The Determinants of the Technical Efficiency of Acute Inpatient Care in Canada

Li Wang , *Michel Grignon* , *Sheril Perry*, *Xi-Kuan Chen* ,
Alison Ytsma, *Sara Allin* , and *Katerina Gapanenko*

Objective. To evaluate the technical efficiency of acute inpatient care at the pan-Canadian level and to explore the factors associated with inefficiency—why hospitals are not on their production frontier.

Data Sources/Study Setting. Canadian Management Information System (MIS) database (CMDB) and Discharge Abstract Database (DAD) for the fiscal year of 2012–2013.

Study Design. We use a nonparametric approach (data envelopment analysis) applied to three peer groups (teaching, large, and medium hospitals, focusing on their acute inpatient care only). The double bootstrap procedure (Simar and Wilson 2007) is adopted in the regression.

Data Collection/Extraction Methods. Information on inpatient episodes of care (number and quality of outcomes) was extracted from the DAD. The cost of the inpatient care was extracted from the CMDB.

Principal Findings. On average, acute hospitals in Canada are operating at about 75 percent efficiency, and this could thus potentially increase their level of outcomes (quantity and quality) by addressing inefficiencies. In some cases, such as for teaching hospitals, the factors significantly correlated with efficiency scores were not related to management but to the social composition of the caseload. In contrast, for large and medium nonteaching hospitals, efficiency related more to the ability to discharge patients to postacute care facilities. The efficiency of medium hospitals is also positively related to treating more clinically noncomplex patients.

Conclusions. The main drivers of efficiency of acute inpatient care vary by hospital peer groups. Thus, the results provide different policy and managerial implications for teaching, large, and medium hospitals to achieve efficiency gains.

Key Words. Technical efficiency, acute inpatient care, peer group, data envelopment analysis

Whether publicly or privately funded, hospitals in most health care systems are shielded from competition for sound normative reasons. As a result, they may be technically inefficient. In a public single-payer system such as Canada (90 percent of hospital spending is publicly funded and most are not-for-profit), where, moreover, hospitals are funded mostly through global budgets rather than activity-based funding, the main concern is that resources allocated to hospitals are not put to best use, thus increasing wait-times to access services or leading to overcrowding of hospitals (occupancy rates of Canadian hospitals are among the highest in the OECD). This is a crucial policy issue in Canada: Hospitals use the issues of wait-times and overcrowding to ask for substantial increases in funding (hospital spending fell from 45 percent of total health care spending in 1975 to 30 percent in the 2010s), while others use them to challenge the public monopoly on most procedures (several cases have been in discussion before provincial or federal Supreme courts). Provincial governments, who are responsible for funding and monitoring hospitals, want to keep rationing within a single-payer system and look for ways to decrease wait-times, for example, through shortening stays and reducing bed use for postacute care (Baker et al. 2004; Sutherland and Crump 2013), while keeping overcrowding and undesirable events such as nosocomial infections or mortality under control (Chan and Cochrane 2016). In other words, they want to know more about how to increase outputs for a given level of inputs in the hospital sector, which amounts to measuring technical inefficiency and, even more important, understanding the policy-amenable levers that explains why some hospitals are not on the frontier.

This policy issue is the main motivation for this study: How can a rationed hospital sector find ways to admit more cases while achieving a good level of quality per case treated? Another motivation for this study is to contribute the broader discussion on the determinants of hospital efficiency: Most of the international literature is concerned (and rightly so) with the role of ownership status (for profit vs. not-for-profit or not-only-for-profit, e.g., Ferreira and Marques 2015) and/or funding schemes (activity-based, global, or fee-for-service), but Canadian hospitals are homogenous along these two dimensions (provincial experiments with funding did not really start before

Address correspondence to Li Wang, Ph.D. candidate, McMaster University, 1280 Main Street West, Hamilton, ON, Canada L8S4L8; e-mail: wangl25@mcmaster.ca. Michel Grignon, Ph.D., is with the McMaster University, Hamilton, ON, Canada. Sheril Perry, Ph.D., is with the Canadian Institute for Health Information, Ottawa, ON, Canada. Xi-Kuan Chen, Ph.D., Alison Ytsma, B.Sc., Sara Allin, Ph.D., and Katerina Gapanenko, Ph.D., are with Canadian Institute for Health Information, Toronto, ON, Canada.

2012), and vary mostly in their environmental constraints such as size, population density, or availability of postacute home care or residential care, as described below. This study therefore explores two empirical questions: What is the overall level of efficiency of acute inpatient care in Canada? And what factors drive inefficiencies within the hospital sector?

It is often misleading to monitor efficiency in one specific component of the health care system in isolation, precisely because health care is a system and all components are articulated together. As a result, one component might appear efficient simply due to an ability to shift costs to another component within the system. However, inpatient acute care provides highly specialized health care services, most of which cannot really be shifted to other providers. Also, Abelson et al. (2017) showed that access to timely care when needed is a key objective of the Canadian health care system and acute care hospitals play a crucial role in timely access and, therefore, in the overall efficiency of the system. Last, hospitals have more ability than primary care providers to devote resources to management and leadership.

Canadian studies published so far have either treated Canada as one data point in an international comparison or been restricted to one or two provinces. Varabyova and Schreyögg (2013) used OECD countries to identify a production frontier of inpatient care and concluded that Canada was more efficient, with fewer beds per capita and shorter average stays, than comparable countries. A study of Quebec hospitals found that up to 17 percent of costs could be saved through improved efficiency (Bilodeau et al. 2004). Asmild, Hollingsworth, and Birch (2013) assess the differences in hospital performance between Ontario and New Brunswick over the years 1998–2004 and suggest that efficiency could be improved by between 4 and 11 percent in Ontario compared with between 34 and 48 percent in New Brunswick.

No consensus as to what drives efficiency in the hospital sector has been reached, mostly due to methodological differences (Hollingsworth 2008). The measurement of technical efficiency of hospitals is a cottage industry around the world, and we rely mostly on systematic reviews conducted at regular intervals (Hollingsworth, 2003; Erlandsen 2008; Hollingsworth and Peacock 2008; Rosko and Mutter 2008; O'Donnell and Nguyen 2011; Giancotti and Mauro 2015). A recent review of 200 studies conducted by O'Donnell and Nguyen (2011) identified a number of data problems that severely limit the validity of conclusions, specifically a lack of consistent definitions of costs and measures of quality. The same is true of Canadian studies of the drivers of efficiency. Appendix SA2 describes the main findings of Canadian studies, which can be summarized as follows: Hospital size, occupancy rate, case mix index, urbanity,

and teaching status have significant influences on hospital efficiency (Gruca and Nath 2001; Bilodeau, Crémieux, and Ouellette 2000; Bilodeau et al. 2004; Bilodeau, Cremieux, and Ouellette 2009; Chowdhury, Wodchis, and Laporte 2011; Asmild, Hollingsworth, and Birch 2013; Chowdhury and Zelenyuk 2016).

This study is the first to measure technical efficiency of Canadian hospitals from a pan-Canadian perspective instead of within a single province. Even though hospital care is a provincial responsibility in Canada, it is organized along the same lines (public funding, global budget, not-for-profit ownership) in all provinces. We use a unique database of hospital characteristics at the national level (assembled by CIHI) and exploit the variability of contexts yet homogeneity in ownership status and funding models across Canada's provinces and regions to contribute to the discussion on the determinants of hospital efficiency.

DATA

Our unit of observation is the hospital, and we use three data sources. First, information on inpatient episodes was extracted from the Discharge Abstract Database (DAD, a standardized set of information on hospital stays provided by hospitals and harmonized and made accessible by CIHI) for the fiscal year 2012–2013. We aggregated the information on episodes by hospital, producing a number of cases measured by resource intensity weight (RIW). Second, we used the Canadian Management Information System (MIS) database (CMDB) for the same fiscal year to construct our input variable (inpatient cost). The CMDB is updated annually by provincial and territorial governments and then sent to CIHI for standardization and quality checks, and it contains financial information at the hospital level across Canada (CIHI 2013). Last, we used publicly available hospital performance indicators (e.g., hospital standardized mortality ratio, readmission rates).

Our main analysis is based on data for fiscal year 2012–13, but we also ran the analyses on data from fiscal year 2013–14 as a robustness check of our findings.

Selection and Exclusion of Hospitals

There are just over 700 hospitals in Canada, but we excluded all hospitals operating in the province of Quebec and Nunavut territory, because, due to differences in the way they collect their financial CMDB data, they do not

have comparable input: The majority of hospital cost in these two jurisdictions does not cover the same perimeter as in the rest of the country. We therefore started with 576 hospitals.

We excluded 356 small hospitals because they do not really provide the same level of “care” as larger hospitals: Most of them provide some surveillance and then transfer complex patients to larger hospitals (Asmild, Hollingsworth, and Birch 2013; Rechel et al. 2016). The analysis of efficiency among small hospitals is the focus of a separate study (currently in progress). We also excluded another 41 hospitals that strongly concentrated on a specific type of care and do not offer the scope of treatments that most hospitals provide. We identified these hospitals using a Herfindahl–Hirschman index applied to the distribution of treatments provided by each hospital (OECD 2011). Overall, we excluded 397 hospitals, leaving 179 hospitals in the analysis, of which 35 were teaching hospitals, 54 large hospitals, and 90 medium hospitals. These 179 hospitals accounted for 84 percent of acute inpatient hospital costs and 94 percent of weighted cases discharged from hospitals in Canada outside of Quebec and Nunavut.

Peer Groups

We ran all analyses by hospital peer groups (teaching, large, medium). Teaching hospitals are identified as those with confirmed teaching status from the provincial ministry or as teaching in the provincial ministry’s submission to the CMDB. Nonteaching hospitals are assigned to a large, medium, or small hospital peer group based on their volumes and patient complexities, as described in Appendix SA3 (CIHI 2016d).

We conducted separate analyses by peer group to make sure that functionality and outputs are comparable across decision-making units (Newhouse 1994). Teaching hospitals are required to provide services that are not required of other hospitals. Large hospitals tend to provide a variety of highly specialized services that medium hospitals do not offer. Thus, a pooled frontier model estimated on all hospitals may be misleading (Gruca and Nath 2001). Hospitals within each of the three peer groups have similar case mixes and service-distribution characteristics, making it reasonable to assume they share a common production technology.

METHOD

Estimation of Efficiency Scores

Data Envelopment Analysis (DEA). In this study, we use a nonparametric approach known as DEA to estimate a production frontier and the distance of each hospital to the frontier. DEA is one of the two main methods used to estimate hospital technical or cost efficiency (Bilodeau, Cremieux, and Quélette 2009; Varabyova and Schreyögg 2013; Chowdhury and Zelenyuk 2016; Ferreira and Marques 2016a). The main advantage of the DEA approach in the present case is that it allows for the estimation of frontiers for multi-outputs; in the case of inpatient acute care, we want to account for the quality as well as the quantity of stays a hospital produces (see below, subsection “outputs”), because it reflects the dilemma governments face: How can we reduce wait-times without jeopardizing quality?

We apply an output orientation version of the DEA approach, which measures how more services could be produced with the same level of inputs. We assume variable returns to scale (increases in inputs do not result in proportional increases in outputs), which seems reasonable given diminishing returns in the hospital sector (Hollingsworth et al. 2003). A DEA on ratio data only would have to make the assumption of CRS, but, as we use here one scale-dependent ratio (number of stays) and one ratio (HSMR), VRS still applies (Hollingsworth and Smith 2003).

There are two drawbacks of the DEA. First, DEA scores are serially correlated; that is, the efficiency score for one hospital is not independent from the efficiency scores of other hospitals, which is problematic in the second-stage regression analysis of the contributions of various factors to inefficiency (Bowlin 1998; Felder and Tauchmann 2013). Second, it does not allow for a random component of efficiency. To address these drawbacks, we submit the initial DEA scores to a “smoothed bootstrap” method designed by Simar and Wilson (1998, 2007).

Outputs. Outputs are measured along two dimensions, quantity of stays and the quality of care. Quantity is measured as the number of discharges from acute care beds, weighed by the resource intensity weight (RIW) developed by CIHI, where each patient receives an RIW by the CMG+ methodology that groups patients by diagnoses and relative resource use and adjusts for the presence of comorbidities and interventions (CIHI 2017). RIWs can be further adjusted for special cases (long-stay outliers, transfers, death in the hospital, or sign-out cases) called

“atypical” weights (CIHI 2013). However, in our analysis we use “typical” RIW, which excludes the atypical cases because these adjustments provide resource for potentially inefficient care. As a robustness check, to ensure this choice did not drive our results, we ran a sensitivity analysis using the normal RIWs which include the atypical weights.

We exclude hospitalizations and costs for mental health and rehabilitation, because they are not reported and weighted in a consistent way across provinces. Our measure of the quantity of outputs is based on inpatient discharges and, as a result, excludes day surgery and outpatient care. Outpatient care is considered separate from inpatient stays for the following reasons: First, most outpatient care is funded separately from hospitals’ global budgets as specialists’ payments flow directly from governments on a fee-for-service basis; second, outpatient care data are collected separately from inpatient care data and these data are only available for all hospitals in two provinces (Ontario and Alberta). Through this exclusion, we are not able to assess the extent to which hospitals vary in their ability to substitute outpatient for inpatient care, and whether this affects the inpatient efficiency that we observe. However, we expect this exclusion to have a limited impact on the results, given the limited ability for hospitals to substitute highly specialized acute inpatient care with outpatient care. More of a concern is the exclusion of day surgery as it can substitute for inpatient elective surgery care when a new, less invasive technology becomes available (e.g., percutaneous coronary interventions). If some hospitals substitute more than others (likely as a result of clinical decisions made differently by different physicians), they will be unfairly seen as less efficient on the quantity dimension, even though they produce the same number of treatments using fewer resources. Evaluation of the CIHI data shows almost 90 percent of interventions that should happen in day surgery are occurring in that setting—meaning most hospitals are consistently performing less invasive procedures in the outpatient setting. As a result, hospitals performing more day surgery will not be overly disadvantaged by the exclusion of day surgery from our measure of output.

Number of stays is not the only output of a hospital. Hospitals are not only supposed to treat as many patients as they can, given the resources made available to them; they are also required to improve quality of care. Also, a trade-off between quantity and quality per stay is plausible, in the sense that resources allocated to quality improvement may prevent the hospital to admit more patients or that, in order to achieve a given level of

quality, the hospital might keep their patients a bit longer, but it does not increase their RIWs (McKay and Deily 2005; Valdmanis, Rosko, and Mutter 2008). There is no positive measure of quality of inpatient care available in Canada (such as patient satisfaction), but negative events are recorded and can give an idea of the effort a hospital puts into treating its patients: A hospital will achieve better quality if it reduces its in-hospital mortality measured by hospital standardized mortality ratio (HSMR), its rate of nosocomial events (such as in-hospital sepsis), or the proportion of patients who have to be readmitted after being discharged (CIHI, 2016c). Because DEA allows us to model several dimensions of output, we considered using several quality indicators as output, provided they pass three tests: (1) They were measured consistently across all hospitals in our sample, (2) they varied across hospitals (based on the coefficient of variation), and (3) the ratio of the variation in efficiency across hospitals due to the introduction of that particular dimension was not purely random (Badunenko, Henderson, and Kumbhakar 2012). Mortality after major surgery failed the first test. Readmission rate failed the second test, as the coefficient of variation across hospitals was smaller than 10 percent (Nairy and Rao 2003). In-hospital sepsis failed the third test, with a ratio of noise to total variance in efficiency of 92 percent. As a result, our only quality indicator for DEA available in the CIHI data source is the HSMR. As mortality is an undesirable outcome, we transform HSMR by taking the inverse ($1/\text{HSMR} \times 100$) in the DEA so as to ensure that, all other things being equal, increased outputs should increase efficiency (Jacobs, Smith, and Street 2006).

Inputs. There are three broad categories of inputs in the production of inpatient care (O'Donnell and Nguyen 2011): capital investments (buildings, beds, etc.), labor (nurses, support staff, etc.), and other operating expenses (food service, etc.) Labor inputs have various skill levels, and some hospitals rely more on labor and others on external providers, for example, for food; to measure the various labor skill levels and types of resources, we use dollar values of labor and other operating expenses aggregated into a broad category of operating costs. We exclude capital costs because they cannot be converted into yearly flows of expenditures. This latter exclusion is not too concerning because capital costs are small compared to operating expenses (CIHI 2016a).

In a robustness check analysis, we use total hospital expenditure (i.e., including capital investments) instead of inpatient only as our input variable to test that our methodological choice is not what drives the results.

Determination of Factors Explaining Hospital Efficiency

In the second stage of the analysis, we treat the robust efficiency scores from bootstrap as dependent variables and used a bootstrapped truncated regression analysis to identify factors associated with these scores. These factors are characteristics of the hospital or of its environment, either actionable ones (the hospital and/or the regulator can do something about it) or descriptors of the unequal or diverse situations that hospitals face. Starting from a long list of potential factors based on the literature, we dropped those that were redundant with variables already considered in the first stage, inputs and outputs to the DEA (e.g., mortality after major surgery); those for which no measure was available in Canada (e.g., technology intensity); and those that were not consistently measured (e.g., alternate level of care days). We were left with 15 potential determinants, and their summary statistics and the underlying assumption in efficiency analysis are presented in SA4 and SA7 of the Appendix, respectively.

Given the small number of observations (Draper and Smith 1998; Jung and Lee 2011), principal component analysis (PCA) is applied to selected independent variables to summarize the dimensions of the hospital efficiency (Child 1990). PCA is a data reduction technique, which transforms the original set of variables into a smaller set of uncorrelated factors (built as linear combinations of the initial variables) that accounts for most of the variation in the original dataset. At 0.7, the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy is classed as great for PCA. Bartlett’s test of sphericity $\chi^2 = 885.33$, $p < .001$, indicating the correlation between the explanatory variables was well defined for a PCA. A factor loading after oblimin rotation of 0.35 or above is used as an arbitrary value to designate a salient factor loading when interpreting the results of the exploratory analyses (Child 1990). The PCA is performed on STATA 14.0.

Finally, we program the double bootstrap following Algorithm #2 in Simar and Wilson (2007) to estimate the marginal effect of the determinants of the hospital efficiency. For the steps 1–4 in Algorithm #2, we use the “dea,” “trunc.reg,” and “rnorm.trunc” command in FEAR (Wilson 2008) to calculate the bias-corrected efficiency score with the bootstrap results based on the truncated empirical normal distribution. Next, the steps 5–7 of Algorithm #2 are performed on STATA and consist in regressing the bias-corrected technical efficiency scores over a set of components derived by the PCA using a bootstrapped truncated regression in order to obtain unbiased coefficients and standard error.

RESULTS

Summary of Hospitals, Inputs, and Outputs Data

There were variations across peer groups in terms of total weighted RIW, HSMR, and hospital expenditure on acute inpatient care (Table 1). There were approximately 32,000 weighted RIWs per hospital in teaching hospitals, 18,000 weighted RIWs in large, and 5,000 in medium hospitals. The HSMR ranged from 45 to 150 across hospitals. The average expenditure on the acute inpatient care per hospital was \$264.2 million in teaching hospitals, \$100.5 million in large, and \$25.3 million in medium hospitals.

Robust Efficiency Scores

Table 2 summarizes the distribution of estimated robust efficiency scores. Average efficiency is 0.76 for all hospitals together with a standard deviation of 0.12 (range from 0.40 to 0.96): This means that hospitals could treat 24 percent more patients on average if all hospitals operated at maximum efficiency at their given input level, without increasing mortality per stay (hospitals could also decrease mortality per stay by 24 percent without treating more cases, but this would not address payers’ concerns). Mean efficiency for teaching hospitals is 0.85, 0.78 for large hospitals, and 0.72 in medium hospitals.

Our results are robust to methodological choices or years of data:

When normal RIWs replace the typical RIWs, Kruskal–Wallis equality-of-populations rank test shows two sets of the technical efficiency scores of

Table 1: Summary Statistics of Inputs and Outputs by Hospital Peer Group

	<i>Teaching[†]</i>		<i>Large[†]</i>		<i>Medium[§]</i>	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
Input						
Inpatient cost ex. mental and rehabilitation care (100,000 [‡])	2,642	1,502	1,005	565	253	123
Output						
Case mixed RIW (100 [‡])	384	197	162	105	35	22
Hospital standardized mortality ratio	103	12	100	13	106	24

[†]Had confirmed teaching status from the provincial ministry; or were identified as teaching in the provincial ministry’s submission to the Canadian MIS Database.

[‡]Meet two of the following three criteria: ≥8,000 inpatient cases; ≥10,000 weighted cases; ≥50,000 inpatient days.

[§]Medium: Do not meet large community hospital criteria and ≥2,000 weighted cases.

Table 2: Summary Statistics of Bias-Corrected Efficiency Scores[†] by Hospital Peer Group

<i>Hospital Peer Group</i>	<i>N</i>	<i>Mean</i>	<i>SD</i>	<i>Range</i>	
				<i>Min.</i>	<i>Max.</i>
Teaching [‡]	35	0.846	0.085	0.652	0.962
Large [§]	54	0.785	0.106	0.57	0.961
Medium [¶]	90	0.717	0.127	0.405	0.938
All hospitals	179	0.763	0.123	0.405	0.962

[†]The estimation of the DEA efficiency scores using “smoothed bootstrap” method by Simar and Wilson (1998, 2007).

[‡]Had confirmed teaching status from the provincial ministry; or were identified as teaching in the provincial ministry’s submission to the Canadian MIS Database.

[§]Meet two of the following three criteria: $\geq 8,000$ inpatient cases; $\geq 10,000$ weighted cases; $\geq 50,000$ inpatient days.

[¶]Medium: Do not meet large community hospital criteria and $\geq 2,000$ weighted cases.

teaching hospitals are significantly different, but the difference for the large hospitals, $\chi^2(1) = 1.139$, $p = .28$ or medium hospitals $\chi^2(1) = 2.01$, $p = .16$. This indicates that the efficiency scores of teaching hospitals are sensitive to the atypical RIWs. It may be the fact that the teaching hospitals are more likely to treat more complex patients who may need very long stays. Using either total hospital cost or total inpatient cost instead of our measure of input generates qualitatively similar rankings of hospitals, and the Kruskal–Wallis test also indicates that these excluded components do not have a significant effect on the efficiency and ranking. Last, performing the analysis on data from 2013 to 2014 generates change one can expect: Hospitals do not stay at the exact same distance from the frontier but the distributions of efficiency scores produce similar hospital rankings. Kruskal–Wallis equality-of-populations rank test shows there is no significant difference in the two sets of the technical efficiency, $\chi^2(1) = 1.617$, $p = .20$.

The Determinants of the Technical Efficiency

The PCA identifies four components representing 76 percent of total variance of the full hospital data.

This is above the baseline parameter of 70 percent as recommended by Field (2009) and explains a significant amount of the original data. The first component is interpreted as a measure of advantaged hospital environments, because it is linked to more hospital beds, low proportion of rural patients,

Table 3: Determinants of Technical Efficiency (Double Bootstrap Regression) Using the Components from PCA

<i>Component</i>	<i>Description of the Components</i>	<i>Coefficient</i>	<i>Bootstrap SE</i>
Teaching hospital [†]			
Component 1	Advantaged environments	0.047***	0.011
Component 2	Higher proportion of noncomplex patients	0.013	0.01
Component 3	Health system cooperation and availability of postacute care	0.008	0.017
Component 4	Poor overall quality of care	0.014	0.012
<i>R</i> ²		52%	
Large hospital [‡]			
Component 1	Advantaged environments	0.027	0.017
Component 2	High proportion of noncomplex patients	0.036**	0.009
Component 3	Health system cooperation and availability of postacute care	0.03***	0.01
Component 4	Poor overall quality of care	0.003	0.009
<i>R</i> ²		65%	
Medium hospital [§]			
Component 1	Advantaged environments	0.03***	0.01
Component 2	Higher proportion of noncomplex patients	0.022***	0.007
Component 3	Health system cooperation and availability of postacute care	0.016**	0.007
Component 4	Poor overall quality of care	0.03	0.031
<i>R</i> ²		42%	

Notes: *** $p < .01$, ** $p < .05$, * $p < .1$
[†]Had confirmed teaching status from the provincial ministry; or were identified as teaching in the provincial ministry's submission to the Canadian MIS Database.
[‡]Meet two of the following three criteria: $\geq 8,000$ inpatient cases; $\geq 10,000$ weighted cases; $\geq 50,000$ inpatient days.
[§]Medium: Do not meet large community hospital criteria and $\geq 2,000$ weighted cases.

and more percentage of individuals with postsecondary education in the region where the hospital is located. The second principal component strongly correlates with the proportion of long-stay patients (negatively) and with maternity cases (positively), and it refers to a hospital with more noncomplex patients. The third component is positively linked to the percentage transferred to long-term care and transferred to home with support services, and it is interpreted as a measure of health system cooperation and availability of postacute care. The fourth component is linked to the percentage of elective surgery and having a major surgery (negatively), and overall readmission rate (positively), reflecting poor overall quality of treatment.

The double bootstrap truncated regressions on the teaching, large, and medium hospitals show the following results: Among teaching hospitals,

highly efficient teaching hospitals are associated with advantaged environments. With respect to the large hospitals, increasing the proportion of non-complex patients is associated with improved hospital technical efficiency. Increasing cooperation within the health system and the availability of post-acute care beds is associated with improved efficiency for both large and medium hospitals. The medium hospitals, with advantaged environment and higher proportion of noncomplex patients, are also more likely to achieve higher technical efficiency.

The regression models explain 52, 65, and 42 percent of variance in teaching, large, and medium hospitals, respectively, indicating substantial idiosyncratic variation in hospital management, as our CIHI database allows us to capture most of the observable variation in hospital environment and management.

DISCUSSION

This study is the first to investigate the technical efficiency of acute inpatient care at the pan-Canadian level. It contributes to the literature on assessing hospital efficiency by incorporating a quality of care metric into the specification of the output. Hospitals are not only supposed to process patients but also to restore health in the process. The number of discharges from acute care beds is the intermediate output of a hospital. The ultimate outcome of the hospital process is health improvement, which depends on the quality of the intermediate outputs. Some articles treat quality as a factor affecting efficiency rather than an output (Zuckerman, Hadley, and Iezzoni 1994; Jacobs 2001). Others estimate quality efficiency and quantity efficiency separately (Nayar and Ozcan 2008). The former excludes quality of care from the production function, and the latter ignores the trade-off between quantity and quality per stay (McKay and Deily 2005; Valdimanis, Rosko, and Mutter 2008). In our study, we included HSMR as an output in the production function. Other quality indicators, such as the overall readmission rate and in-hospital sepsis rate, enter the explanatory regression analysis on the hospital efficiency. This approach allows us to estimate potential gains in both quality and quantity of care when a hospital achieves its efficiency.

One strength is that we analyze efficiency by hospital peer groups. Each group has its production technology: Teaching hospitals provide care for the most-complex patients and adopt new technologies and treatments sooner than nonteaching hospitals (Shahian et al. 2012), or around 20 percent of

medium hospitals in Canada do not perform major surgery, such as hip replacement. It is reasonable for a hospital to learn and improve from being benchmarked against the best-performing hospitals from their own peers.

Another strength is that we considered a wide array of factors of efficiency, covering organization, management, demographics, and patient characteristics, using PCA to summarize, instead of ad hoc selection or stepwise regressions (Grafen and Hails 2002). Therefore, we can provide actionable recommendations to hospital and health system leaders to achieve greater efficiency. Specifically, among teaching hospitals, the social composition of the caseload (e.g., rural vs. urban patients) is a key driver of efficiency, suggesting that provinces should redistribute resources toward those teaching hospitals treating more rural patients. Simultaneously, teaching hospitals could receive help and resources to develop care plans across the continuum of health care or provide remote care for patients from rural areas so as to be able to discharge them sooner. The main driver of efficiency among large and medium nonteaching hospitals is their ability to discharge patients to postacute care facility; this, again, suggests action from provinces, in increasing the number of postacute care beds and personnel, but also on the ground to develop links between acute care hospitals and these facilities, as well as procedures to smooth the transition (e.g., discharges on weekends). Last, medium hospitals could improve their efficiency by transferring out more complex cases (to large and teaching hospitals) and concentrating on cases such as maternity.

Our conclusions are robust and indicative of the main determinants of efficiency among Canadian hospitals. We now briefly outline what remains to be done in this area of inquiry:

First, we approach the output of hospitals by the number of discharges weighted by resources used. Ideally, however, the value of a hospital stay should be based on the value of the cure, rather than the resources put into it. The value of a cure is the difference between the health-related quality of life of the patient before and after the cure, and it does not always reflect the resources used in the treatment. One option to measure activity based on value for the patient is to use quality-adjusted life-years (QALYs). However, this method raises several issues, mostly of practicality.

The main issue in using resources to measure value is that hospitals using more low-resource options are penalized. Statistics Canada weighted hospital activities based on their value to patients: They assigned the same RIW to both inpatient and outpatient activities within the same case mix group (Gu and Morin 2014). This is one option, but it assumes implicitly that hospitals are always free to decide to go outpatient. If they are not, and can

only outpatient milder cases, assigning the same RIW to outpatient and inpatient visits will penalize hospitals with more severe cases. The effect of outpatient care on the overall hospital efficiency is needed to be considered in the future.

Another limitation of our study is that HSMR is the sole indicator of quality of care. HSMR is an important component of the hospital output, but patient-reported outcomes and patient-reported experience would be interesting to add, once available.

Last, we excluded capital costs. Even though the sensitive analysis shows the capital cost does not influence the efficiency significantly, they might change efficiency at the margin. In addition, the exclusion of capital expenditures means that we do not distinguish between technologically innovative and more traditional hospitals and miss the effect of investment on efficiency (Valdmanis, Rosko, and Mutter 2008; Chowdhury et al., 2011).

CONCLUSION

The cross-sectional analysis of the hospital sector production efficiency in Canada using nonparametric DEA approach reveals that on average, in Canada, acute hospital care output could be increased by 24 percent with the same resources by eliminating inefficiency. Our analysis shows the following factors have positive influences on the technical efficiency of a hospital: more clinically noncomplex patients, effective health system cooperation and availability of postacute services, and advantaged hospital environments.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the supporting information tab for this article:

Appendix SA1: Author Matrix.

Appendix SA2: Selected Canadian Studies in the Hospital Efficiency.

Appendix SA3: Hospital Peer Groups.

Appendix SA4: Glossary of Terms.

Appendix SA5: Summary Statistics of the Potential Determinants of the Hospital Efficiency by Hospital Peer Group.

Appendix SA6: Rotate Factor Loading from the PCA by Hospital Peer Group.

Appendix SA7: The Underlying Assumption of Each Potential Determinant in Efficiency Analysis.