REPLICATION OF LEWIN HOSPITAL COST MODELS USING COMMERCIAL INPATIENT DATA

Report to Bridges to Excellence

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Thomson Medstat
5425 Hollister Ave., Suite 140
Santa Barbara, CA 93111

Table of Contents

Index of Tables

I. Background and Purpose

Third-party payers and administrators have increasingly focused on hospitals' relative level of efficiency, which is often measured by hospital costs. Hospital cost structure and financial status are affected by important hospital characteristics like case mix index, teaching status, and share of care provided to poor populations.

Severity adjustment models have been developed in the Leapfrog Hospital Rewards Program (LHRP) to account for the effects of varying case-mix complexity and severity of illness on hospital efficiency measures. Likewise, "mission adjustments," which are calculations that take into account the type of hospital (teaching vs. non-teaching) and the proportion of the poor population served, are currently under development. These adjustments account for the effects of hospital characteristics (relating to the hospital's mission) on the measures of efficiency and calculations of hospital cost savings. For example, teaching hospitals are known to have higher costs than non-teaching hospitals because their infrastructure (facilities, equipment, and personnel) is geared to training doctors and to caring for patients using the most current treatment methodologies. Likewise, hospitals that treat a large proportion of poor and uninsured patients are faced with financial challenges that may compromise measures of healthcare efficiency.

In 2005, Bridges to Excellence (BTE) commissioned The Lewin Group to develop mission-adjustment models by clinical condition that could be used to adjust for teaching status, proportion of poor patients, and other mission-related hospital characteristics in the LHRP. Because of limited data availability, Lewin conducted its condition-specific analyses using Medicare's MedPAR databases (consisting of Medicare hospital discharges). The resulting mission-adjustment models perform well with Medicare data, but their applicability to non-Medicare data is unknown. BTE and The Leapfrog Group (LFG, the umbrella organization sponsoring LHRP) will be focusing their Hospital Rewards Program on the commercial (privately-insured) inpatient population. The applicability of the mission-adjustment models to commercial hospital discharges must be determined before they can be legitimately applied in the Hospital Rewards Program.

This report describes a set of analyses using large databases of privately-insured hospital discharges to validate the mission-adjustment models previously developed by The Lewin Group for BTE. These analyses are important because they examine whether the Lewin results based on Medicare hospital discharges are consistent with the results based on commercial hospital discharges.

II. Analytic Approach

In this section, we describe data sources, variables, and approaches to building the database for this replication effort.

A. Data Source

We utilized the 2002 Nationwide Inpatient Sample (NIS) developed by the Healthcare Cost and Utilization Project (HCUP) under the Agency for Healthcare Research and Quality (AHRQ) for this effort. The NIS is the largest nationwide all-payer hospital inpatient care database in the U.S. Each year the NIS contains data from approximately seven to eight million hospital stays – all discharge data from nearly 1,000 hospitals selected from HCUP State Inpatient Databases (SID) data. This figure approximates a 20% stratified sample of U.S. non-rehabilitation, community hospitals. The target universe includes all acute care discharges from community hospitals, as defined by the American Hospital Association (AHA), in the United States. There were 4,840 hospitals in the hospital universe in 2002. The 2002 NIS comprises all discharges from a sample of 995 hospitals in this target universe.

The NIS features standard UB92 data elements, including diagnoses, procedures, DRG, length of stay, hospital charges, service dates, primary pay source, and patient characteristics. For the purposes of this study, privately-insured patients were selected, key analytic variables were created based on these data elements, and the data were aggregated to the hospital level. All analyses were conducted at the hospital level.

In addition, we employed data provided by The Lewin Group originally obtained from other sources and used in their original modeling effort. We merged these data at the hospital level with the aggregated NIS data. The primary source for hospital financial data and share of care to poor populations is the Hospital Cost Report (HCR), which is available on the Healthcare Cost Reporting Information System (HCRIS) data set. Data on teaching status were obtained from the CMS Inpatient Impact File.

B. Analytic Variables

Table 1 presents the list of analytic variables and their source.

Table 1: Analytic Variables

Analytic Variables	Description (ICD-9-CM codes) and Source
Grouping Variable: Clinical Condition/Procedure (4)	Community-acquired pneumonia (480.xx–486.xx, 487)
	Coronary artery bypass graft (CABG) (36.1x)
	Percutaneous Coronary Intervention (PCI) (36.01, 36.02, 36.05 – 36.07)
	Acute myocardial infarction (AMI) (410.x1)
Dependent Variable: Hospital average cost of care	Average charge per case is converted to average cost per case using hospital-specific inpatient cost-to-charge ratio, when possible, or a weighted group average cost-to-charge ratio from HCUP data.
Key Independent Variables: Academic Health Center status	Teaching hospitals that are integrated with a medical school (AAMC: supplied by Lewin)
Teaching intensity	Intern- and resident-to-bed ratio (HCR: Lewin)
Disproportionate Share (DSH)	Medicare DSH payments (HCR: Lewin)
Percentage Medicaid	Medicaid days as % of total days (HCR: Lewin)
Cardiac Care Specialty Hospital	Hospital with >= 2/3 of cases in cardiac DRGs (Medstat)
Other (Control) Variables:	
Medicare outlier payments	HCR: Lewin
Wage index	HCR: Lewin
Urban Indicator	HCR: Lewin
Medicare days	HCR: Lewin – only in All-Case analyses
Nursery days	HCR: Lewin – only in All-Case analyses
Cardiac care unit days	HCR: Lewin – only in All-Case analyses
Burn care days	HCR: Lewin – only in All-Case analyses
ICU days	HCR: Lewin – only in All-Case analyses
Nursing facility days	HCR: Lewin – only in All-Case analyses
SNF days	HCR: Lewin – only in All-Case analyses
Surgical care days	HCR: Lewin – only in All-Case analyses
Hawaii Indicator	HCR: Lewin

These variables are described further below:

Clinical Condition: In addition to analyses on the entire population of commercial patient hospitalizations, separate analyses were conducted on each of six populations defined by clinical condition or procedure. These include community-acquired pneumonia (CAP), coronary artery bypass graft (CABG), percutaneous coronary intervention (PCI), and acute myocardial infarction (AMI). AMI and pneumonia cases are identified by the principal diagnoses only; CABG and PCI are identified by principal and secondary procedures. Because patients can have both an AMI and receive a CABG or PCI, we separated cardiac patients into five mutually exclusive categories:

1. AMI only
2. AMI with a CABG
3. AMI with a PCI
4. CABG without AMI
5. PCI without AMI.

Hospitalizations for these conditions and combinations were flagged on the NIS and grouped into sub-files for analysis.

Hospital average cost per case: At the hospital discharge level, the NIS contains measures of hospital charges, not costs. We estimated hospitalization costs using HCUP cost-to-charge ratios derived from total hospital cost and charge data, which contain a single, hospital-level cost-to-charge ratio per hospital. We applied the ratio to the charge for each hospitalization to estimate cost.

Teaching status: Teaching status is defined using two measures: academic health center status, and intern- and resident-to-bed (IRB) ratio.

Share of care provided to poor populations: A hospital's Medicare DSH payments and its percentage of Medicaid days are used as measures of the care it provides to poor populations.

Cardiac Care Specialty Hospital: If a hospital had two-thirds or more of its discharges in cardiac DRGs (DRG = 103-145, 478, 479, or 514-518), we considered it a cardiac care specialty hospital. Because the Lewin cardiac care specialty indicator was based on Medicare data, we created the indicator using our own commercial data.

Hospital Case Mix: Each hospital's mix of patients is quantified by DRG relative weights provided by Lewin.

Other Measures: To replicate the Lewin analyses, we included several additional hospital-level measures to control for other sources of variability in hospital costs. These measures consist of:

- Percentage of Medicare outlier payments as a percentage of total payments
- Wage index
- Urban/rural status
- Percentage of Medicare days – only in All-Case analyses
- Percentage of nursery days – only in All-Case analyses
- Percentage of cardiac care unit days – only in All-Case analyses
- Percentage of burn care days – only in All-Case analyses
- Percentage of ICU days – only in All-Case analyses
- Percentage of nursing facility days – only in All-Case analyses
- Percentage of SNF days – only in All-Case analyses
- Percentage of surgical care days – only in All-Case analyses

- Hawaii Indicator.

C. Building the Analytic Files

Step 1: We selected commercially-insured discharges, and flagged those with specific clinical conditions or procedures (see Table 1 for ICD-9-CM codes defining those conditions/procedures). A total of six clinical categories of hospitalization were defined.

Step2: We defined key discharge-level measures (e.g., DRG, hospitalization cost).

Step 3: We aggregated condition-specific databases to the hospital level, averaging DRG relative weights to define hospital-level case-mix.

Step 4: We merged hospital-level characteristics (e.g., teaching status, share of care to poor populations, and other measures) by the AHA hospital identification number. Of the 995 NIS hospitals, 654 have a valid AHA hospital identification number; in addition, only 544 hospitals in Lewin's hospital sample have a valid AHA hospital identification number. Thus, more hospitals were lost upon merging the hospital-level characteristics.

D. Methods

To replicate Lewin's models, we estimated linear models using hospital-level data. The dependent variable was log(average cost per case), and all continuous independent variables were also log-transformed. As Lewin did, we added a 1 to some variables before taking the log, if some of the values were zero. All models were fitted by weighting each hospital by the number of its discharges.

When both the average cost and the independent variables were log-transformed, the coefficients could then be interpreted as elasticities. For example, a coefficient of 0.5 would indicate that a 10 percent change in the explanatory variable would result in a 5 percent change in the average cost per case.

III. Findings

In this section, we present our findings on All-Case models and condition-specific models.

A. Findings from the All-Case Models

In Table 2, we report weighted means and standard deviations for hospitals included in the All-Case models in the NIS private-payer data and the HCR data, where the weight is equal to the number of discharges. Because the HCR contains all hospitals, while the NIS consists of a sample of hospitals, the HCR has a much larger sample size than the NIS. Of all the variables under consideration, the case-mix index, Hawaii Indicator, percentage of SNF days, and percentage of nursing facility days reveal the greatest degree of difference between these two samples. The average case-mix index is 1.190 in the NIS data, while the corresponding figure for the HCR data is 1.455. No Hawaii hospitals appear in the NIS data. The percentage of SNF days is almost twice as high in the HCR as in the NIS (0.147 vs. 0.079), and the percentage of nursing facility days is three times as high in the HCR as in the NIS sample (0.024 vs. 0.008).

If weighted by the number of discharges per hospital, the average cost per case in the NIS is $6,389 and, if not weighted, $5,405 (This information is not shown in Table 2). The weighted average cost per case is $6,536 in the HCR data, which is very close to the weighted cost in the NIS.

The last four rows of Table 2 present the percentage of discharges that are CAP, CABG, PCI, and AMI. For all clinical conditions, NIS hospitals have a smaller percentage than HCR hospitals, which is expected because Medicare data are included in the HCR, while the NIS sample includes only commercial payers. Thus, the HCR data contain records for a more elderly and chronically ill population.

Table 2: Comparison of the NIS and HCR data

	NIS			HCR		
Analytic Variables	N	Mean	Std Dev	N	Mean	Std Dev
average cost per case	533	$6,389	$2,735	3802	$6,536	$2,162
case-mix index: DRG weight	533	1.190	0.22	3949	1.455	0.27
wage index	522	1.061	0.16	3949	0.996	0.14
DSH payments/total payments	522	0.065	0.07	3944	0.066	0.07
Medicare inpatient days/total days	522	0.412	0.14	3949	0.478	0.13
Medicaid inpatient days/total days	519	0.118	0.09	3901	0.126	0.09
Intern- and resident-to-bed ratio	522	0.114	0.18	3949	0.096	0.18
swing bed SNF days/total days	522	0.003	0.02	3949	0.007	0.04
swing bed NF days/total days	522	0.000	0.01	3949	0.001	0.02
other special care unit days/total days	522	0.024	0.05	3949	0.020	0.04

Analytic Variables	NIS N	NIS Mean	NIS Std Dev	HCR N	HCR Mean	HCR Std Dev
nursery days/total days	522	0.068	0.05	3949	0.052	0.04
SNF days/total days	522	0.079	0.23	3949	0.147	0.91
burn care days/total days	522	0.001	0.01	3949	0.001	0.01
other long term days/total days	522	0.007	0.07	3949	0.013	0.24
outlier payments/total payments	522	0.051	0.06	3944	0.047	0.06
ICU days/total days	522	0.080	0.05	3949	0.085	0.05
cardiac care unit days/total days	522	0.018	0.03	3949	0.019	0.03
nursing facility days/total days	522	0.008	0.10	3949	0.024	0.27
surgical care days/total days	522	0.008	0.02	3949	0.005	0.02
Urban Indicator	522	0.900	0.30	3949	0.811	0.39
Hawaii Indicator	522	0	0	3949	0.002	0.05
Academic Health Center Indicator	516	0.064	0.25	3846	0.063	0.24
Cardiac Specialty Hospital Indicator	525	0.003	0.05	3870	0.004	0.06
% of total discharges that are CAP	636	2%	0.01	3846	10%	0.04
% of total discharges that are CABG	636	1%	0.01	3846	2%	0.02
% of total discharges that are PCI	636	2%	0.02	3846	3%	0.03
% of total discharges that are AMI	636	2%	0.01	3846	4%	0.02

Notes: The means are weighted by the number of discharges in each hospital.

Table 3 presents estimated coefficients from four models. Major findings across all models include:

- Hospitals with a higher case-mix index and a higher wage index tend to have significantly higher costs per case.

- Hospitals with a higher rate of disproportionate share (DSH) payments have significantly higher estimated costs for NIS hospitals; this is not always the case for HCR hospitals.

- The intern- and resident-to-bed (IRB) ratio significantly increases estimated costs per case for both NIS and HCR hospitals.

- Estimated costs are always significantly higher for academic health centers (AHC) than for non-AHC in the HCR data, but not in the NIS sample. NIS models in which the IRB was excluded still reveal an insignificant AHC impact. This might be to the fact that the NIS data only contain 13 AHC hospitals.

- Urban hospitals in the NIS sample appear to have significantly lower costs as compared with rural hospitals; in contrast, these hospital types do not reveal significant differences in the HCR data.

We now turn to an exploration of the four statistical models in Table 3.

In Model 1, although both DSH and IRB significantly increase estimated hospital costs, their impact is much higher in the NIS model than in the HCR model. Specifically, a 10% increase in DSH raises estimated costs by more than five times in the NIS as compared with the HCR (11% vs. 2%); a 10% increase in IRB increases costs by 3% in the NIS, compared with only 1% in the HCR. In the HCR model, estimated costs are significantly higher for AHC than for non-AHC, while in the NIS model, estimated costs reveal no significant differences between academic and other health centers.

In Model 2, the percentage of Medicaid days and percentage of specific inpatient days are added and the Medicare outlier payment is excluded. The estimated coefficient of DSH becomes insignificant and drops from 0.228 to 0.011 in the HCR model. DSH remains a significant factor in the NIS sample. IRB is still associated with significantly higher estimated costs in both HCR and NIS models. In addition, the impact of AHC on estimated costs remains significant in the HCR and insignificant in the NIS.

Four more variables on specialty care unit days are added to Model 3 to capture differences in patients' severity of illness across hospitals. The impact of DSH, IRB, and AHC on estimated costs is roughly the same in Model 3 as in Model 2.

In Model 4, we see all the explanatory variables included in Model 3, with the addition of Medicare outlier payments. This variable significantly increases estimated cost per case in both the NIS and HCR models. IRB is associated with significantly higher estimated costs in both the NIS and the HCR models: a 10% increase in IRB increases costs by 3.3% in the NIS and 1.8% in the HCR. DSH appears to have differential impacts on costs for NIS hospitals and HCR hospitals: a 10% increase in DSH raises estimated costs by 17% for NIS facilities, while revealing no impact on HCR hospitals.

Because Model 4 has the highest adjusted R-square of all models, we focus our discussion on this model during the remainder of this paper. The Lewin report also devotes considerable attention to the fourth model in its investigation of cost per case.

Table 3: Coefficients from All Cases Models

	Model 1		Model 2		Model 3		Model 4	
	NIS	HCR	NIS	HCR	NIS	HCR	NIS	HCR
Intercept	8.373*	8.384*	8.547*	8.431*	8.469*	8.385*	8.459*	8.362*
log(case-mix index)	1.170*	1.054*	1.200*	1.019*	1.131*	0.988*	1.067*	0.942*
log(wage index)	0.971*	0.710*	1.182*	0.669*	1.199*	0.681*	0.955*	0.624*
log(1+DSH payments/total payments)	1.113*	0.228*	2.072*	0.011	2.098*	0.000	1.714*	-0.027
log(1+Medicare inpatient days/total days)			0.017	-0.145*	0.073	-0.118*	-0.143	-0.113*
log(1+Medicaid inpatient days/total days)			-1.060*	-0.202*	-1.170*	-0.204*	-0.851*	-0.154*
log(1+intern- and resident-to-bed ratio)	0.322*	0.097*	0.240*	0.149*	0.221*	0.153*	0.330*	0.184*
log(1+swing bed SNF days/total days)			-0.632	0.272*	-0.586	0.340*	-0.384	0.348*
log(1+swing bed NF days/total days)			0.706	0.738*	0.877	0.799*	0.642	0.801*
log(1+ other special care unit days/total days)			0.285	0.243*	0.520	0.353*	0.302	0.309*
log(1+nursery days/total days)			-0.343	-1.038*	-0.220	-0.956*	-0.242	-0.900*
log(1+SNF days/total days)			0.023	0.016	0.026	0.020	0.084	0.031*
log(1+burn care days/total days)			0.103	0.391	0.302	0.366	0.291	0.281
log(1+other long term days/total days)			0.255	-0.021	0.282	-0.017	0.373	-0.010
Urban Indicator	-0.158*	0.026*	-0.153*	0.018	-0.152*	0.018	-0.188*	0.013
Hawaii Indicator		0.262*		0.252*		0.265*		0.264*
Academic Health Center Indicator	-0.036	0.101*	0.048	0.169*	0.057	0.165*	-0.008	0.150*
log(1+outlier payments/total payments)	2.531*	1.130*					2.487*	0.762*
log(1+ ICU days/total days)					0.511	0.405*	0.591*	0.394*
log(1+cardiac care unit days/total days)					0.997*	0.324*	0.775*	0.264*
log(1+nursing facility days/total days)					0.203	-0.023	0.186	-0.021
log(1+surgical care days/total days)					1.013	0.289	0.525	0.260
N	503	3678	503	3802	503	3802	503	3802
adjusted R2	0.732	0.764	0.636	0.690	0.639	0.692	0.741	0.707

Notes: * significant at the 5% level.

Because NIS models are based on a sample of hospitals, while the HCR contains all hospitals, HCR estimates are less likely to be biased. We therefore adjusted the NIS private-payer estimates to reduce this bias. To implement the adjustment for all-payer data, Model 4 is estimated one more time using NIS all-payer discharges. These estimates are then compared with those from the HCR, which also contain all-payer discharges. We assume that NIS private-payer estimates are biased to the same extent that the NIS all-payer estimates are biased. For this reason, we first calculated the difference between NIS all-payer estimates and HCR estimates and then modified NIS private-payer estimates by that difference. The formula for coefficients is:

Revised NIS private-payer estimate = NIS private-payer + (HCR – NIS all-payer)

The last column in Table 4 reports the revised estimated coefficients for NIS private-payer data. After the adjustment, the coefficients of many variables, including DSH, IRB, and AHC, approach the HCR estimates. For example, the estimated coefficient of DSH was originally 1.714; after adjustment, it becomes 0.157, which is much closer to -0.027, the HCR coefficient. This is similar to the strategy that Lewin analysts used to adjust Medicare coefficients to all-payer data.

Table 4: Adjusted NIS Private-Payer Estimates for All Cases

	NIS Private Payer	NIS All Payer	HCR	Difference between HCR and NIS All Payer	Revised NIS Private Payer
Intercept	8.459*	8.534*	8.362*	-0.172	8.287
log(case mix index)	1.067*	0.848*	0.942*	0.094	1.161
log(wage index)	0.955*	0.982*	0.624*	-0.358	0.597
log(1+DSH payments/total payments)	1.714*	1.530*	-0.027	-1.557	0.157
log(1+Medicare inpatient days/total days)	-0.143	-0.017	-0.113*	-0.096	-0.239
log(1+Medicaid inpatient days/total days)	-0.851*	-0.951*	-0.154*	0.797	-0.054
log(1+intern- and resident-to-bed ratio)	0.330*	0.280*	0.184*	-0.096	0.234
log(1+swing bed SNF days/total days)	-0.384	-0.804*	0.348*	1.152	0.768
log(1+swing bed NF days/total days)	0.642	1.175	0.801*	-0.374	0.268
log(1+ other special care unit days/total days)	0.302	0.541	0.309*	-0.232	0.070
log(1+nursery days/total days)	-0.242	-0.325	-0.900*	-0.575	-0.817
log(1+SNF days/total days)	0.084	0.058	0.031*	-0.027	0.057
log(1+burn care days/total days)	0.291	0.241	0.281	0.04	0.331
log(1+oher long term days/total days)	0.373	0.437*	-0.010	-0.447	-0.074
Urban Indicator	-0.188*	-0.152*	0.013	0.165	-0.023
Hawaii Indicator			0.264*	0.264	0.264
Academic Health Center Indicator	-0.008	0.022	0.150*	0.128	0.120
log(1+outlier payments/total payments)	2.487*	3.025*	0.762*	-2.263	0.224
log(1+ ICU days/total days)	0.591*	0.632*	0.394*	-0.238	0.353
log(1+cardiac care unit days/total days)	0.775*	0.703*	0.264*	-0.439	0.336

	NIS Private Payer	NIS All Payer	HCR	Difference between HCR and NIS All Payer	Revised NIS Private Payer
log(1+nursing facility days/total days)	0.186	0.086	-0.021	-0.107	0.079
log(1+surgical care days/total days)	0.525	0.617	0.260	-0.357	0.168

Notes: * significant at the 5% level.

B. Findings from Condition-Specific Models

In addition to the All-Case model, we estimated condition-specific models that contain only discharges of a specific condition or procedure.

Table 5 summarizes weighted mean values of three selected explanatory variables, using the number of condition-specific discharges as the weight. For all conditions except PCI without AMI, the case-mix index is lower in the NIS data than in the MedPAR data. The average cost per case is higher for NIS hospitals than for MedPAR hospitals for all conditions. However, Medicare outlier payments in the two samples are not as different as the case-mix index or cost per case. As can be seen in the Hospitals column of this table, MedPAR data contain more hospitals than the NIS data across all conditions.

Table 5: Comparisons of Mean Values from the NIS Private-Payer Sample and the MedPAR Sample

	Case Mix Index		Average Cost		Medicare Outlier Payments		Hospitals	
	NIS	MedPAR	NIS	MedPAR	NIS	MedPAR	NIS	MedPAR
AMI only	1.43	1.58	$9,133	$8,129	0.04	0.04	486	3459
AMI with CABG	5.57	5.72	$36,999	$34,165	0.11	0.11	139	974
AMI with PCI	2.55	2.91	$17,866	$15,503	0.04	0.05	163	1140
CABG w/o AMI	4.92	5.20	$28,766	$27,935	0.07	0.09	144	988
PCI w/o AMI	2.38	2.18	$13,959	$11,505	0.03	0.03	157	1149
CAP	1.15	1.31	$6,846	$6,844	0.04	0.04	459	3521

Notes: MedPAR numbers are based on Table 6 of the Lewin report. NIS means are weighted by the number of private-payer discharges within a hospital.

Similar to the All Cases estimates, we improved the estimated coefficients for NIS private-payer discharges. Because NIS models are based on a sample of hospitals, while the MedPAR data contain all hospitals, MedPAR estimates are less likely to be biased. We therefore compared estimated coefficients using NIS Medicare discharges with MedPAR models. Assuming that NIS private-payer estimates are biased to the same extent that NIS Medicare estimates are biased, we adjusted NIS private-payer estimates using the following formula:

Revised NIS private-payer estimate = NIS private-payer + (MedPAR – NIS Medicare)

The Lewin Group did not possess all-payer data for the condition-specific regressions. Therefore, they fit regressions to the MedPAR data and, in order to estimate the all-payer coefficients, they multiplied the all-payer estimates in Model 4 by the following ratio:

Ratio = condition-specific Medicare estimated coefficient / all-condition Medicare estimated coefficient.

In Tables 6-11, we report estimated coefficients for NIS private payer, NIS Medicare, MedPAR, revised NIS private-payer coefficients, and revised MedPAR coefficients for each condition. The adjusted estimates between the NIS data and the MedPAR data are much closer than the unadjusted coefficients.

We now focus our discussion on the modified coefficients. Major findings for these coefficients include:

- For both the NIS and the MedPAR data, hospitals with a higher case-mix index, higher wage index, or higher Medicare outlier payments have significantly higher estimated costs for most conditions.

- MedPAR hospitals with higher DSH payments have significantly lower estimated costs; in contrast, the DSH impact on costs is not consistent across conditions in the NIS data.

- AHC tend to have higher estimated costs than non-AHC for all conditions, with the exception of AMI. This impact is significant in all MedPAR models, while insignificant in all NIS models.

AMI-Specific Discharges

The results in Table 6 suggest that both NIS and MedPAR hospitals with higher DSH payments have significantly lower estimated costs. Hospitals with higher IRB seem to have higher costs, although the impact is significant only for MedPAR hospitals. Estimated costs for AHC are significantly higher than those for non-AHC in the MedPAR data, while AHC does not appear to have a significant impact on costs for NIS hospitals. Similarly, cardiac care specialty hospitals do not appear to have significantly different costs, when compared with non-specialty hospitals.

Table 6: Coefficients for AMI Only

	NIS Private-Payer	NIS Medicare	MedPAR	Revised Coefficients for NIS Private-Payer	Revised Coefficients for MedPAR
Intercept	8.380*	8.465*	8.224*	8.139	8.202
log(case mix index)	1.200*	1.053*	1.161*	1.308	1.037

	NIS Private-Payer	NIS Medicare	MedPAR	Revised Coefficients for NIS Private-Payer	Revised Coefficients for MedPAR
log(wage index)	0.801*	1.060*	0.661*	0.402	0.581
log(1+ DSH payments/total payment)	0.735*	1.335*	0.497*	-0.104	-0.059
log(1+ intern- and resident-to-bed ratio)	0.374*	0.035	0.295*	0.635	0.559
log(1 + outlier payment/total payment)	2.341*	2.739*	1.499	1.101	1.011
Urban Indicator	0.029	-0.029	0.082*	0.140	0.041
Hawaii Indicator			0.390*	0.390	0.394
Academic Health Center Indicator	-0.105	0.089	0.077*	-0.117	0.114
Cardiac Specialty Hospital Indicator	-0.075	-0.033	-0.027	-0.069	-0.027
N	438	459	3459		
adjusted R2	0.603	0.645	0.651		

Notes: * significant at the 5% level.

AMI with CABG

Table 7 presents estimated coefficients for AMI with CABG cases. Hospitals with higher DSH have significantly lower estimated costs in the MedPAR data but significantly higher estimated costs in the NIS. Hospitals with higher IRB seem to have higher costs in both the NIS and MedPAR data, although the impact of IRB is only significant for MedPAR hospitals. For both NIS and MedPAR hospitals, the costs of AHC facilities do not appear to be significantly different from non-AHC facilities, while cardiac specialty hospitals seem to have a significantly lower estimated cost than other hospitals.

Table 7: Coefficients for AMI with CABG

	NIS Private-Payer	NIS Medicare	MedPAR	Revised Coefficients for NIS Private-Payer	Revised Coefficients for MedPAR
Intercept	7.964*	8.982*	8.405*	7.387	8.383
log(case mix index)	1.285*	0.786*	1.045*	1.543	0.934
log(wage index)	1.266*	1.204*	0.540*	0.601	0.475
log(1+ DSH payments/total payment)	1.898*	2.326*	0.459*	0.030	-0.054
log(1+ intern- and resident-to-bed ratio)	0.134	0.268	0.175*	0.041	0.331
log(1 + outlier payment/total payment)	1.451*	1.987*	1.398	0.862	0.943
Urban Indicator	-0.031	-0.177*	-0.047*	0.099	-0.023
Hawaii Indicator			0.361*	0.361	0.364
Academic Health Center Indicator	-0.071	-0.170	0.041	0.140	0.061
Cardiac Specialty Hospital Indicator	-0.343*	-0.151	-0.091*	-0.283	-0.091
N	123	127	974		
adjusted R2	0.554	0.675	0.593		

Notes: * significant at the 5% level.

AMI with PCI

Table 8 reports estimated coefficients for AMI with PCI cases. It appears that higher DSH is associated with significantly lower costs in both models. The coefficients of IRB suggest that the impact of IRB on estimated costs is not significant in either model. Furthermore, cardiac specialty hospitals appear no different from other hospitals in terms of costs per case. AHC facilities have significantly higher estimated costs than non-AHC facilities in the MedPAR data, but this is not the case in the NIS data.

Table 8: Coefficients for AMI with PCI

	NIS Private-Payer	NIS Medicare	MedPAR	Revised Coefficients for NIS Private-Payer	Revised Coefficients for MedPAR
Intercept	8.532*	8.715*	8.347*	8.163	8.325
log(case mix index)	1.159*	0.997*	1.140*	1.302	1.019
log(wage index)	1.160*	1.168*	0.472*	0.463	0.415
log(1+ DSH payments/total payment)	1.557*	1.920*	0.306*	-0.057	-0.036
log(1+ intern- and resident-to-bed ratio)	-0.133	0.106	-0.069	-0.308	-0.131
log(1 + outlier payment/total payment)	2.389*	3.184*	1.470	0.675	0.992
Urban Indicator	-0.111	-0.138	-0.052*	-0.026	-0.026
Hawaii Indicator			0.126	0.126	0.127
Academic Health Center Indicator	-0.041	-0.063	0.082*	0.105	0.122
Cardiac Specialty Hospital Indicator	-0.131	-0.027	-0.011	-0.115	-0.011
N	146	148	1140		
adjusted R2	0.5026	0.584	0.328		

Notes: * significant at the 5% level.

CABG without AMI

Estimated coefficients for CABG without AMI cases are reported in Table 9. The impact of DSH is different in the NIS and the MedPAR data: a 10% point increase in DSH is associated with a 2.7% cost increase among NIS hospitals, while a 0.6% decrease occurs for MedPAR hospitals. IRB does not seem to have a significant impact on estimated costs in either data set. AHC status appears to result in higher estimated costs in both the NIS and MedPAR, but the impact is significant only in the MedPAR sample. In both data, cardiac specialty hospitals appear to be able to perform CABGs at lower cost than other hospitals.

Table 9: Coefficients for CABG with No AMI

	NIS Private-Payer	NIS Medicare	MedPAR	Revised Coefficients for NIS Private-Payer	Revised Coefficients for MedPAR
Intercept	7.620*	8.712*	8.340*	7.249	8.318
log(case mix index)	1.523*	0.891*	1.047*	1.679	0.936
log(wage index)	1.412*	1.284*	0.474*	0.603	0.417
log(1+ DSH payments/total payment)	2.419*	2.621*	0.470*	0.268	-0.055
log(1+ intern- and resident-to-bed ratio)	-0.179	-0.002	0.076	-0.101	0.144
log(1 + outlier payment/total payment)	2.215*	2.591*	1.423*	1.046	0.960
Urban Indicator	-0.161	-0.176*	-0.047	-0.032	-0.023
Hawaii Indicator			0.300*	0.300	0.303
Academic Health Center Indicator	-0.145	-0.149	0.082*	0.086	0.122
Cardiac Specialty Hospital Indicator	-0.430*	-0.269*	-0.135*	-0.296	-0.135
N	126	130	988		
adjusted R2	0.594	0.6795	0.528		

Notes: * significant at the 5% level.

PCI without AMI

Results for PCI with no AMI cases are presented in Table 10. Hospitals with higher DSH seem to have higher costs in the NIS but lower costs in the MedPAR data. IRB is associated with lower estimated costs, while AHC status is associated with higher estimated costs in both the MedPAR and NIS data. In addition, the impacts of IRB and AHC status are significant for MedPAR hospitals but not for NIS hospitals.

Table 10: Coefficients for PCI with No AMI

	NIS Private-Payer	NIS Medicare	MedPAR	Revised Coefficients for NIS Private-Payer	Revised Coefficients for MedPAR
Intercept	8.443*	8.031*	7.917*	8.329	7.896
log(case mix index)	1.097	1.672*	1.792*	1.217	1.601
log(wage index)	1.102*	1.012*	0.271*	0.361	0.238
log(1+ DSH payments/total payment)	0.857*	0.905*	0.215*	0.167	-0.025
log(1+ intern- and resident-to-bed ratio)	-0.144	0.072	-0.201*	-0.417	-0.380
log(1 + outlier payment/total payment)	3.098*	3.218*	1.700	1.580	1.147
Urban Indicator	-0.083	-0.135	-0.073*	-0.022	-0.036
Hawaii Indicator			0.021	0.021	0.021
Academic Health Center Indicator	-0.103	-0.110	0.093*	0.100	0.138
Cardiac Specialty Hospital Indicator	-0.218	-0.175	-0.012	-0.056	-0.012
N	140	146	1049		
adjusted R2	0.446	0.5124	0.219		

Notes: * significant at the 5% level.

CAP

Table 11 describes the results on CAP cases. Again, hospitals with higher DSH payments appear to have significantly higher costs in the NIS data but lower costs in the MedPAR data. IRB does not have a significant impact on estimated costs in either data set. AHC status appears to be associated with higher costs than non-AHC hospitals in both samples, but the association is significant only for MedPAR hospitals.

Table 11: Coefficients for CAP

	NIS Private Payer	NIS Medicare	MedPAR	Revised Coefficients for NIS Private Payer	Revised Coefficients for MedPAR
Intercept	8.421*	8.603*	8.461*	8.279	8.439
log(case mix index)	1.321*	1.094*	0.854*	1.081	0.763
log(wage index)	1.117*	1.122*	0.762*	0.757	0.670
log(1+ DSH payments/total payment)	0.647*	0.715*	0.269*	0.201	-0.032
log(1+ intern- and resident-to-bed ratio)	0.063	-0.112	-0.022	0.153	-0.042
log(1 + outlier payment/total payment)	2.751*	3.164*	0.247	-0.166	0.167
Urban Indicator	-0.082*	-0.120*	1.669*	1.706	0.834
Hawaii Indicator			0.012*	0.012	0.012
Academic Health Center Indicator	0.044	-0.037	0.080*	0.161	0.119
N	459	465	3521		
adjusted R2	0.707	0.693	0.641		

Notes: Coefficients in bold are significant at the 5% level.

C. Development of Adjustment Factors

To be able to compare costs across different types of hospitals, we developed adjustment factors that can be applied to modify costs for teaching hospitals or for hospitals treating a large proportion of poor and uninsured patients. It is important to keep in mind that the adjustment factors based on revised NIS private-payer coefficients reflect the commercial population, while the adjustment factors based on HCR coefficients and revised MedPAR coefficients are applicable to an all-payer population.

The dependent variable in the regression models was the logarithmic value of cost per case. Adjustment factors for continuous independent variables in the log form are their estimated coefficients. The academic health center indicator and the cardiac specialty hospital indicator are dummy variables that assume a value of zero or one. Thus, the adjustment factors for these two variables are exponentials of estimated coefficients. Although Lewin assumed no impact on costs for variables whose estimated coefficients are not statistically significant, we created adjustment factors for these variables. Table 12 presents adjustment factors for Medicare DSH, teaching intensity (the IRB ratio),

academic health center status, and cardiac specialty hospital status for All Cases and for specific conditions.

Table 12: Estimated Adjustment Factors

	All Cases		AMI Only		AMI with CABG		AMI with PCI	
	NIS	HCR	NIS	MedPAR	NIS	MedPAR	NIS	MedPAR
Medicare DSH	0.16*	0.00	-0.10*		0.03*		-0.06*	
Teaching Intensity (IRB)	0.23*	0.18	0.63*	0.56	0.04	0.33	-0.31	0.00
Academic Health Center	1.13	1.16	0.89	1.12	1.15	1.06	1.11	1.13
Cardiac Specialty Hospital			0.93	1.00	0.75*	0.91	0.89	1.00

	CABG w/o AMI		PCI w/o AMI		CAP	
	NIS	MedPAR	NIS	MedPAR	NIS	MedPAR
Medicare DSH	0.27*		0.17*		0.20*	
Teaching Intensity (IRB)	-0.10	0.14	-0.42	-0.38	0.15	0.00
Academic Health Center	1.09	1.13	1.11	1.15	1.17	1.13
Cardiac Specialty Hospital	0.74*	0.87	0.95	1.00		

Notes: Adjustment factors for the HCR and the MedPAR are based on Table 8 of the Lewin report. If a variable was not significant in the regression model, Lewin set the adjustment factor equal to zero (0.00); * significant at the 5% level for NIS adjustment factors.

Adjustment factors for AHC and cardiac specialty hospitals are very similar in the NIS and the HCR/MedPAR data. The adjustment factor for teaching intensity is similar for the NIS and HCR/MedPAR data for All Cases, for AMI only, and for PCI without AMI.

We use Lewin's example to compare an AHC (Hospital 1) to a non-teaching hospital (Hospital 2). The calculation used to derive the All Cases adjusted costs for Hospital 1 is:

$$\$7{,}200 / [(\text{Wage Index})^{0.597} * (1+\text{IRB ratio})^{0.234} * 1.127^{\text{AHC Indicator}}]$$
$$= \$7{,}200 / [(1.000)^{0.597} * (1.250)^{0.234} * 1.127^{1}]$$
$$= \$6{,}061$$

Table 13 presents adjusted costs using NIS adjustment factors and HCR/MedPAR adjustment factors. For both NIS and HCR/MedPAR data, the adjustment lowers the costs for AHC hospitals and brings them more into agreement with costs for non-AHC hospitals. For example, for All Cases, before the adjustment, case-mix adjusted costs for teaching and non-teaching hospitals were $1,200 ($7,200 - $6,000). After applying the adjustment factors, the costs of AHC hospitals become more consistent with costs for non-teaching hospitals ($6,061 vs. $6,000 for the NIS and $5,952 vs. $6,000 for the HCR). However, it is worth noting that with the exception of CAP discharges and AMI with CABG discharges, the cost difference between AHC and non-AHC facilities is higher when NIS adjustment factors are applied.

Table 13: An Example: Comparing Adjusted Cost per Case Derived from NIS Adjusted Factors and HCR/MedPAR Adjusted Factors

Hospital 1	Input Variables	All Cases	CAP	AMI only	AMI w/ CABG	AMI w/ PCI	CABG w/o AMI	PCI w/o AMI
Case-Adjusted Cost	$7,200							
Medicare Wage Index	1.0000	0.597	0.757	0.402	0.601	0.463	0.603	0.361
Intern- and Resident-to-Bed Ratio	0.2500	0.234	0.153	0.635	0.041	-0.308	-0.101	-0.417
=1 if Academic Health Center	1	1.127	1.174	0.890	1.150	1.110	1.090	1.105
=1 if Cardiac Specialty Hospital	0	1.000	1.000	0.933	0.753	0.892	0.744	0.946
Adjusted Cost per Case		$6,061	$5,925	$7,024	$6,202	$6,946	$6,758	$7,150
HCR/MedPAR Adjusted Cost per Case		$5,952	$6,389	$5,694	$6,298	$6,389	$6,192	$6,815

Hospital 2	Input Variables	All Cases	CAP	AMI only	AMI w/ CABG	AMI w/ PCI	CABG w/o AMI	PCI w/o AMI
Case-Adjusted Cost	$6,000							
Medicare Wage Index	1.0000	0.597	0.757	0.402	0.601	0.463	0.603	0.361
Intern- and Resident-to-Bed Ratio	0.0000	0.234	0.153	0.635	0.041	-0.308	-0.101	-0.417
=1 if Academic Health Center	0	1.127	1.174	3.006	1.150	1.110	1.090	1.105
=1 if Cardiac Specialty Hospital	0	1.000	1.000	1.151	0.753	0.892	0.744	0.946
Adjusted Cost per Case		$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000
HCR/MedPAR Adjusted Cost per Case		$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000
Hospital 1 - Adjusted Costs		$6,061	$5,925	$7,024	$6,202	$6,946	$6,758	$7,150
Hospital 2 - Adjusted Costs		$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000
Percent Difference		1.0%	-1.3%	17.1%	3.4%	15.8%	12.6%	19.2%
HCR/MedPAR Percent Difference		-0.8%	6.5%	-5.1%	5.0%	6.5%	3.2%	13.6%

Notes: HCR/MedPAR results are based on Table 10 of the Lewin report.

The adjustment factor for disproportionate share payment is not explicitly included in Table 13. In Table 14, we use a similar example but add the DSH adjustment factor to adjust costs per case for an AHC and a non-AHC hospital. We assumed that Hospital 1 has a DSH of 0.06, and Hospital 2 has no DSH. Because the Lewin report does not contain an example using the DSH adjustment factor, Table 14 only reports the adjusted costs based on NIS adjustment factors. The formula to derive All Cases adjusted costs for Hospital 1 is:

$$\$7{,}200 / [(\text{Wage Index})^{0.597} * (1+\text{IRB ratio})^{0.234} * 1.127^{\text{AHC Indicator}} * (1+\text{DSH})^{0.157}]$$
$$= \$7{,}200 / [(1.000)^{0.597} * (1.250)^{0.234} * 1.127^{1} * (1+0.06)^{0.157}]$$
$$= \$6{,}006$$

Table 14: An Example: Comparing Adjusted Cost per Case Derived from NIS Adjusted Factors including DSH

Hospital 1	Input Variables	All Cases	Pneu-monia	AMI only	AMI w/ CABG	AMI w/ PCI	CABG w/o AMI	PCI w/o AMI
Case-Adjusted Cost	$7,200							
Medicare Wage Index	1.0000	0.597	0.757	0.402	0.601	0.463	0.603	0.361
Intern- and Resident-to-bed Ratio	0.2500	0.234	0.153	0.635	0.041	-0.308	-0.101	-0.417
=1 if Academic Health Center	1	1.127	1.174	0.890	1.150	1.110	1.090	1.105
=1 if Cardiac Specialty Hospital	0	1.000	1.000	0.933	0.753	0.892	0.744	0.946
Disproportionate Share Payments	0.0600	0.157	0.201	-0.104	0.030	-0.057	0.268	0.167
Adjusted Cost per Case:		$6,006	$5,856	$7,067	$6,191	$6,969	$6,653	$7,081

Hospital 2	Input Variables	All Cases	Pneu-monia	AMI only	AMI w/ CABG	AMI w/ PCI	CABG w/o AMI	PCI w/o AMI
Case-Adjusted Cost	$6,000							
Medicare Wage Index	1.0000	0.597	0.757	0.402	0.601	0.463	0.603	0.361
Intern- and Resident-to-bed Ratio	0.0000	0.234	0.153	0.635	0.041	-0.308	-0.101	-0.417
=1 if Academic Health Center	0	1.127	1.174	3.006	1.150	1.110	1.090	1.105
=1 if Cardiac Specialty Hospital	0	1.000	1.000	0.933	0.753	0.892	0.744	0.946
Disproportionate Share Payments	0.0000	0.157	0.201	-0.104	0.030	-0.057	0.268	0.167
Adjusted Cost per Case:		$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000
Hospital 1 - Adjusted Costs		$6,006	$5,856	$7,067	$6,191	$6,969	$6,653	$7,081
Hospital 2 - Adjusted Costs		$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000
Percent Difference		0.1%	-2.4%	17.8%	3.2%	16.2%	10.9%	18.0%

IV. Discussion

The unadjusted estimated coefficients of NIS private payer, HCR, and MedPAR appear to be quite different. Some of the differences we observed in these models can be attributed to different patient samples: the HCR sample includes both commercial and Medicare data, the MedPAR file is limited to Medicare data, and the NIS sample used in this paper contains only private-payer data.

To adjust the bias resulting from the small sample of NIS hospitals, we fitted the same models using NIS all-payer discharges and NIS Medicare discharges, and then adjusted the NIS private-payer estimates for All Cases and specific conditions. Lewin has also revised MedPAR estimated coefficients so the results from the Medicare population-based models are applicable to an all-payer model. The revised NIS private-payer estimates are more consistent with HCR estimates and revised MedPAR estimates.

Although the differences between the NIS estimates and the HCR/MedPAR estimates become much smaller, they still remain after the adjustment. A possible explanation for the differences is that we employed different case-mix indexes. The case-mix index was higher in the HCR data and the MedPAR data than in the NIS data for All Cases and all specific conditions except PCI without AMI. To investigate the impact of a different case-mix index on hospital cost per case, we have also measured the case mix in NIS hospitals by all-payer severity-adjusted DRG charge weights. The resulting estimates were more different from the HCR/MedPAR estimates than the NIS estimates based on DRG weights.

The purpose of this study was to replicate the cost models developed by Lewin and to compare the coefficients generated from the various data sources. Testing alternative model specifications was beyond the scope of the present study. We utilized the same analytic variables that Lewin analysts used in their models, even though some of these variables may have a different impact on commercial payers as compared to Medicare payers. For example, Medicare outlier payment was included in all the models as an explanatory variable, but Medicare outlier payments might have a quite different effect on the commercial population. In addition, we did not investigate whether some of the independent variables might have had non-linear effects on the dependent variable, nor did we explore whether some of the independent variables might have had interactive effects (e.g., whether the effect of disproportionate share was different between urban and rural hospitals).

Despite this limitation linked to not testing alternative model specifications, it appears that the effects of some key variables are still substantially different between the NIS and the HCR/MedPAR data. For example, variables such as intern-to-bed ratio and disproportionate share still reveal important differences. However, other variables, such as indicators for academic health center and cardiac specialty hospital, suggest similar impacts on the various data sets.

In conclusion, this replication study suggests that mission adjustments are vital in hospital cost comparisons. The exact magnitude of the adjustment factors, however, deserves further study.