Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.

eMethods. Definitions, Weighting, Low-Value Service Measures, and Proportion of Variation

Defining Beneficiary Covariates

Because the receipt of low-value services may be correlated with the completeness with which diagnoses are recorded in Medicare claims, for each year of data, we assessed patients' chronic conditions as of December 31st of the prior calendar year. Regressions included binary indicators for each chronic condition as well as counts for total conditions, up to 9 or greater. Beneficiary age was also defined as of the start of the calendar year. Regressions included age and age-squared.

Weighting Scheme for Composite Physician Scores

When calculating physician-level composite scores by summing physician-level component scores for each low-value service, we weighted each component score by the proportion of patient-level observations satisfying a measure's denominator criteria. As described in Schwartz et al. (2016),[5] this weighting scheme allows one to interpret the composite measure as the total number of low-value services per patient per year the physician would be expected to deliver to a standardized population of patients, plus some constant. (The constant reflects the fact that composite measures are relative, representing the difference service use between a physician and a reference physician.) The approach standardizes a service's contribution by the number of beneficiaries for whom there is a non-zero probability that they might receive the service. For example, the contribution of a service score to a composite score would be equal if a service were used once per person in an entire population or if a service were used twice per person in half of that population.

Narrower Sets of Low-Value Service Measures

In sensitivity analyses, we employed two narrower sets of low-value service measures that are less likely to reflect the decisions of specialist providers. The first set included 12 low-value care measures, including all measures falling within the clinical categories of cancer screening, preoperative testing, and imaging (Table 1), as well as the measure of bone mineral density testing at frequent intervals. The results pertaining to this analysis are presented in the manuscript body, in eFigure 1 and eTable 1.

The second set consisted of 8 low-value care measures included all these measures also excluded the preoperative testing measures. The average rate of these services was 23.1 services per 100 beneficiaries per year. The adjusted $90^{th}/10^{th}$ percentile ratio of low-value service rates within region was 2.19 services per 100 beneficiaries per year, with a 10^{th} percentile of 14.5 services per 100 beneficiaries per year; the adjusted $90^{th}/10^{th}$ percentile ratio of low-value service rates within organization was 1.72 services per 100 beneficiaries per year, with a 10^{th} percentile of 17.0 services per 100 beneficiaries per year (eFigure 2). Physician characteristics accounted for 4.6% of within-region variance and 1.8% of within-organization variance.

Proportion of Variation Predicted by Physician Characteristics.

To estimate associations between physician characteristics and low-value services, we employed ordinary least squares regression to model the total number of the 17 low-value services a beneficiary received in a year as a function of the physician characteristics and patient covariates described above, as well as year indicators. The within-region analysis included HRR fixed effects, while the within-organization analysis included both HRR and organization fixed effects. Using the model coefficients, we predicted the number of low-value services each

physician would provide based only on the physician's characteristics, holding the other variables constant. The variance of these predictions was calculated. The proportion of variation predicted by physician characteristics was calculated as the ratio of this variance to the variance in observed rates of low-value services from the prior multilevel modeling analysis.

eTable 1. Codes for Measures of Low-Value Services

Measure	Codes for Detection and Restriction Criteria
Cervical cancer screening for women over age 65	**CPT:** G0123 G0124 G0141 G0143 G0144 G0145 G0147 G0148 P3000 P3001 Q0091 (cervical screening) **ICD-9:**180 184x 2190 2331 2332 2333x 6221 (cervical and other relevant cancers, dysplasias) 7950x-7951x (abnormal Papanicolaou finding, human papillomavirus positivity) V1040 V1041 V1322 V1589 (history of cervical cancer, other relevant cancers, dysplasia)
Colorectal cancer screening for adults older than age 85 years	**CCW:** Colorectal cancer first indication date **ICD-9:** V7651 (colon cancer screening) **CPT:** 45330-45345 45378-45392 G0104-G0106 G0120-G0122 G0328 82270 (sigmoidoscopy, colonoscopy, barium enema or blood occult test for colon cancer screening)
Prostate-specific antigen (PSA) testing for men over age 75	**CCW:** Prostate cancer first indication date **CPT:** G0103 84152-84154 (PSA testing)
Bone mineral density testing at frequent intervals	**CCW:** Osteoporosis first indication date **CPT:** 76070 76071 76075 76076 76078 76977 77078-77081 77083 78350 78351 (bone density testing)
Hypercoagulability testing for patients with deep vein thrombosis	**CPT:** 81240 81241 83090 85300 85303 85306 85613 86147 (hypercoagulability chemistries) **ICD-9:** 4151 (pulmonary embolism) 4510 45111 45119 4512 45181 4519 4534 4535 (phlebitis, thrombophlebitis and venous embolism of lower extremity vessels) V1251 V1255 (history of venous thrombosis and embolism, pulmonary embolism)
Total or free T3 level testing for patients with hypothyroidism	**CPT:** 84480 84481 (total or free T3)

	CCW: Hypothyroidism first indication date
Preoperative chest radiography	**BETOS:** P1x P3D P4A P4B P4C P5C P5D P8A P8G (selected surgeries) **CPT:** 71010 71015 71020-71023 71030 71034 71035 (chest x-ray), 19120 19125 47562 47563 49560 58558 (relevant surgical codes not included in BETOS categories)
Preoperative echocardiography	**BETOS:** P1x P3D P4A P4B P4C P5C P5D P8A P8G (selected surgeries) **CPT:** 93303 93304 93306-93308 93312 93315 93318 (echocardiogram) 19120 19125 47562 47563 49560 58558 (relevant surgical codes not included in BETOS categories)
Preoperative pulmonary function testing (PFT)	**BETOS:** P1x P2x P3D P4A P4B P4C P5C P5D P8A P8G (selected surgeries) **CPT:** 94010 (spirometry)
Preoperative stress testing	**BETOS:** P1x P3D P4A P4B P4C P5C P5D P8A P8G (selected surgeries) **CPT:** 75552-75564 75574 78451-78454 78460 78461 78464 78465 78472 78473 78481 78483 78491 78492 93015-93018 93350 93351 0146T 0147T 0148T 0149T (stress testing, cardiac MRI, CT angiography) 19120 19125 47562 47563 49560 58558 (relevant surgical codes not included in BETOS categories)
Computed tomography (CT) of the sinuses for uncomplicated acute rhinosinusitis	**CPT:** 70486-70488 (CT of maxillofacial area) **ICD-9:** 461x 473x (sinusitis), 2770x 042 07953 279xx (immune disorders), 471x (nasal polyp) 373xx 37600 (eyelid/orbit inflammation), 800xx-804xx 850xx-854xx 870xx-873xx 9590x 910xx 920xx-921xx (head or face trauma)
Back imaging for patients with non-specific low back pain	**CPT:** 72010 72020 72052 72100 72110 72114 72120 72200 72202 72220 72131-72133 72141 72142 72146-72149 72156 72157 72158 (radiologic, CT, and MRI imaging of spine)

	ICD-9: 7213 72190 72210 72252 7226 72293 72402 7242-7246 72470 72471 72479 7385 7393 7394 846x 8472 (back pain, various causes), 14xx–208xx 230xx-239xx (cancer), 800x-839xx 850xx-854xx 86xxx 905xx-909xx 92611 92612 929, 952xx 958xx-959xx (trauma), 3040x-3042x 3044x 3054x-3057x (IV drug abuse), 34460 7292x (neurologic impairment), 4210 4211 4219 (endocarditis), 038xx (septicemia), 01xxx (tuberculosis), 730xx (osteomyelitis), 7806x 7830x 7832x 78079 7808x 2859x (fever, weight loss, malaise, night sweats, anemia not due to blood loss) 72142 72191 72270 72273 7244 (myelopathy, neuritis and radiculopathy)
Screening for carotid artery disease in asymptomatic adults	**CPT:** 70498 70547-70549 93880 93882 3100F (carotid imaging) **CCW:** Stroke/TIA first indication date **ICD-9:** 430 431 43301 43311 43321 43331 43381 43391 43400 43401 43410 43411 43490 43491 4350 4351 4353 4358 4359 436 99702 V1254 (stroke/TIA), 3623 36284 (retinal vascular occlusion/ischemia), 7802 781xx 7820 78451 78452 78459 9921 (nervous and musculoskeletal symptoms)
Imaging for diagnosis of plantar fasciitis/heel pain	**CPT:**73620 73630 73650 (foot radiograph) 73718 73719 73720 (foot MRI) 76880 76881 76882 (extremity ultrasound) **ICD-9:**72871 7294 (plantar fasciitis), 71947 7295 (foot pain)
Stress testing for stable coronary disease	**CPT:** 75552-75564 75574 78451-78454 78460 78461 78464 78465 78472 78473 78481 78483 78491 78492 93015-93018 93350 93351 0146T 0147T 0148T 0149T (stress testing, cardiac MRI, CT angiography) **CCW:** AMI first indication date

Arthroscopic surgery for knee osteoarthritis	**CPT:** 29877 29879 29880 29881 G0289 (knee arthroscopy with chondroplasty) **ICD-9:** 7177 73392 71500 71509 71510 71516 71526 71536 71596 (chondromalacia, osteoarthritis), 8360-8362 7170 71741 (meniscal tear)
Spinal injection for low-back pain	**CPT:** 62311 64483 (epidural injections) 20552 20553 (trigger point injections) 64493 64475 (facet injections) J1438 (etanercept injection) **ICD-9:** 72142 72191 72270 72273 7243 7244 (back pain with radiculopathy) 7213 72190 72210 7222 72252 7226 72280 72283 72293 72400 72402 72403 7242 7245 7246 72470 72471 72479 7384 7385 7393 7384 7385 7393 7394 75612 8460-8463 8468 8469 8472 (other back pain)

eTable 2. Association Between Physician Characteristics and Low-Value Services (Narrower Set)											
	Within-Region Analysis[a]						*Within-Organization Analysis*[b]				
Physician Characteristic	Additional Services per 100 Beneficiaries per year	p-value	95% CI				Additional Services per 100 Beneficiaries per year	p-value	95% CI		
MD credential (vs DO)	-0.41	0.04	-0.81	–	-0.02		-0.46	0.007	-0.83	–	-0.13
Foreign medical graduate	1.38	<0.001	1.08	–	1.68		0.53	<0.001	0.30	–	0.77
Graduate of medical school in US News top 20 rank	-0.39	0.04	-0.78	–	-0.01		-0.36	0.03	-0.69	–	-0.03
Age[b]	0.32	<0.001	0.22	–	0.42		0.27	<0.001	0.18	–	0.35
Female gender	0.85	<0.001	0.65	–	1.06		1.09	<0.001	0.91	–	1.27
Academic title (vs no professorship)											
Full professor	-3.55	<0.001	-4.58	–	-2.51		-0.53	0.26	-1.44	–	0.38
Associate professor	-2.77	<0.001	-3.69	–	-1.85		-0.40	0.34	-1.22	–	0.43
Assistant professor	-2.12	<0.001	-2.62	–	-1.63		0.33	0.18	-0.83	–	0.16
Any publication authorship	-0.21	0.10	-0.47	–	0.04		-0.18	0.11	-0.39	–	0.04
Number of publications authored	0.01	0.15	0.00	–	0.03		0.01	0.14	-0.003	–	0.02
Clinical trial investigator	-0.44	0.70	-2.70	–	1.82		-0.36	0.67	-2.01	–	1.29
NIH grant recipient	-0.63	0.51	-2.52	–	1.26		-0.45	0.52	-1.82	–	0.92
Any pharmaceutical/device company payments	1.46	<0.001	1.27	–	1.66		0.37	<0.001	0.18	–	0.57
Pharmaceutical/device company payment amount[c]	0.07	0.007	0.02	–	0.13		0.07	0.004	0.02	–	0.12
Medicare FFS panel size[d]	10.41	<0.001	8.47	–	12.35		4.19	<0.001	2.77	–	5.60

CI = Confidence Interval FFS = Fee-For-Service. Confidence intervals were estimated using robust variance estimators, clustered at the physician level.

a In addition to patient sociodemographic and clinical characteristics, this model contains indicators for each patient hospital referral region, effectively comparing physicians within the same geographic service area.

b In addition to patient sociodemographic characteristics, clinical characteristics, and hospital referral region, this model also contains indicators for provider organization tax identification number, effectively comparing physicians within the same provider organization.

c Coefficient is scaled to represent the additional services per 100 beneficiaries that are associated with a 10 year increase in age.

d Coefficient is scaled to represent the additional services per 100 beneficiaries that are associated with a $5000 increase in pharmaceutical/device company payments.

e Coefficient is scaled to represent the additional services per 100 beneficiaries that are associated with an increase of 100 patients per year.

eTable 3. Association Between Physician Characteristics and Low-Value Services (Narrowest Set)											
	Within-Region Analysis[a]						*Within-Organization Analysis*[b]				
Physician Characteristic	Additional Services per 100 Beneficiaries per year	p-value	95% CI				Additional Services per 100 Beneficiaries per year	p-value	95% CI		
MD credential (vs DO)	-0.37	0.06	-0.75	–	0.01		-0.42	0.010	-0.74	–	-0.10
Foreign medical graduate	1.23	<0.001	0.94	–	1.52		0.45	<0.001	0.23	–	0.68
Graduate of medical school in US News top 20 rank	-0.33	0.09	-0.70	–	0.05		-0.33	0.04	-0.65	–	-0.02
Age[b]	0.33	<0.001	0.23	–	0.42		0.27	<0.001	0.19	–	0.35
Female gender	0.76	<0.001	0.56	–	0.96		0.98	<0.001	0.80	–	1.15
Academic title (vs no professorship)											
Full professor	-3.48	<0.001	-4.45	–	-2.50		-0.55	0.21	-1.42	–	0.32
Associate professor	-2.51	<0.001	-3.41	–	-1.62		-0.28	0.49	-1.07	–	0.52
Assistant professor	-2.13	<0.001	-2.60	–	-1.67		-0.41	0.09	-0.87	–	0.06
Any publication authorship	-0.22	0.08	-0.47	–	0.03		-0.17	0.11	-0.38	–	0.04
Number of publications authored	0.01	0.11	0.00	–	0.03		0.01	0.10	-0.002	–	0.02
Clinical trial investigator	-0.42	0.71	-2.63	–	1.78		-0.31	0.70	-1.91	–	1.28
NIH grant recipient	-0.72	0.44	-2.56	–	1.12		-0.50	0.45	-1.81	–	0.81
Any pharmaceutical/device company payments	1.42	<0.001	1.23	–	1.61		0.34	<0.001	0.15	–	0.54
Pharmaceutical/device company payment amount[c]	0.07	0.004	0.02	–	0.12		0.07	0.002	0.03	–	0.11
Medicare FFS panel size[d]	10.12	<0.001	8.21	–	12.02		4.33	<0.001	2.96	–	5.71

CI = Confidence Interval FFS = Fee-For-Service. Confidence intervals were estimated using robust variance estimators, clustered at the physician level.

a In addition to patient sociodemographic and clinical characteristics, this model contains indicators for each patient hospital referral region, effectively comparing physicians within the same geographic service area.

b In addition to patient sociodemographic characteristics, clinical characteristics, and hospital referral region, this model also contains indicators for provider organization tax identification number, effectively comparing physicians within the same provider organization.

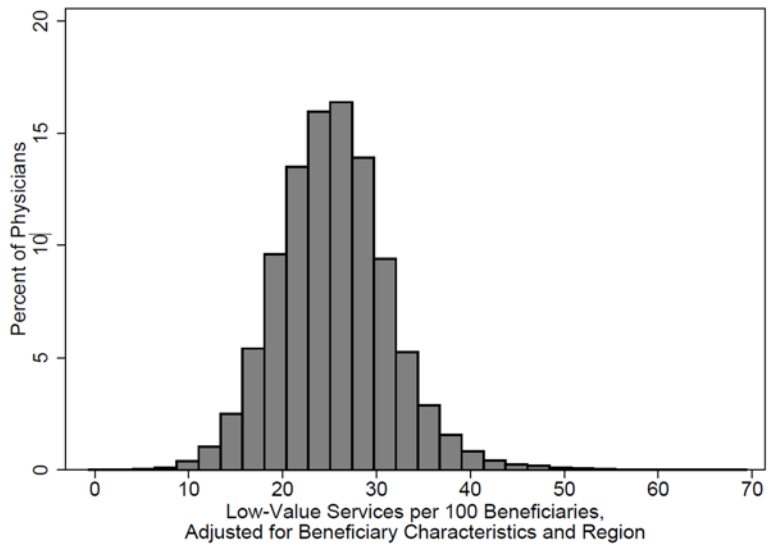
c Coefficient is scaled to represent the additional services per 100 beneficiaries that are associated with a 10 year increase in age.

d Coefficient is scaled to represent the additional services per 100 beneficiaries that are associated with a $5000 increase in pharmaceutical/device company payments.

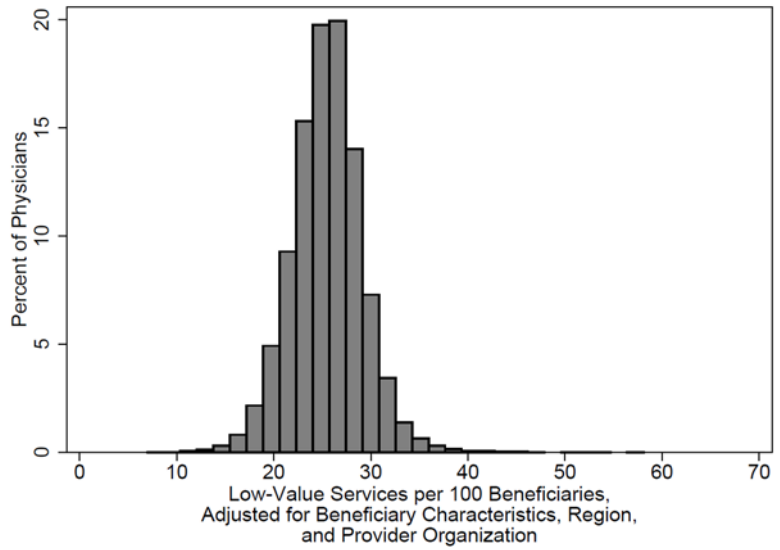
e Coefficient is scaled to represent the additional services per 100 beneficiaries that are associated with an increase of 100 patients per year.

eFigure 1. Variation in Low-Value Services (Narrower Set) Across Physicians

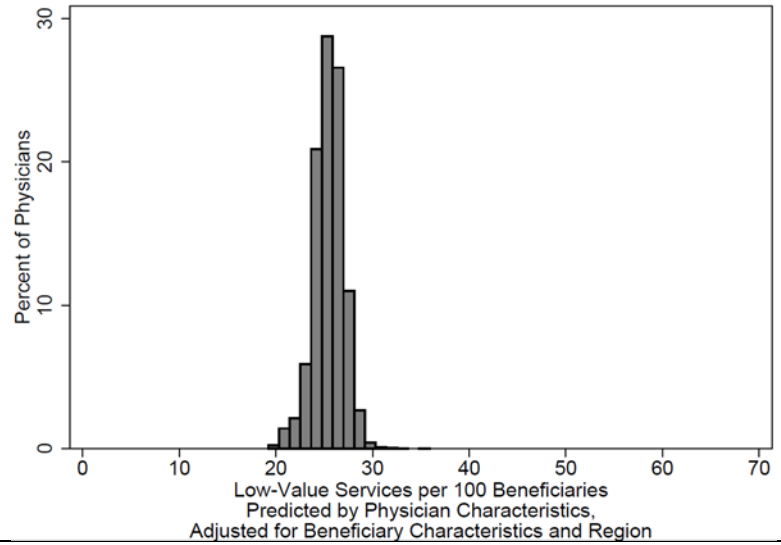
Panel A



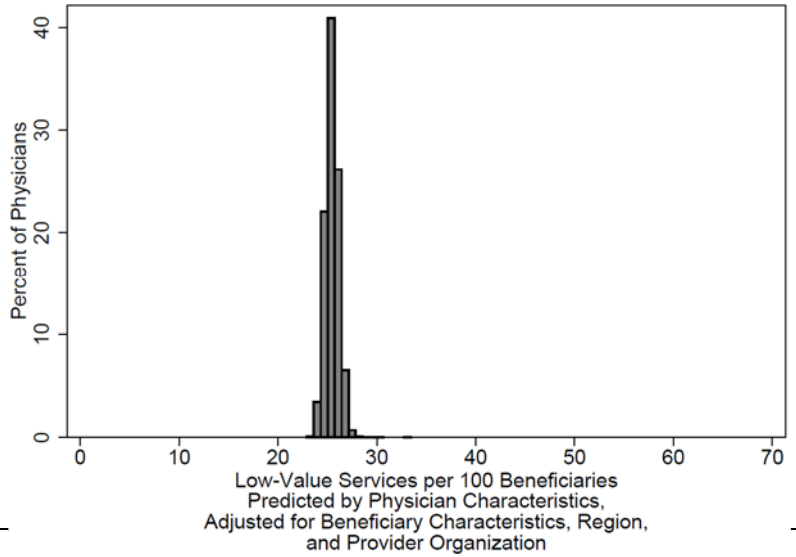
Panel B



Panel C

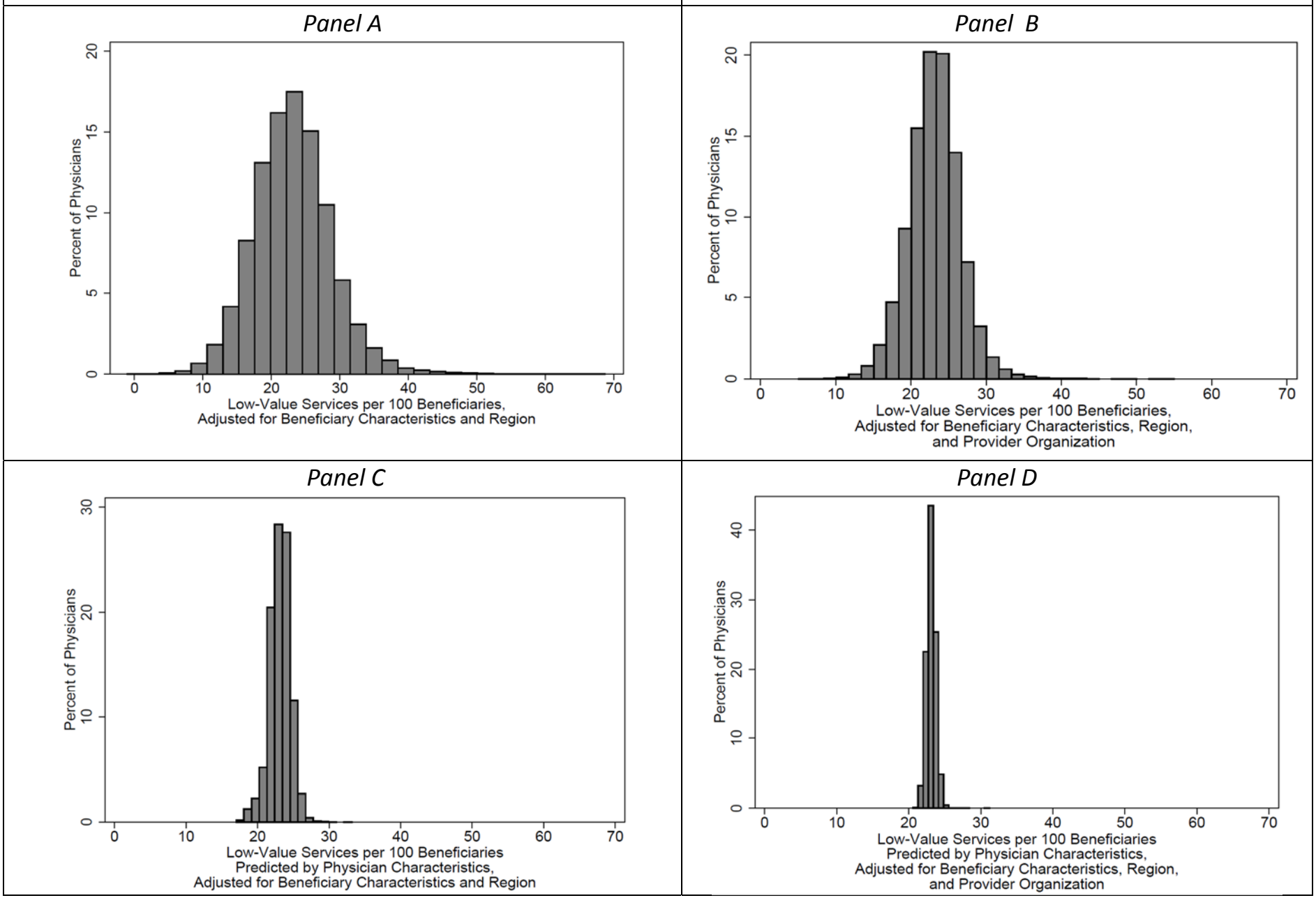


Panel D



Panel A and B present distributions of annual rates of low-value services adjusted for beneficiary sociodemographic and clinical characteristics, local area economic and educational characteristics, year, and hospital referral region, as well as provider organization (Panel B only). Panels C and D present corresponding predicted distributions of annual rates of low-value services, adjusted for the same factors, based on physician characteristics. To aid in visualization, panels are truncated at 70 services per 100 beneficiaries per year.

eFigure 2. Variation in Low-Value Services (Narrowest Set) Across Physicians



Panel A and B present distributions of annual rates of low-value services adjusted for beneficiary sociodemographic and clinical characteristics, local area economic and educational characteristics, year, and hospital referral region, as well as provider organization (Panel B only). Panels C and D present corresponding predicted distributions of annual rates of low-value services, adjusted for the same factors, based on physician characteristics. To aid in visualization, panels are truncated at 70 services per 100 beneficiaries per year.