Appendix To:

Hospital Allocation and Racial Disparities in Health Care

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A Performance Measurement

Our main dataset is developed from 100% Research Identifiable Files (RIFs). Specifically, we use inpatient stays form the MEDPAR file and capture patient enrollment status and demographic factors from the Denominator and Master Beneficiary Summary Files from 1995-2014. We identify patients admitted to a hospital with AMI as MEDPAR records with a principal ICD-9 diagnosis code of 410, 410.X, 410.X0 - 410.X1, 410.X3-410.X9. Patients must be at least age 66 and carry full FFS (not Medicare Advantage) Part A and B coverage during the year prior to admission and up to one year following admission or death, whichever comes first. Only short-term acute care and critical access hospitals are included. Stays which were preceded by an AMI stay by the same patient in the year prior are omitted. As noted in the main text, we call the hospitalizations that satisfy these criteria index events.

Hospital performance is given by our estimates of risk-adjusted survival, which we define by estimating the following equation period-by-period:

$$s_{iht} = \alpha_t + \beta_t X_{iht} + \gamma_{ht} + \epsilon_{iht}, \tag{A1}$$

where s_{iht} is 30-day survival following hospital admission for patient i at hospital h in each period t, X_{iht} is a vector of patient controls, and γ_{ht} is a hospital fixed effect. In the main analyses, the vector contains indicators for patient comorbidities and demographics. The comorbidities are indicators for the presence of 23 conditions as given by diagnoses in inpatient stays in the year prior to the index event, counting principal and secondary diagnosis codes. The conditions captured are: unstable angina, chronic atherosclerosis, respiratory failure, hypertensive heart disease or heart failure, valvular heart disease, arrhythmia, hypertension, stroke, cerebrovascular disease, renal failure disease, dialysis, COPD, pneumonia, diabetes, protein calorie malnutrition, dementia, paralysis and disability, peripheral vascular disease, metastatic cancer, trauma, substance abuse, major psychiatric disorder, and chronic liver disease. The demographic indicators are age/race/sex interactions, where the age groups are 66-69, 70-74, 75-79, 80-84, 85-89, 90-94, and 95+, the race groups are Black, white, and other (neither Black nor white), and the sex groups are male and not male.

By extracting estimates of the fixed effects $\hat{\gamma}_{ht}$, this model yields performance measures for each hospital h in each period t:

$$\hat{q}^B_{ht} = \hat{\alpha}_t + \hat{\gamma}_{ht} + \bar{X}^B_t \hat{\beta}_t \tag{A2}$$

$$\hat{q}^W_{ht} = \hat{\alpha}_t + \hat{\gamma}_{ht} + \bar{X}^W_t \hat{\beta}_t, \tag{A3}$$

where $\hat{q}^B_{ht}$ and $\hat{q}^W_{ht}$ are expected 30-day survival rates for a Black and white AMI patients, respectively, at the given hospital-period, for a patient with control variables at the average for those in their race group and period ($\bar{X}^B_t$ and $\bar{X}^W_t$).

The standard deviation of $\hat{q}^B_{ht}$ (or equivalently $\hat{q}^W_{ht}$, since the two measures differ only by a constant) is expected to be greater than the standard deviation of true hospital performance q^B_{ht} due to measurement error. Table 1 reports a measurement error-adjusted standard deviation based on Chandra et al. (2016) and Sacarny (2018) to address this issue. We first form an adjusted variance estimate by taking the variance of the noisy performance measure $\hat{q}^B_{ht}$ and subtracting the average of the squared standard errors of the $\hat{\gamma}_{ht}$. The standard deviation reported in the table is the square root of this estimate.

Section 4.3 presents results using several alternative approaches to estimate hospital performance. Four of these alternatives are modifications to the risk-adjustment approach. The **no risk adjustment** approach replaces X_{iht} with the null vector while the **age/race/sex adjustment** approach includes only the demographic (but not comorbidity) indicators in it. The **race-comorbidity interactions** approach interacts the 23 comorbidity indicators with two indicators for patient race (Black and other, i.e. non-Black non-white, with white race the omitted group), adding 46 indicators to X_{iht} in addition to the comorbidity main effects. Finally, the **AMI type** approach adds an indicator for ST-segment elevation myocardial infarction or not (STEMI vs. NSTEMI), a key marker that can inform treatment decisions.[6]

The remaining two alternatives use random effects rather than fixed effects. The first **random effects** model repeats our baseline fixed effects analysis treating γ_{ht} as a random effect and

[6]We measure NSTEMI events by the presence of an ICD-9 diagnosis code of 410.7x on the patient's index MEDPAR record. Prior to October 2005, these codes were not explicitly labeled NSTEMI but were still typically used to indicate such events (Steinberg et al., 2008).

extracting BLUPs $\hat{\gamma}_{ht}$. The second estimates an alternative model with **race-specific hospital performance**. Specifically, we estimate the following specification:

$$s_{iht} = \alpha_t + \beta_t X_{iht} + \gamma_{ht}^0 + Black_{iht} * \gamma_{ht}^1 + other_{iht} * \gamma_{ht}^2 + \epsilon_{iht}, \tag{A4}$$

where $\left(\gamma_{ht}^0, \gamma_{ht}^1, \gamma_{ht}^2\right)$ is a vector consisting of the hospital random effect and two race-specific hospital random slopes which are distributed Normal $(\mathbf{0}, \Omega)$. The model yields an estimate of Ω, the variance-covariance matrix of the random terms. Appendix Table A5 reports on relevant terms from elements Ω: the standard deviation of hospital performance for white patients (the γ_{ht}^0 term in the equation), the standard deviation of the Black-white differential (the γ_{ht}^1 term), and the correlation between these two elements. We also report the correlation between hospital performance for white and Black patients (Corr $\left[\gamma_{ht}^0, \gamma_{ht}^0 + \gamma_{ht}^1\right]$). To construct race-specific performance, we extract BLUPs $\hat{\gamma}_{ht}^0$ and $\hat{\gamma}_{ht}^1$. Equations A2 and A3 are modified to replace race-agnostic performance $\hat{\gamma}_{ht}$ with race-specific performance $\hat{\gamma}_{ht}^0 + \hat{\gamma}_{ht}^1$ (Black patients, equation A2) and $\hat{\gamma}_{ht}^0$ (white patients, equation A3).

B Decomposition with Entry and Exit

We assess the robustness of the decompositions to several alternative specifications in Appendix Section A, including one approach in which we drop the restriction that hospitals appear in both the baseline and endline periods. This approach permits hospitals to enter and exit the sample. The static decomposition only changes in that the market shares and summations are taken over all available hospitals in the period, H_t. The dynamic decomposition requires more extensive modification which yields terms that account for the role of net entry in the evolution of the Black-white gap. This approach is based on Foster, Haltiwanger and Krizan (2001) and yields the following augmented decomposition:

$$\Delta\text{Between}_t = \sum_{h \in B} \left(\theta^B_{h,t-1} - \theta^W_{h,t-1}\right)\left(\Delta \hat{q}_{h,t}\right) \qquad \leftarrow \text{Differential Performance Improvement} \tag{A5}$$

$$+ \sum_{h \in B} \left(\Delta\theta^B_{h,t} - \Delta\theta^W_{h,t}\right)\left(\hat{q}_{h,t-1} - \bar{q}_{t-1}\right) \qquad \leftarrow \text{Reallocation} \tag{A6}$$

$$+ \sum_{h \in B} \left(\Delta\theta^B_{h,t} - \Delta\theta^W_{h,t}\right)\left(\Delta \hat{q}_{h,t}\right) \qquad \leftarrow \text{Cross} \tag{A7}$$

$$+ \sum_{h \in N} \left(\theta^B_{h,t} - \theta^W_{h,t}\right)\left(\hat{q}_{h,t} - \bar{q}_t\right) \qquad \leftarrow \text{Entry} \tag{A8}$$

$$- \sum_{h \in X} \left(\theta^B_{h,t-1} - \theta^W_{h,t-1}\right)\left(\hat{q}_{h,t-1} - \bar{q}_{t-1}\right), \quad \leftarrow \text{Exit} \tag{A9}$$

where B is the set of hospitals open in both periods, N is the set of entering hospitals, X is the set of exiting hospitals, and $\bar{q}_t$ is the market-share weighted average performance of hospitals open in t. The entry term captures the narrowing (widening) in the Black-white gap explained by Black patients using higher (lower) performing newly entering hospitals than white patients. The exit term enters negatively and captures the narrowing (widening) of the gap due to Black patients using lower (higher) performing exiting hospitals than white patients.

The baseline dynamic decomposition approach is not sensitive to the race group for which we measure performance because in our main specification, the measures $\hat{q}^B_{h,t}$ and $\hat{q}^W_{h,t}$ differ by a constant within a period and that constant drops from all summations. When the decomposition is augmented to allow for entry and exit, the findings are no longer necessarily algebraically identical for $\hat{q}^B_{h,t}$ and $\hat{q}^W_{h,t}$ because the constant no longer drops out of the summations. In practice, however, we found that the results were essentially unchanged with either performance measure.

C Measurement of Technology Adoption

C.1 Main analysis

We measure low- and high-cost technology adoption in Section 5 by tracking hospital use of beta-blockers and cardiac catheterization, respectively. The beta-blockers measure is given by the share of AMI patients receiving beta-blockers at hospital discharge among those for whom it is appropriate. Unfortunately standard hospital administrative data does not provide information on most prescribing. Instead, we track use at baseline with a dataset of medical chart abstracts of Medicare AMI patients nationally in 1994-1995 called the Cooperative Cardiovascular Project. To observe their use at endline, we draw on public 2010-2014 hospital quality data from Medicare Hospital Compare.

We sought to match the CCP exclusion criteria to the Hospital Compare criteria to the greatest extent possible. Specifically, the Hospital Compare measure makes the following patient exclusions: $<$18 years of age, length of stay $>$120 days, enrolled in clinical trials, discharged to another hospital, died in hospital, left against medical advice, discharged for hospice care, documented to receive only comfort measures, or documented reason for not providing a beta-blocker at discharge (Centers for Medicare and Medicaid Services, 2020). Since the CCP data includes only Medicare FFS patients, we make no age exclusion in that data. To best match the remaining Hospital Compare criteria, we make the following CCP patient exclusions: length of stay $>$120 days, documented terminal illness, died during the hospital stay, discharged to another facility, or documented reason for not providing a beta-blockers. The aspirin measure presented in Appendix Table A6 uses the same approach and exclusions with the exception of the final one, which is changed to patients with a documented reason for not providing aspirin. More details on acceptable reasons for which a patient may be exempt from receiving beta-blockers (or aspirin) can be found in Marciniak et al. (1998).

The information needed to produce the cardiac catheterization measure is observable in Medicare claims. Specifically, we identify a patient as having received cardiac catheterization if one of the following ICD-9 procedure codes appeared in the MEDPAR record for their index admission: 37.21, 37.22, 37.23, 88.5, 88.5X, 00.66, 36.0, 36.00-36.02, 36.05-36.07, 36.09. In the main text, we analyze same-day catheterization, which only counts procedures that occurred on the patient's admission day. To produce the risk-adjusted measures, we estimate equations 1-3 with the catheterization indicator on the left-hand side rather than survival.

Appendix Table A6 considers an alternative measure that includes catheterization procedures performed on any day of the stay (i.e. the presence of any catheterization ICD-9 procedure on the index MEDPAR record). It also includes two additional measures that more broadly capture intensive intervention by including bypass surgeries, otherwise known as coronary artery bypass graft (CABG), performed on any day. We assess CABG intervention using the following ICD-9 procedure codes on the patient's index admission MEDPAR record: 36.03, 36.10-36.19,36.2, 36.3, 36.31-36.39.

D Inference in static and dynamic decompositions

We use a bootstrapping approach to estimate standard errors for all decomposition results. Specifically, we estimate standard errors using 1000 bootstrap replicates. All study analyses are based on summations of interactions between hospital market shares and hospital performance measures (or the first differences thereof). Thus, to construct each replicate sample, hospitals are drawn with replacement from the full sample. Then, in each sample, we re-scale all market shares so that they sum to 1 within-period while keeping the performance measures from the original patient-level sample.

Appendix Tables

Appendix Table A1 - Robustness of Static Decomposition to Alternative Risk Adjustment

Specification	A. Analysis in main text			B. No risk adjustment			C. Age/race/sex only		
Time period	Baseline	Endline	Change	Baseline	Endline	Change	Baseline	Endline	Change
Between-Race Gap (Black-White)	-0.96	-0.29	0.66	-0.63	-0.10	0.53	-1.04	-0.47	0.57
	(0.11)	(0.11)	(0.13)	(0.11)	(0.12)	(0.13)	(0.11)	(0.10)	(0.12)
Components of Between-Race Gap									
Between Hospital Markets	-0.42	-0.01	0.40	-0.32	-0.02	0.30	-0.48	-0.12	0.36
	(0.07)	(0.07)	(0.09)	(0.08)	(0.08)	(0.10)	(0.07)	(0.07)	(0.09)
Between ZIP Codes (Within Hospital Markets)	-0.24	-0.13	0.10	-0.05	0.04	0.09	-0.23	-0.16	0.07
	(0.07)	(0.07)	(0.10)	(0.07)	(0.08)	(0.09)	(0.07)	(0.07)	(0.09)
Within ZIP Codes	-0.30	-0.15	0.16	-0.26	-0.12	0.14	-0.34	-0.19	0.14
	(0.05)	(0.05)	(0.06)	(0.05)	(0.05)	(0.06)	(0.05)	(0.05)	(0.06)

Specification	D. Add race-comorbidity interactions			E. Add AMI type		
Time period	Baseline	Endline	Change	Baseline	Endline	Change
Between-Race Gap (Black-White)	-0.95	-0.31	0.64	-0.97	-0.42	0.54
	(0.11)	(0.10)	(0.13)	(0.12)	(0.10)	(0.14)
Components of Between-Race Gap						
Between Hospital Markets	-0.41	-0.01	0.40	-0.41	-0.09	0.32
	(0.07)	(0.07)	(0.09)	(0.07)	(0.07)	(0.09)
Between ZIP Codes (Within Hospital Markets)	-0.24	-0.14	0.09	-0.24	-0.14	0.10
	(0.07)	(0.07)	(0.09)	(0.07)	(0.07)	(0.10)
Within ZIP Codes	-0.30	-0.15	0.15	-0.32	-0.20	0.13
	(0.05)	(0.05)	(0.07)	(0.05)	(0.05)	(0.07)

N=2,712 hospitals. All values are percentage points (i.e. 1 indicates 1 percentage point). Notes: This robustness table displays estimates of the between-race gap (Table 2) under alternative approaches to risk-adjusting hospital performance. See main text and notes to Table 2 for more details on the decomposition and see Appendix Section A for more details on the risk-adjustment approaches. Panel A repeats the approach of the main text. Panels B and C present more limited approaches to adjustment while Panels D and E augment the model in the main text with additional covariates. Bootstrapped standard errors using 1,000 replicates in parentheses.

Appendix Table A2 - Robustness of Static Decomposition to Alternative Specifications

Specification	A. Analysis in main text			B. Random effects			C. Performance for white patients		
Time period	Baseline	Endline	Change	Baseline	Endline	Change	Baseline	Endline	Change
Between-Race Gap (Black-White)	-0.96	-0.29	0.66	-0.66	-0.26	0.40	-0.60	-0.25	0.35
	(0.11)	(0.11)	(0.13)	(0.09)	(0.08)	(0.10)	(0.08)	(0.07)	(0.09)
Components of Between-Race Gap									
Between Hospital Markets	-0.42	-0.01	0.40	-0.30	-0.02	0.28	-0.28	-0.02	0.25
	(0.07)	(0.07)	(0.09)	(0.06)	(0.06)	(0.07)	(0.06)	(0.05)	(0.07)
Between ZIP Codes (Within	-0.24	-0.13	0.10	-0.15	-0.12	0.04	-0.14	-0.12	0.02
Hospital Markets)	(0.07)	(0.07)	(0.10)	(0.05)	(0.06)	(0.07)	(0.05)	(0.05)	(0.07)
Within ZIP Codes	-0.30	-0.15	0.16	-0.20	-0.12	0.09	-0.19	-0.11	0.07
	(0.05)	(0.05)	(0.06)	(0.04)	(0.04)	(0.05)	(0.04)	(0.03)	(0.04)
Hospitals		2,712			2,712			2,712	

Specification	D. Performance for Black patients			E. Below median MA penetration			F. Unbalanced panel		
Time period	Baseline	Endline	Change	Baseline	Endline	Change	Baseline	Endline	Change
Between-Race Gap (Black-White)	-0.57	-0.16	0.41	-1.15	-0.39	0.77	-1.07	-0.32	0.75
	(0.08)	(0.07)	(0.09)	(0.16)	(0.13)	(0.18)	(0.11)	(0.10)	(0.13)
Components of Between-Race Gap									
Between Hospital Markets	-0.27	-0.02	0.25	-0.64	-0.16	0.48	-0.46	-0.03	0.43
	(0.06)	(0.05)	(0.07)	(0.12)	(0.09)	(0.13)	(0.07)	(0.07)	(0.09)
Between ZIP Codes (Within	-0.14	-0.07	0.07	-0.30	-0.11	0.19	-0.27	-0.13	0.13
Hospital Markets)	(0.05)	(0.05)	(0.07)	(0.11)	(0.09)	(0.13)	(0.07)	(0.07)	(0.09)
Within ZIP Codes	-0.17	-0.08	0.09	-0.22	-0.11	0.10	-0.34	-0.15	0.18
	(0.03)	(0.03)	(0.04)	(0.07)	(0.05)	(0.09)	(0.05)	(0.05)	(0.07)
Hospitals		2,712			1,199		3,998	2,877	

All values are percentage points (i.e. 1 indicates 1 percentage point). Notes: This robustness table displays estimates of the between-race gap (Table 2) under alternative approaches to estimating hospital performance or developing the sample of hospitals. See main text and notes to Table 2 for more details on the decomposition and see Appendix Section A for more details on the alternative approaches. Panel A repeats the approach of the main text. Panel B uses random effects to estimate hospital performance. Panels C and D use performance measures derived from a random-effects model with race-specific performance. Panel E restricts to markets with below median Medicare Advantage penetration at endline. Panel F uses an unbalanced panel with all hospitals for which performance could be estimated in each period. Bootstrapped standard errors using 1,000 replicates in parentheses.

Appendix Table A3 - Robustness of Dynamic Decomposition to Alternative Risk Adjustment

	(A)	(B)	(C)	(D)	(E)
Specification	Analysis in main text	No risk adjustment	Age/race/sex only	Add race-comorbidity interactions	Add AMI type
Change in Between-Race Gap	0.66	0.53	0.57	0.64	0.54
from Baseline to Endline	(0.13)	(0.13)	(0.12)	(0.13)	(0.14)
Components of Change					
Differential Performance	0.68	0.92	0.67	0.66	0.64
Improvement	(0.15)	(0.15)	(0.14)	(0.14)	(0.16)
Differential Hospital	0.19	0.03	0.17	0.19	0.15
Reallocation	(0.08)	(0.09)	(0.08)	(0.08)	(0.08)
Cross	-0.21	-0.42	-0.27	-0.21	-0.24
	(0.09)	(0.098)	(0.09)	(0.08)	(0.09)

N=2,712 hospitals. All values are percentage points (i.e. 1 indicates 1 percentage point). Notes: This robustness table displays and decomposes the change in the between-race gap (Table 3) under alternative approaches to risk-adjusting hospital performance. See main text and notes to Table 3 for more details on the decomposition and see Appendix Section A for more details on the risk-adjustment approaches. Column A repeats the approach of the main text. Columns B and C present more limited approaches to adjustment while Columns D and E augment the model in the main text with additional covariates. Bootstrapped standard errors using 1,000 replicates in parentheses.

Appendix Table A4 - Robustness of Dynamic Decomposition to Alternative Specifications

	(A)	(B)	(C)	(D)	(E)	(F1)	(F2)
Specification	Analysis in main text	Random effects	Performance for white patients	Performance for Black patients	Below median MA penetration	Unbalanced panel (q^B)	Unbalanced panel (q^W)
Change in Between-Race Gap	0.66	0.40	0.35	0.41	0.77	0.75	0.75
from Baseline to Endline	(0.13)	(0.10)	(0.09)	(0.09)	(0.18)	(0.13)	(0.09)
Components of Change							
Differential Performance	0.68	0.41	0.38	0.38	0.64	0.46	0.45
Improvement	(0.15)	(0.10)	(0.09)	(0.09)	(0.19)	(0.16)	(0.10)
Differential Hospital	0.19	0.15	0.14	0.14	0.11	0.10	0.10
Reallocation	(0.08)	(0.05)	(0.05)	(0.05)	(0.11)	(0.07)	(0.08)
Cross	-0.21	-0.16	-0.17	-0.11	0.02	0.08	0.10
	(0.09)	(0.05)	(0.05)	(0.05)	(0.13)	(0.12)	(0.07)
Entry						-0.12	-0.13
						(0.02)	(0.02)
Exit (enters negatively)						-0.22	-0.22
						(0.04)	(0.03)
Hospitals	2,712	2,712	2,712	2,712	1,199	4,163	4,163

All values are percentage points (i.e. 1 indicates 1 percentage point). Notes: This robustness table displays and decomposes the change in the between-race gap (Table 3) under alternative approaches to estimating hospital performance or developing the sample of hospitals. See main text and notes to Table 3 for more details on the decomposition and see Appendix Section A for more details on the alternative approaches. Column A repeats the approach of the main text. Column B uses random effects to estimate hospital performance. Columns C and D use performance measures derived from a random-effects model with race-specific performance. Column E restricts to markets with below median Medicare Advantage penetration at endline. Columns F1 and F2 use an unbalanced panel with all hospitals for which performance could be estimated in each period, emitting entry and exit terms; this approach is sensitive to the reference group and so we show it using performance for Black and white patients derived from the main text (not the random-effects model), respectively. Bootstrapped standard errors using 1,000 replicates in parentheses.

Appendix Table A5 - Race-Specific Performance Model

Model statistic		Baseline (1995-1999)	Endline (2010-2014)
Standard deviation of performance for white patients	$\mathrm{SD}(\gamma_{ht}^{0})$	2.94	2.63
Standard deviation of Black-white performance differential	$\mathrm{SD}(\gamma_{ht}^{1})$	1.31	1.50
Correlation between performance for white patients and Black-white differential	$\mathrm{Corr}(\gamma_{ht}^{0}, \gamma_{ht}^{1})$	-0.21	-0.32
Correlation between performance for white patients and Black patients	$\mathrm{Corr}(\gamma_{ht}^{0}, \gamma_{ht}^{0} + \gamma_{ht}^{1})$	0.90	0.83

Units for standard deviation estimates are percentage points (i.e. 1 indicates 1 percentage point). Notes: This table presents statistics from a random effects model with race-specific performance. The model includes a hospital random effect (yielding performance for white patients) and two race-specific random slopes (yielding performance differentials between the race groups and white patients). These statistics are derived from estimates of the model's variance-covariance matrix. See Appendix Section A for more details.

Appendix Table A6 - Decomposition of Additional Technology Adoption Measures

	(1) Cardiac Cath (Any Day)	(2) Cath or CABG (Any Day)	(3) CABG (Any Day)	(4) Aspirin
Avg at Baseline (All Patients)	53.8%	54.4%	9.9%	58.4%
Avg at Endline (All Patients)	78.9%	79.7%	8.8%	98.9%
Between-Race Gap (Black-White)				
Baseline	3.53	3.74	0.80	1.75
	(0.68)	(0.72)	(0.28)	(0.61)
Endline	0.20	0.41	-0.02	-0.15
	(0.57)	(0.61)	(0.17)	(0.06)
Change	-3.33	-3.33	-0.81	-1.90
	(0.57)	(0.57)	(0.23)	(0.60)
Components of Change				
Differential Performance	-1.56	-1.63	-0.60	-1.84
Improvement	(0.50)	(0.5)	(0.21)	(0.59)
Differential Hospital	-1.01	-0.96	-0.13	-1.05
Reallocation	(0.45)	(0.46)	(0.18)	(0.38)
Cross	-0.76	-0.75	-0.08	1.00
	(0.32)	(0.33)	(0.13)	(0.37)
Hospitals	2,712	2,712	2,712	2,535

All values are percentage points (i.e. 1 indicates 1 percentage point) except for shares indicated with a % symbol. Notes: This table displays decompositions of additional technology measures beyond those presented in the main text. See text and notes to Table 4 for more details. Columns 1-3 present alternative measures of intensive intervention: receipt of cardaic catheterization on any day of the index admission, receipt of cardiac catheterization or coronary artery bypass graft (CABG) on any day, and receipt of CABG on any day, respectively. Column 4 presents adoption of aspirin at discharge, which is calculated simularly to the approach for beta blockers. Bootstrapped standard errors using 1,000 replicates in parentheses.