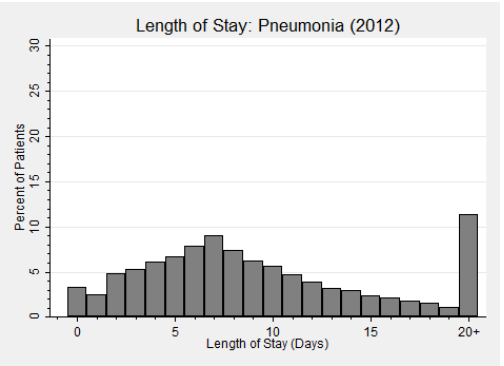












Appendix 2B- Length of stay distribution (before dropping any outlier) for each episode of care

	Skewness	Kurtosis
AMI	6.590868	90.63245
Appendectomy	4.620844	44.26898
Breast Cancer Surgery	4.292982	52.10421
Cholecystectomy	6.563344	75.92096
Inguinal Hernia Surgery	5.041982	10.16667
Pneumonia	19.17504	970.8536

Note: If the coefficient of skewness is negative, the distribution is skewed left. If the coefficient is positive, skewed right. As a benchmark, the normal distribution has a coefficient of kurtosis of 3.

Appendix 3- Calculation of the outliers

	Standard deviation of logarithm LoS	3 times standard deviation of logarithm LoS	Outliers
AMI	0.856638	2.569914	LoS>13
Appendectomy	0.6231127	1.869338	LoS>6
Breast cancer Surgery	0.596584	1.789751	LoS>5
Cholecystectomy	0.800111	2.400333	LoS>11
Inguinal Hernia Surgery	0.613834	1.841502	LoS>6
Pneumonia	0.86604	2.598119	LoS>13

Appendix 4- definition and explanation of first-stage level variables and ICD-9-CM codes used in the analysis

	Defined by	ICD-9-CM code	exclude	Additional information
Urinary tract infection	diagnosis	599.0		
Postoperative surgical infection	Diagnosis	998.59		
Adverse events	diagnosis	038, 415.1, 451.11, 998.4, 996.62, E870		
AMI				
Eligible patients	Main Diagnosis	410.xx	ICD-9-CM procedure code 36.1	
AMI: Treatment-specific variables				
ST-elevated Myocardial Infarction	diagnosis	410.0x-410.6x and 410.8x	if the fifth digit is 2	*Abbr*.: ST-elevated MI
non-ST-elevated Myocardial Infarction	Diagnosis	410.7x	if the fifth digit is 2	*Abbr*.: non-ST-elevated MI
subsequent Myocardial Infarction	diagnosis	410.x2		*Abbr*.: subsequent MI
Unspecified AMI	Diagnosis	410.9x	if the fifth digit is 2	Used as the reference group
PTCA	procedure	00.66		No observations
Appendectomy				
Eligible patients	Main Diagnosis and procedure	Diagnosis: 540-543.9; procedure: 47-479.9		
Appendectomy: comorbidities				
(essential) hypertension		401.9		
Appendectomy: treatment-specific variables				
laparoscopy	procedure	47.01		
Breast cancer surgery				
Eligible patients	Main Diagnosis and procedure	Diangosis: 174-174.9 or 233.0 Procedure: 85.20-85.23 or 85.33-85.36, 85.4	Male patients	
Breast cancer surgery: treatment-specific variables				
main diagnosis “carcinoma in situ of breast”	Diagnosis	233.0		*Abbr*.: maindiagnosis_carcinomabreast
Secondary diagnosis of “malignant neoplasm of female breast”	Diagnosis	174		No observations *Abbr*.:secondarydiag_maligneoplasm
Secondary and unspecified malignant neoplasm of lymph nodes	Diagnosis	196		No observations *Abbr*.:secondaryunspecified_lymphnodes
secondary diagnosis related to metastases	diagnosis	196.1-196.9		*Abbr*.: secondarydiagnosis_metastases
lymph node resection	Procedure	0.3-40.5, 85.43-85.48		
plastic operation	Procedure	85.5-85.8		

(continues)

(continued)

	Defined by	ICD-9-CM code	exclude	Additional information
Total mastectomy	Procedure	85.33-85.36, 85.4		
Cholecystectomy				
Eligible patients	Main Diagnosis and procedure	Diagnosis: 574-574.91; procedure: 51.2-51.224		
Cholecystectomy: treatment-specific variables				
Laparoscopy	Procedure	51.23		
Inguinal hernia surgery				
Eligible patients	Main Diagnosis and procedure	Diagnosis: 550-550.93; procedure: 17.1- 17.13, 17.2-17.22, 53.0-53.17		
Inguinal hernia surgery: comorbidities				
Essential hypertension		401.9		
Connective tissue disorders		710.9		No observations
Inguinal hernia surgery: treatment-specific variables				
Unilateral Inguinal Hernia	Diagnosis	550.90, 550.91		Used as the reference group
Bilateral inguinal hernia	Diagnosis	550.92, 550.93		
Unspecified inguinal hernia	Diagnosis	550, 550.0, 550.1, 550.9		No observations
laparoscopy	procedure	17.1-17.24		
implants	Diagnosis	530.3, 530.4, 531.4, 531.5, 531.6, 531.7		
Pneumonia				
Eligible patients	Main or main and secondary diagnosis	Pneumonia: 480-482.83, 482.89-486 Respiratory failure: 518.8, 518.82		Pneumonia is the reference group
Pneumonia: comorbidities				
Diabetes		250.00-250.93		
Chronic pulmonary disease		490, 491, 492, 494, 496		
Congestive heart failure		428.0		
Pneumonia: treatment-specific variables				
Antibiotic	Procedure	99.21		
Injection Or Infusion Of Electrolytes	Procedure	99.18		
Injection or infusion NEC (of other therapeutic or prophylactic substance)	procedure	99.29		

Appendix 5- All Patient Diagnosis-Related Groups (version 21) used in the DRGs' dummies

	AMI	Appendectomy	Breast Cancer Surgery	Cholecystectomy	Inguinal Hernia Surgery	Pneumonia
DRG1	121	165	259	197	160	79
DRG2	122	166	260	198	161	80
DRG3	123	167		493	162	89
DRG4	144	883		494	163	90
DRG5	550			556		540
DRG6	808					541
DRG7	853					772
DRG8						773
DRG9						882
Other DRGs	105, 106, 107, 108, 109, 110, 111, 112, 115, 116, 119, 120, 124, 125, 145, 468, 470, 477, 478, 479, 543, 545, 546, 547, 548, 549, 795, 796, 804, 849, 852, 854, 878	148, 149, 150, 151, 153, 155, 158, 164, 170, 171, 468, 553	257, 258, 265, 266, 564	191, 192, 193, 194, 196, 555, 787	148, 149, 151, 157, 158, 159, 166, 167, 553, 554, 585	75, 76, 77, 87, 99, 100, 468, 470, 477, 538, 539, 631, 700, 701, 704, 705, 706, 707, 708, 710, 712, 713, 714, 740, 770, 771, 877, 878, 881

Appendix 6- Definition of the age categories for each Episode of care

Age category	AMI	Appendectomy	Breast Cancer Surgery	Cholecystectomy	Inguinal Hernia Surgery	Pneumonia
Agecat1	20-55	2-12	17-47	6-40	1-51	1-62
Agecat2	56-65	13-19	48-55	41-52	51-61	63-76
Agecat3	66-73	20-28	56-62	53-61	62-69	77-82
Agecat4	74-81	29-42	63-68	62-71	70-76	83-87
Agecat5	>82	>43	>69	>72	>77	>88

Appendix 7- Descriptive Statistics: patient variables and hospital variables for all Episodes of Care

	AMI		Appendectomy		Breast Cancer Surgery		Cholecystectomy		Inguinal Hernia Surgery		Pneumonia	
No. Patients	10744		7591		2573		11479		7738		33219	
No. Hospitals	38		40		36		42		41		41	
Patients variables	Mean (Std. Dev.)											
LoS	5.21	(3.14)	2.92	(1.37)	2.59	(1.14)	3.01	(2.10)	1.93	(1.09)	6.55	(3.46)
Age	67.88	(13.94)	27.9	(17.83)	58.24	(11.72)	56.76	(16.05)	62.27	(19.36)	71.63	(22.98)
Totaldiag	2.91	(0.35)	1.43	(0.72)	2.31	(0.84)	2.19	(0.88)	2.02	(0.91)	2.85	(0.45)
Totalproc	2.95	(0.25)	2.6	(0.72)	2.72	(0.57)	2.41	(0.84)	2.09	(0.93)	2.92	(0.37)
	Percentage of pacients (%)											
DRG1	17.26		11.63		13.02		1.71		2.69		2.56	
DRG2	29.72		1.71		84.88		7.27		9.59		1.06	
DRG3	6.21		56.26				8.78		84.22		47.31	
DRG4	1.29		28.65				78.72		1.74		13.62	
DRG5	4.72						2.20				1.28	
DRG6	15.80										23.69	
DRG7	19.95										1.84	
DRG8											4.02	
DRG9											1.02	
otherDRGs	5.05		1.74		2.10		1.32		1.73		3.59	
Gender	66.23		54.78		0		34.34		90		52.05	
Transin	14.29		2.16		0		0.16		0.05		2.83	
Transout	19.27		5.74		18.93		4.51		5.71		8.79	
emergency	91.10		98.59		1.01		18.53		10.34		96.69	
Deceased	8.59		0.09		0		0.25		0.05		21.74	
charlson_0	74.14		95.77		88.73		84.18		85.67		53.89	
charlson_1	22.31		3.99		11.04		14.25		12.73		33.40	
charlson_2	3.55		0.24		0.23		1.57		1.60		12.71	
Urinary tract infection	0.83		0.07		0		0.05		0.03		4.02	
Postoperative surgical infection	0		0.12		0		0.13		0.03		0.00003	
Adverse events	0.02		0		0		0		0		0.02	
ST-elevated MI	44.49											
Non-ST elevated MI	50.95											
Subsequent MI	1.12											

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	AMI	Appendectomy	Breast Cancer Surgery	Cholecystectomy	Inguinal Hernia Surgery	Pneumonia
Unspecified AMI	3.44					
PTCA	0					
Stents	0					
Laparoscopy		29.01		89.48	0.74	
maindiagnosis_carcinomabreast			8.7			
secondarydiag_maligneoplasm			0			
secondaryunspecified_lymphnodes			0			
secondarydiagnosis_metastases			7.00			
Partialexcision_mammarygland			99.53			
Lympnode resection			3.34			
Plastic operation			0.66			
Total mastectomy			0.47			
Essential hypertension		4.83			26.03	
Connective tissue disorders					0	
Unilateral IH					79.98	
Bilateral IH					13.41	
Other IH					0	
Implants					73.42	
pneumonia						97.19
Respiratory failure						2.81
diabetes						9.90
Chronic pulmonary disease						1.13
Congestive heart failure						9.27
Antibiotic						25.20
Injection or infusion of electrolytes						11.12
Injection or infusion NEC						3.55
hospital variables	Percentage of patients (%)					
University hospital	7.89	7.50	8.33	7.14	7.32	7.32
	Mean (Std. Dev.)					
totvol1000	40.74 (31.76)	41.8 (33.6)	44.53 (35.99)	42.88 (36.27)	40.61 (33.57)	43.7 (36.46)
EoC percent	1.4 (2.31)	0.91 (1.5)	0.32 (0.44)	1.5 (2.96)	1.97 (3.92)	4.89 (9.74)
spec_index	0.61 (0.08)	0.61 (0.08)	0.62 (0.12)	0.62 (0.11)	0.61 (0.09)	0.62 (0.11)
Rate infections	8.70 (4.78)	8.64 (4.67)	7.93 (4.5)	8.27 (4.88)	8.46 (4.79)	8.16 (4.57)
Rate adverse events	0.11 (0.11)	0.11 (0.11)	0.12 (0.11)	0.11 (0.1)	0.11 (0.1)	0.12 (0.10)

Appendix 8- OLS Regression Results of Stage 1 for all Episodes of Care

Stage1	AMI		Appendectomy		Breast Cancer Surgery		Cholecystectomy		Inguinal Hernia Surgery		Pneumonia	
DRG1	1.014***	(0.083)	0.255***	(0.016)	0.218**	(0.072)	1.295***	(0.200)	0.180**	(0.068)	1.430***	(0.117)
DRG2	Ref		0.173***	(0.039)	Ref		0.700***	(0.172)	1.175***	(0.042)	0.867***	(0.177)
DRG3	0.265	(0.216)	Ref				0.921***	(0.058)	Ref		Ref	
DRG4	0.556*	(0.253)	0.120	(0.091)			Ref		-0.556***	(0.089)	-0.537***	(0.056)
DRG5	1.351***	(0.137)					1.998***	(0.119)			1.856***	(0.153)
DRG6	-0.114	(0.091)									0.384***	(0.044)
DRG7	-0.165	(0.087)									-1.739***	(0.137)
DRG8											-1.798***	(0.116)
DRG9											0.226	(0.177)
otherDRGs	1.522***	(0.143)	0.215***	(0.043)	0.651***	(0.134)	3.324***	(0.161)	0.777***	(0.085)	1.204***	(0.126)
agecat1	Ref		0.0261***	(0.015)	Ref		Ref		Ref		-0.463***	(0.059)
agecat2	0.240**	(0.080)	Ref		0.0109	(0.053)	0.0980*	(0.048)	0.0840*	(0.035)	Ref	
agecat3	0.724***	(0.085)	0.00451**	(0.015)	0.0585	(0.054)	0.160***	(0.048)	0.173***	(0.035)	-0.0147***	(0.053)
agecat4	1.111***	(0.085)	0.0329*	(0.015)	0.0765	(0.056)	0.392***	(0.05)	0.177***	(0.036)	0.0376	(0.054)
agecat5	1.087***	(0.093)	0.108***	(0.017)	0.0533	(0.056)	0.850***	(0.051)	0.373***	(0.037)	-0.0289	(0.055)
Gender	-0.0713	(0.058)	-0.00460	(0.009)			0.0802*	(0.032)	-0.108**	(0.036)	-0.0106	(0.035)
Transout	-0.641	(0.367)	-0.309	(0.417)	0.0700	(0.876)	-3.516**	(1.209)	-1.327**	(0.478)	-0.764**	(0.247)
Transin	-1.562***	(0.361)	0.189	(0.419)			1.639	(1.143)			-2.750***	(0.240)
Totaldiag	0.692***	(0.079)	0.0171	(0.009)	0.0378	(0.024)	0.0812***	(0.022)	0.0667***	(0.018)	0.717***	(0.050)
Totalproc	1.314***	(0.112)	0.00479	(0.008)	0.181***	(0.035)	0.332***	(0.024)	0.125***	(0.016)	0.568***	(0.057)
emergency	0.842***	(0.105)	-0.131**	(0.042)	-0.245	(0.171)	1.688***	(0.042)	0.392***	(0.037)	0.0506	(0.104)
Deceased	-3.169***	(0.183)	-0.103	(0.163)			-0.935**	(0.308)	-0.434	(0.478)	-3.093***	(0.045)
charlson_1	0.186**	(0.065)	-0.0210	(0.026)	0.0549	(0.057)	-0.0766	(0.047)	-0.0905*	(0.036)	-0.00536	(0.044)
charlson_2	0.301*	(0.143)	0.0554	(0.101)	0.313	(0.353)	-0.00312	(0.126)	-0.0841	(0.091)	0.0548	(0.055)
Urinary tract infection	0.607*	(0.289)	-0.118	(0.19)			0.396	(0.660)	1.517*	(0.674)	0.329***	(0.088)
Postoperative surgical infection			0.390**	(0.141)			2.926***	(0.419)	1.816**	(0.677)	-2.896	(3.086)
Adverse events	1.888	(1.898)									0.489	(1.381)
ST-elevated MI	0.268	(0.159)										
Non-ST elevated MI	0.322*	(0.158)										
Subsequent MI	-0.764*	(0.303)										
Unspecified AMI	Ref											

(continues)

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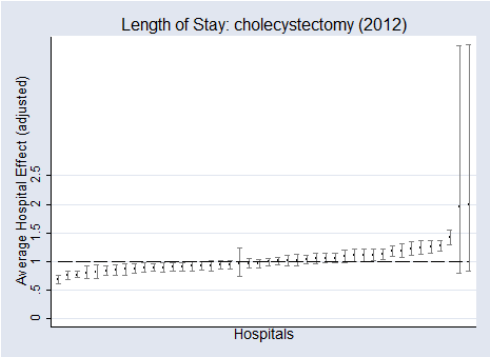
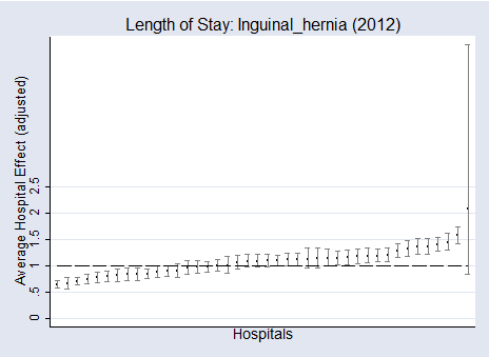
Stage1	AMI	Appendectomy	Breast Cancer Surgery	Cholecystectomy	Inguinal Hernia Surgery	Pneumonia
Laparoscopy		-0.00314 (0.090)		-1.078* (0.163)	-0.131 (0.130)	
maindiagnosis_carcinomabreast			-0.201** (0.063)			
secondarydiag_maligneoplasm			0.573*** (0.093)			
Partialexcision_mammarygland			Ref			
Lympnode resection			0.376*** (0.107)			
Plastic operation			0.0471 (0.212)			
Total mastectomy			0.455 (0.283)			
Essential hypertension		-0.0444 (0.026)			-0.00361 (0.030)	
Unilateral IH					Ref	
Bilateral IH					0.249*** (0.033)	
Implants					-0.00416 (0.028)	
pneumonia						Ref
Respiratory failure						-2.014*** (0.140)
diabetes						-0.200** (0.063)
Chronic pulmonary disease						-0.219 (0.163)
Congestive heart failure						0.213** (0.066)
Antibiotic						-0.252*** (0.043)
Injection or infusion of electrolytes						-0.377*** (0.059)
Injection or Infusion NEC						-0.465*** (0.095)
N	10744	7591	2573	11479	7738	33219
Intercept	-2.014*** (0.398)	1.183*** (0.051)	1.872*** (0.203)	2.290*** (0.186)	1.454*** (0.066)	3.849*** (0.243)
adjusted R^2	0.273	0.079	0.447	0.414	0.242	0.206

Standard errors are presented in parentheses. Ref: reference category
* p<0.05, ** p<0.01, ***p<0.001

Appendix 9- Average hospital effect for all Episodes of Care before excluding hospitals with wide confidence intervals





Appendix 10- hospitals' ranking

	AMI	appendecetomy	Breast cancer surgery	cholecystectomy	Inguinal hernia surgery	pneumonia
Rank	Hospital_id					
1	CHGE	EVOR	IPOL	CASC	CHDV	CHGE
2	CHAL	ULSL	LOUR	EVOR	CASC	MATO
3	CHUC	CHSJ	IPOP	PREL	AMAD	IPOL
4	CHSE	ULSG	CHVS	ULSL	XIRA	CHPO
5	ULAM	CHSE	BRAG	BARC	LOUR	XIRA
6	SANT	ULBA	CASC	CHLP	EVOR	EVOR
7	XIRA	BRAG	BARC	LOUR	CHVS	FIGU
8	CASC	ULCB	CHSE	CHDV	BARC	CHMT
9	CHLP	BARC	SANT	XIRA	BRAG	CHUC
10	CHTV	CHGE	ULAM	CHAA	CHMA	CHSE
11	EVOR	CHAL	CHGE	CHSJ	ULAM	CHO
12	ULNA	XIRA	CHLO	CHVS	CHAA	CHTV
13	CHLO	CHLC	CHSJ	BRAG	CHSJ	CHDV
14	LOUR	CHUC	CHO	CHPO	PREL	CHSJ

(continues)

(continued)

	AMI	appendecetomy	Breast cancer surgery	cholecystectomy	Inguinal hernia surgery	pneumonia
rank	Hospital_id					
15	ULSN	CHVS	CHAA	CHGE	CHGE	ULAM
16	CHLC	CHBM	MATO	FIGU	CHTA	CHAA
17	ALMA	PVVC	CHLC	CHCB	CHLP	BARC
18	MATO	CHLP	CHTA	MATO	ULSL	CBVG
19	CHBM	ULAM	CHPO	AMAD	CHSE	CHLP
20	ULCB	AMAD	EVOR	IPOL	CHCB	CHLC
21	CHPO	CHTV	ULSL	ULAM	CHUC	AMAD
22	BRAG	LOUR	ULNA	CHMA	CHMT	ULSL
23	CHMA	CASC	CHDV	CHUC	FIGU	CHVS
24	CHDV	CHLO	PVVC	CHLC	ULBA	CHMA
25	ULSL	CHMT	CHAL	CHSE	CHO	CASC
26	CHAA	CHAA	CHLN	CHTA	ULSG	BRAG
27	CHCB	CHCB	AMAD	CHTV	PVVC	SANT
28	CBVG	FIGU	ULBA	CBVG	MATO	ALMA
29	CHO	CBVG	CHBM	CHO	CHTV	LOUR
30	ULBA	MATO	CHMA	ALMA	CHPO	ULCB
31	CHTA	CHO	CHUC	CHBM	OVAR	CHBM
32	CHVS	CHDV	IPOC	ULBA	CBVG	CHAL
33	CHSJ	ULNA	CHCB	PVVC	CHBM	CHLO
34	CHMT	CHTA	CHTV	CHMT	CHLC	ULNA
35	AMAD	CHPO	XIRA	ULCB	CHAL	CHCB
36	CHLN	ULSN	ALMA	CHLO	CHLO	ULBA
37	ULSG	CHMA		OVAR	ULCB	CHLN
38	PVVC	ALMA		ULSG	SANT	ULSN
39		SANT		ULSN	ALMA	ULSG
40		CHLN		SANT	ULSN	CHTA
41				CHAL	ULNA	IPOP
42				ULNA		