

# Association between costs and quality of acute myocardial infarction care hospitals under the Korea National Health Insurance program

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## Abstract

If cost reductions produce a cost–quality trade-off, healthcare policy makers need to be more circumspect about the use of cost-effective initiatives. Additional empirical evidence about the relationship between cost and quality is needed to design a value-based payment system. We examined the association between cost and quality performances for acute myocardial infarction (AMI) care at the hospital level.

In 2008, this cross-sectional study examined 69 hospitals with 6599 patients hospitalized under the Korea National Health Insurance (KNHI) program. We separately estimated hospital-specific effects on cost and quality using the fixed effect models adjusting for average patient risk. The analysis examined the association between the estimated hospital effects against the treatment cost and quality. All hospitals were distributed over the 4 cost × quality quadrants rather than concentrated in only the trade-off quadrants (i.e., above-average cost and above-average quality, below-average cost and below-average quality). We found no significant trade-off between cost and quality among hospitals providing AMI care in Korea.

Our results further contribute to formulating a rationale for value-based hospital-level incentive programs by supporting the necessity of different approaches depending on the quality location of a hospital in these 4 quadrants.

**Abbreviations:** AMI = acute myocardial infarction, AR = artificial respiration, CABG = coronary artery bypass grafting, CI = confidence interval, CPR = cardiopulmonary resuscitation, CVD = cerebrovascular disease, DRG = Diagnosis-Related Groups, HIRA = Health Insurance Review & Assessment, ICU = intensive care unit, KNHI = Korea National Health Insurance, LMCA = left main coronary artery, OR = odds ratio, p4p = pay-for-performance, PCI = percutaneous coronary intervention, SD = standard deviation.

**Keywords:** cost-effectiveness, hospital cost, quality, value-based incentive program

## 1. Introduction

Most countries with public health insurance based on fee-for-service have introduced cost-containment measures to curb rising healthcare expenditures.<sup>[1,2]</sup> In many cases, cost-containment policies focused primarily on cost measures.<sup>[1–3]</sup> As more appropriate and reliable measures of the care quality have been developed, some healthcare systems started to introduce incentive programs that consider costs and quality simultaneously.<sup>[2,4,5]</sup>

This approach continues to be at the center of discussions about healthcare policies, aiming at reducing healthcare costs without compromising quality. One of the critical issues there concerns the relationship between costs and health outcomes. Pioneering studies have reported contradictory results, with the major concerns related to the cost–quality trade-off (if there is a choice between minimizing costs and maximizing quality, there is a cost/quality trade-off).<sup>[2,5–14]</sup> If cost reduction compromises quality, healthcare policy makers need to be more circumspect about the use of cost-effective initiatives.

Recently, the relationship between inefficient spending and adverse outcomes has become the focus of efforts to formulate and implement realistic policies.<sup>[6–10]</sup>

In this context, Hvenegaard et al<sup>[2]</sup> found a U-shaped relationship between net costs and quality, indicating that net costs are differentially associated with levels of quality when net costs are calculated as the sum of the costs associated with adverse events and the costs invested for providing quality services.<sup>[2]</sup> Thus, the link between costs and health outcomes may depend on the specifics of the process which healthcare is delivered to the patient by the hospital.<sup>[7,8]</sup> Hospitals can choose between better quality and lower costs when making initial quality-related decisions. This is not a desirable choice; caretakers would prefer to have better quality with lower costs, or at least a proper balance between the 2. Thus, additional reliable empirical evidence regarding the relationship between costs and quality is needed to understand the implications of measuring value-based performance and to develop realistic policies in this regard.

This study examined the association between costs and quality performances among acute myocardial infarction (AMI) care hospitals, which were subjects of an existing pay-for-quality

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program sponsored by the Korea National Health Insurance (KNHI) program.

## 2. Methods

### 2.1. Study setting

In an effort to improve the quality of healthcare, the KNHI has initiated a national pay-for-performance (p4p) system that financially rewards healthcare institutions that show considerable improvement in the quality of care. It started with 43 tertiary hospitals providing secondary care services for 2 important conditions: AMI and Caesarian deliveries in 2007.<sup>[15,16]</sup> The KNHI classifies healthcare institutions according to number of beds as general hospitals (more than 99 beds), hospitals (30–99 beds), and clinics (fewer than 30 beds). Tertiary general hospitals are general hospitals that meet the standards for teaching hospitals and some additional requirements.<sup>[17]</sup> Health Insurance Review & Assessment Service (HIRA), a public agency which is responsible to assess the appropriateness of services provided by healthcare institutions under the KNHI program, assess the quality improvement of each institution for p4p system. The target was extended to general hospitals in 2011. Since then, HIRA has expanded its efforts to change the p4p system from “pay for quality” to “pay for value” which is to give more financial reward to hospitals showing both lower costs and better quality not just better quality. Our study was approved by the Institutional Review Boards of the Health Insurance Review and Assessment Service.

### 2.2. Construction of cost and quality performance measures

Typically, there have been 2 challenges to analyzing the relationship between cost and quality at the hospital level. First, some studies have encountered the problem of the potential endogeneity of quality with respect to costs, which is inherently difficult to solve.<sup>[2,6,8]</sup> Second, a hospital-level analysis raises the probability that the treatment processes in different hospitals are not strictly comparable owing to case-mix heterogeneity.<sup>[8,12]</sup>

Initial studies exploring the relationship between costs and quality have used a 2-stage model that estimated a cost inefficiency as the residual in the cost function and then measured the relationship in terms of a *beta* coefficient of the residual, which was included in a multivariate model adjusting for the effect of risk factors on quality.<sup>[6,8,9,13]</sup> In relation to hospital treatment, quality was measured primarily in terms of mortality, readmission, and disease-specific complications.<sup>[6–14]</sup>

Hospital level cost has also been estimated using the economic construct of allocative efficiency, relying on “best practices” and peer grouping using Data Envelop Analysis (DEA) and Pareto efficiency.<sup>[9,13,14]</sup> Some studies have tried to use instrumental variables to avoid the endogeneity issue.<sup>[8]</sup> However, this approach was not adopted in the present study because we were unable to find appropriate instruments.

Recent studies have proposed more sophisticated statistical methods for standardizing heterogeneity in the type of patients treated and in the process of providing care because the health outcomes experienced by patients are not determined solely by the efforts and skills of the healthcare team but are also affected by the nature of the disease and the risk of the patient.<sup>[12]</sup> These new methods attempt to measure hospital errors during service delivery, defined as inefficiency, by controlling for stochastic patient factors.<sup>[8]</sup> These studies have suggested multilevel

multivariate model or stochastic frontier analysis (SFA) as an economic approach.<sup>[2,7,8]</sup> Multilevel models consider clustering patients within hospitals and use patient-level measures for costs, outcome, and comorbidity by taking the form of a standard panel data model to overcome problems associated with aggregate measures.<sup>[6]</sup>

To avoid problems of endogeneity and case-mix heterogeneity, Hvenegaard et al<sup>[2]</sup> proposed a method of analyzing cost and quality separately using a fixed-effect model commonly applied to account for unobservable hospital-specific individual effects.<sup>[2,14]</sup> Based on the approach developed by Hvenegaard et al,<sup>[2]</sup> we were able to specify a linear and logistic fixed effect models for cost (1) and quality outcome (2) after accounting for the same line of risk factors for each model.<sup>[2,12,14]</sup>

$$C_{ij} = \beta_0 + \alpha_j + \beta X_{ij} + v_{ij}, \quad \sum_j \alpha_j = 0 \quad (1)$$

where  $C_{ij}$  is the cost of patient  $i$  in hospital  $j$ .  $\beta_0$  is an intercept and  $X_{ij}$  is a vector of risk adjustment factors. The model has a hospital-specific constant (a fixed effect),  $\alpha_j$  containing unobserved average characteristics of patients and characteristics of the hospital in which the patient was treated. The error term  $v_{ij}$  captures unobserved characteristics of individual patients.<sup>[2]</sup> Hospital cost effect ( $\alpha_j$ ) is defined more generally as the difference between observed hospital cost ( $\bar{c}_j$ ) and expected hospital cost ( $E(\bar{c}_j | \alpha, \beta, \bar{X}_j)$ ), where expectation is formed using only risk-adjustment factors and not hospital information.<sup>[2]</sup> The hospital cost effects would be positive if hospitals had higher costs than expected.

Given that the quality measures as mortality (death 1, survival 0) are binomial, we therefore specify a logistic regression model for quality outcomes (2).<sup>[2]</sup>

$$q_{ij} = 1(\gamma_j + \delta X_{ij} + \varepsilon_{ij} > 0), \quad \sum_j \gamma_j = 0 \quad (2)$$

where  $q_{ij}$  is the quality outcome for patient  $i$  in hospital  $j$  and  $1()$  is the indicator function.  $X$  is the same vector of risk adjustment factors as for costs.  $\gamma_j$  is a hospital-specific constant, and the error term  $\varepsilon_{ij}$  captures the unexplained variation in patient quality. The  $\gamma_j$  term refers to a hospital quality effect in the same sense as does  $\alpha_j$  in the cost equation. However, as they were measured on a logistic scale, we converted  $\gamma_j$  back to a probability of dying within 30 days and adjusted the effect to yield the difference between observed and expected quality based on Hvenegaard et al.<sup>[2]</sup>

As the overall mean predicted quality does not correspond to overall mean observed quality in logistic models, we adjust the effect to ensure that the hospital quality effect is still measured relatively to an overall zero mean (3).<sup>[2]</sup> The model is described in more detail in Hvenegaard et al.<sup>[2]</sup>

$$\hat{\mu}_j = \bar{q}_j - \hat{E}(\bar{q}_j | X_{ij}) - [\bar{q} - \hat{E}(\bar{q} | X_{ij})],$$

$$\hat{E}(\bar{q}_j | \delta, X_{ij}) = \sum_{i=1}^{n_j} \frac{e^{\delta X_{ij}}}{1 + e^{\delta X_{ij}}} \quad (3)$$

We viewed predictions of the fixed unknown parameters ( $\alpha_j, \hat{\mu}_j$ ) as hospital performance measures. Finally, we plotted those hospital-specific effects into a diagram according to the cost performance (on the  $y$ -axis) and the quality performance (on the  $x$ -axis). All hospitals were distributed across all 4 quadrants (Fig. 1). It is analogous to a cost-effectiveness plane to place each hospital in 1 of 4 quadrants. Hospitals of the northeastern are

providing AMI care at higher quality but at higher than average costs. Meanwhile, hospitals of southeastern hospitals are providing at higher quality with lower costs.

We analyzed fixed intercept linear or logistic models to estimate hospital-specific intercepts which are treated as fixed, unknown parameter  $\alpha_j(\hat{\mu}_j)$  on cost and quality using xtreg or xtlogit of STATA 13. A significant Housman test was in favor of a fixed effect model for cost ( $X^2=41.3, P<.001$ ) but was not for 30-day mortality ( $X^2=15.82$ ). We used fixed effect model also for 30-day mortality because our study is to provide explicit estimates of the hospital effects and the predication of hospital-specific fixed effects is unbiased even if risk adjustments factors,  $X$ , and the hospital effects are correlated  $\alpha_j$ .<sup>[2]</sup>

**2.3. Study data and variables**

This study used the data which HIRA had constructed to assess quality of AMI care of the year 2008 under the national p4p program. The HIRA extracted the claims of patients who were hospitalized in general hospitals or tertiary general hospitals via the emergency room with ICD-10 primary or secondary diagnoses of I21.0 to I21.9 during the year 2008 from KNHI claims submitted to the HIRA until the end of March 2009. The claims of tertiary general hospitals were collected only for the second half of 2008, but those of general hospitals were collected for all of 2008, as these facilities treated fewer patients with the relevant diagnoses than did tertiary general hospitals. All claims submitted within a single day were combined into an inpatient episode. Patients who suffered from AMI episodes who were younger than 18 years of age, those admitted during pregnancy, childbirth, or the puerperium (MDC 14), and those who suffered from HIV infection (V103), metastatic cancer (C77-79), or heart or lung implants (V087, V088) were excluded. The HIRA confirmed the diagnosis of AMI and created a quality-assessment database by collecting medical records and additional information from care institutions. We used data from 11,656 AMI episodes in general hospitals and tertiary general hospitals that had been confirmed in a quality assessment as of 2008. We excluded patients suffering from additional episodes (3893) who were transferred from or to other institutions; cost outliers (408),

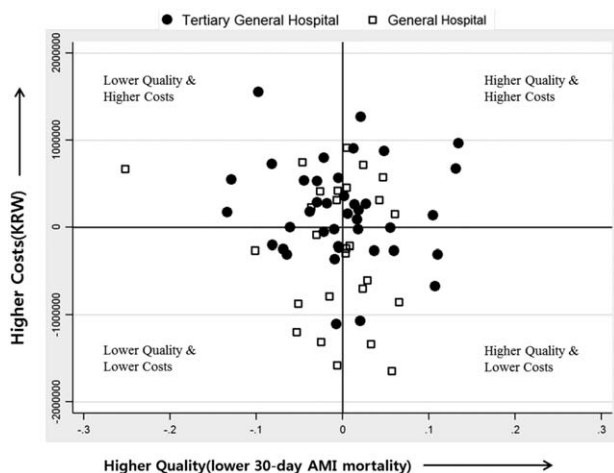
defined as more than 2 SDs from the mean medical cost per episode by DRG (Diagnosis-Related Groups); and episodes (756) in hospitals with fewer than 30 cases. The final analysis included data from 69 hospitals that treated 6599 episodes: 40 tertiary general hospitals accounted for 4957 episodes, and 29 general hospitals accounted for 1642 episodes.

The dependent variables for the cost and quality fixed-effect model were the medical costs per episode and 30-day postadmission deaths (1: death, 0: live). The medical costs were the total amount claimed for services provided to study subjects (episodes); these included procedures, therapies, and medications for patients who were hospitalized via the emergency room due to AMI, but costs not covered under the KNHI were excluded. Costs were standardized to adjust for differences in the KNHI fee schedule for the same procedure between tertiary general and general hospitals.

To estimate hospital-specific fixed effects, we controlled for the general characteristics of patients, including risk factors, severity-related variables, and comorbidities, which a review of previous studies and bivariate analysis identified as significant or interesting variables within the scope of HIRA quality assessment data. We controlled for the following general characteristics: age (<60, ≥60), sex (male, female), insurance type (Medicare, Medicaid), and intensive care unit (ICU) days (>3 days or 0).<sup>[2,6,12,18]</sup>

The severity-related variables were AMI history, which was confirmed by reviewing claims data for the year before hospitalization; occlusion of the left main coronary artery (LMCA) (yes, no, and no report); and procedures during hospital stay, including surgery (coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI, if performed more than once = yes); artificial respiration (AR; if performed more than once = yes); and cardiopulmonary resuscitation (CPR; if performed more than once = yes) to adjust for heart attack severity.<sup>[8]</sup> A previous study reported that LMCA was a rare but serious condition that was associated with a very high mortality rate due to massive AMI.<sup>[19]</sup> The occurrence of LMCA was confirmed by survey information. Performance of more surgical procedures may reflect more severe or critical situations.<sup>[8,19,20]</sup>

Comorbid conditions including diabetes (yes, no), hypertension (yes, no), cerebrovascular disease (CVD; yes, no), and cancer (yes, no) were confirmed by reviewing all claims for the year before hospitalization.<sup>[2,6,12,18]</sup>



**Figure 1.** Association between cost and quality performance of acute myocardial infarction (AMI) care hospitals.

**3. Results**

Table 1 presents the general characteristics and case mix of study hospitals. Forty of the 44 tertiary general hospitals in Korea in 2008 were included in our study. These accounted for more than half the study hospitals. An average of 3.7% of patients admitted for an AMI in the study hospitals had a previous history of AMI, and 62.7% had comorbid hypertension.

Table 2 shows results of fixed-intercept model for cost and quality. The cost per episode was significantly higher for patients who were older than 60 years of age, treated in the ICU for more than 3 days, had AMI history, had LMCA, received AR or CPR, received CABG or PCI, or had comorbid diabetes. In terms of 30-day mortality rates, the odds of death were higher for patients who were older than 60, female, had LMCA or no report about it, received AR or CPR, or had comorbid CVD.

Figure 1 presents scatter plot of the hospital cost and quality performance according to cost (on the y-axis) and quality (on the

**Table 1**  
**Characteristics of study hospitals (n = 69).**

Variable	Description	N (%)	Mean (SD)	Mean % (SD)
General characteristics				
Hospital type	Tertiary general hospital	40 (58.0)		
	General hospital	29 (42.0)		
Location	Capital area	33 (47.8)		
	Other	36 (52.2)		
Cost (observed)	Cost per episode (1000 WON, KRW)		6,636 (939)	
30-day mortality	Death within 30 days of admission, %		8.2 (5.0)	
Patient volume	Average number of AMI episodes		96 (61.1)	
Hospitals' AMI patient case mix				
Age	Dummy of 1 if the patient is 60 or older			59.3 (8.7)
Sex	Dummy of 1 if the patient is male			71.2 (7.1)
Insurance type	Dummy of 1 if the patient is covered by Medical aid			7.0 (4.6)
ICU >3 days	Dummy of 1 if the patient is treated in intensive care for more than 3 days			8.5 (10.1)
AMI history	Dummy of 1 if the patient has history			3.7 (12.5)
Left main	Dummy of 1 if the patient has LMCA			8.2 (9.3)
Surgery	Dummy of 1 if the patient received CABG or PCI			2.2 (2.9)
AR	Dummy of 1 if the patient received AR			10.7 (4.3)
CPR	Dummy of 1 if the patient received CPR			7.1 (4.4)
Diabetes	Dummy of 1 if the patient had type 1 or 2 diabetes			31.7 (8.9)
Hypertension	Dummy of 1 if the patient had hypertension			62.7 (11.6)
CVD	Dummy of 1 if the patient had cerebrovascular disease			11.2 (5.3)
Cancer	Dummy of 1 if the patient had cancer			10.6 (3.8)

AMI = acute myocardial infarction, AR = artificial respiration, CABG = coronary artery bypass grafting, CPR = cardiopulmonary resuscitation, CVD = cerebrovascular disease, ICU = intensive care unit, LMCA = left main coronary artery, PCI = percutaneous coronary intervention, SD = standard deviation.

x-axis). The upper left quadrant contains hospitals providing care above-average costs at below-average quality. The upper right and lower left quadrants contain hospitals with trade-offs. According to Fig. 1, the hospitals are dispersed in the 4 quadrants rather evenly and not concentrated in the trade-off (above-average or below-average hospital effects on both cost and quality) quadrants. Tertiary general hospitals tended to have higher costs compared with general hospitals. However, we found no significant difference in the relationship between cost and quality in relation to type of hospital.

#### 4. Discussion

We found no significant evidence of a trade-off relationship between cost and quality in Korean hospitals providing treatment for AMI. These data support the use of different approaches depending on the location of each hospital in different quadrants.

The relationship between quality improvement and cost reduction is complex, and it is not yet clear whether these 2 goals are complementary or in competition with one another.<sup>[16,17]</sup> One continuing policy concern is whether efforts to control costs could lead to worsened health outcomes. Healthcare providers have criticized rigid cost-containment measures based on this argument. However, a relationship between cost efficiency and quality (i.e., that cost inefficiency could decrease mortality rates) has also been reported.<sup>[9,10]</sup> These studies tested the hypothesis that eliminating primarily wasteful costs rather than simply reducing costs would improve health outcomes. In recent years, healthcare policy makers have been trying to enhance quality without an overall increase in costs or to reduce or mitigate costs without reducing quality by reducing unnecessary costs or cost inefficiency.<sup>[3,9,10]</sup>

In this study, all hospitals were not only in the trade-off quadrant (of higher quality and higher costs). It is reflecting the absence of a linear relationship between costs and quality. When

hospitals are ranked according to cost-effectiveness rather than cost minimization (or quality maximization), it produces a different ordering of hospitals. And it should be acknowledged that ranking according to relative cost-effectiveness implies that the aim is to minimize the cost per unit of quality produced. Therefore, in the case that other objectives are pursued, a different approach depending on the quality of the hospital in these 4 quadrants should be applied.

Linking reimbursement rates to value-based performance while simultaneously considering costs and quality may be a promising approach to overcoming the trade-off between costs and outcomes.<sup>[6]</sup>

This study directly examined the association between the costs and quality for the study hospitals and our results may have certain value to formulating better healthcare policies.

Our focus on AMI has several important advantages with regard to investigating the relationship between costs and outcomes. First, as AMI requires immediate medical attention, medical cares are more homogeneous than they are for other conditions. Second, the incidence of AMI is high, and it is the leading cause of death in elderly individuals, resulting in a substantial number of hospital cases. Third, it was shown that high quality hospitals generally achieve substantially lower mortality rates.<sup>[6,21]</sup>

Hospital-specific intercepts on cost and quality using multilevel modeling may increase the validity of measures of a hospital's ability to improve quality and control costs while avoiding problems related endogeneity and case-mix heterogeneity. As our analysis included most hospitals in Korea, we had a sufficient number of AMI cases to produce reliable measurements relevant to the KNHI program.

Meanwhile, the estimated fixed effect still could capture partly unobserved patient characteristics and other factors beyond the control of the hospitals.<sup>[2]</sup> However, the fixed effect estimate seems to be the more objective and intuitive information for

**Table 2**  
**Results of fixed-intercept models for cost and quality.**

	Medical costs (KRW1) <sup>†</sup>		30-day mortality (death = 1)	
	Coefficient	95% CI	OR	95% CI
Age				
≥60	212,579**	52,665 to 372,493	3.86***	2.61–5.70
<60				
Sex				
Male	57,382	–111,114 to 225,877	0.57***	0.43–0.75
Female				
Insurance				
NHI	275,859	–1,339 to 553,057	1.25	0.78–2.00
Medical aid				
ICU stay				
>3 days	1,210,741***	957,756 to 1,463,725	0.71	0.46–1.07
≤3 days				
AMI history				
Yes	496,915*	43,616 to –950,214	0.49*	0.24–0.99
No				
Left main				
Yes				
No	–440,870**	–734,252 to –147,488	0.37***	0.25–0.57
No report	–4,908,471**	–5,288,329 to –4,528,612	3.64***	2.26–5.86
Surgery				
CABG or PCI	7,783,497***	7,237,703 to 8,329,290	0.52	0.26–1.02
No				
AR				
Yes	2,447,005***	2,149,514 to 2,744,497	7.10***	5.21–9.68
No				
CPR				
Yes	369,468*	43,551 to 695,386	38.96***	27.85–54.51
No				
Comorbidity				
Diabetes				
Yes	310,738***	154,484 to 466,992	1.26	0.96–1.65
No				
Hypertension				
Yes	–42,816	–198,162 to 112,530	1.13	0.84–1.53
No				
CVD				
Yes	210,070	–18,612 to 438,752	1.70**	1.21–2.39
No				
Cancer				
Yes	–390,852**	–621,990 to –159,715	0.75	0.51–1.11
No				
Constant	6,373,758***	5,935,258 to 6,812,259		
Heterogeneity between hospitals <sup>‡</sup>	$F(686,516) = 3.75^{***}, \sqrt{\psi} = 675, 326, \rho = 0.051$		Log likelihood = –922.6***, $\psi = 0.11, \rho = 0.034$	
Observations				
No. of hospitals	69		67	
No. of episodes	6,599		6,514	

95% CI = 95% confidence interval, AMI = acute myocardial infarction, AR = artificial respiration, CABG = coronary artery bypass grafting, CI = confidence interval, CPR = cardiopulmonary resuscitation, CVD = cerebrovascular disease, ICU = intensive care unit, NHI = National Health Insurance, OR = odds ratio, PCI = percutaneous coronary intervention.

\*  $P < .05$ .

\*\*  $P < .01$ .

\*\*\*  $P < .001$ .

<sup>†</sup> 1 USD = 1,156.25 KRW as of 2010 (average basic rate of exchange).

<sup>‡</sup> F test that all  $u_{ij} = 0$  in fixed intercept model for costs and likelihood ratio test of  $\rho = 0$  in random intercept model for death.

policy makers to compare hospitals’ relative performance giving care at better quality and lower cost for AMI patients after adjusting for average patient risk.

**5. Conclusion**

This study found no evidence of a trade-off relationship between costs and quality in Korean hospitals providing care for AMI and

demonstrated an implication of taking quality into account when comparing efficiency that it alters the ranking of the hospitals. These results provide a rational foundation for the establishment of value-based hospital-level incentive programs by supporting different approaches depending on the location of a hospital in these 4 quadrants. This framework may manage healthcare expenditures more efficiently by reducing wasteful costs and improving quality on the national level.

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