Whaley CM, Zhao X, Richards M, Damberg CL. Higher Medicare spending on imaging and lab services after primary care physician group vertical integration. Health Aff (Millwood). 2021;40(5).

APPENDIX

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1. DATA AND SAMPLE CONSTRUCTION

1.1. Attribution of Physicians and Physician Groups to Hospitals and Health Systems

To measure vertical integration, we linked physician groups to hospitals and health systems. This process involved several data sources and steps.

1. First, we used data from the Medicare Data on Provider Practice and Specialty (MD-PPAS) data to physician-level National Provider Identifiers (NPIs) to organization-level Tax Identification Numbers (TINs). This mapping constructed our preliminary physician organizations.
2. Next, we combined TINs for academic physician organizations into a single entity.
3. We then combined TINs for non-academic physician organizations by evaluating how frequently two TINs were listed by the same physician in MD-PPAS. If two TINs had a sufficient number of physicians in common and/or had similar enough names in MD-PPAS, we considered the TINs to belong to the same physician organization. After an initial round of combining TINs into physician organizations, a second round of physician organizations were created considering the physician overlap between a TIN and the physician organizations from the first round.
4. After mapping physicians to groups, we mapped groups to hospitals and health systems using the Provider Enrollment and Chain Ownership System (PECOS) data. We supplemented this data with data from IRS Form 990 reports for non-profit hospitals.

1.2. Attribution of Medicare Beneficiaries to Physician Groups

After linking physician groups to hospital and health systems, we linked Medicare beneficiaries to physician groups. We developed eight attribution rules that consider patient visits and

expenditures. Out of a total Medicare fee-for-service (FFS) population of 38.4 million, our mapping successfully matched 26,442,987 beneficiaries to a physician group. Of the 38.4 million beneficiaries during the 2013 to 2016 time period, 12.0 million did not have an evaluation and management visit with a primary care provider (step 4) and were thus not mapped to a primary care provider in their respective year.

Our mapping uses the following steps:

1. Assign beneficiaries to the physician group where the beneficiary receives the most evaluation and management visits (CPT codes 99201- 99499) from a primary care provider. Primary care providers were defined as general internal medicine, family medicine, and geriatrics specialties as well as nurse practitioners and physician assistants (88.1% of attributed beneficiaries).
    a. In cases of ties, we only considered the three physician specialties.
    b. For additional ties, we looked at all evaluation and management visits performed by any type of provider.
    c. For unresolved ties, we calculated total standardized spending on evaluation and management services to any type of provider and used the provider with the largest spending amount for a beneficiary's care.
2. For beneficiaries with no evaluation and management visits from a primary care provider, we assigned the beneficiary to the group that performed the most evaluation and management visits among internal medicine subspecialists (2.2% of attributed beneficiaries).
    a. In cases of ties, we used all evaluation and management visits performed by any type of provider (0.3% of attributed beneficiaries).

b. For additional ties, we used standardized evaluation and management spending attributable to any type of provider (0.7% of attributed beneficiaries).

3. If steps 1 and 2 result in ties, we use the location of both the annual Medicare Wellness visit and the last visit (1.2% of attributed beneficiaries).
4. We did not attribute beneficiaries with no evaluation and management services to primary care providers or internal medicine subspecialists.

1.3. Diagnostic Imaging and Laboratory Test Procedures

We examine the impact of vertical integration using common diagnostic imaging and laboratory tests. For each service, we selected 5 of the most common tests in the initial year for imaging and laboratory tests, respectively. Each test can contain multiple specific procedures that we included as the same procedure (e.g. MRI of the brain with dye and without dye are counted as MRI of the brain). In our regression models, we include controls for each specific procedure, which we identify using Current Procedure Terminology (CPT) codes. The full list of procedures is listed in Appendix Exhibit 1.

Over the sample period, these services accounted for approximately 30 million imaging services and 341 million laboratory tests. For computational reasons, we collapse the data to the physician group, year, month, and procedure (CPT) level.

1.4. Outcomes of Interest

We examined the association between vertical integration and three outcomes:

1) The number of diagnostic tests per 1,000 Medicare FFS beneficiaries attributed to the group that occur in a hospital-based or non-hospital-based site of care. We defined site of care by place of service codes in Carrier files and the combination of facility type codes and service type codes in Outpatient files. Appendix Exhibit 2 presents the map from those codes to our definition of site of care.

2) The Medicare spending amount for the procedure. To define spending amount, we used the "allowed amount" that represents the transacted amount paid to the provider by the Medicare system and the patient. We did not use the "chargemaster" price, which is often not reflective of the actual amount paid.

2. REGRESSION ANALYSIS

To estimate the association between vertical integration and each of the three outcomes (y), we use multivariate difference-in-difference regressions. For each provider group (j), procedure (k), and calendar month (t), we estimated a regression of the form

$$y_{jkt} = \alpha + \delta integrated_{jt} + \beta_1 Year_t + \beta_2 Month_t + \beta_3 CPT_k + \beta_4 Provider_j + \varepsilon_{jkt}.$$

In this model, the main independent variable of interest, $integrated_{jt}$, indicates that physician group j is vertically integrated with a hospital or health system in year t. We estimate these models using linear regressions and cluster standard errors at the group practice level.

To control for temporal trends, we include fixed effects for year (t) and month (t). We include procedure code (CPT) fixed effects (k) to control for time-invariant differences across procedures. Finally, we include fixed effects for each physician group. Importantly, our identifiers for physician group persist, even if a group is integrated with a health system. Thus, the inclusion of group fixed effects allows us to control for characteristics of each group that may impact each outcome.

Our primary identification assumption is that the group fixed effects account for group-specific differences in referral patterns, and that these group-specific differences do not vary across years. In other words, we assume that the group-level decision to integrate with a hospital or health system is not made based on contemporaneous changes in referral patterns. We test this assumption by conducting an event study, where we test for changes in the referral patterns before and after integration using an event study approach. Finding trends in referral patterns prior to integration suggests that integration decisions may be endogenously related to our outcomes of interest.

3. SENSITIVITY TESTS

To test the importance of each covariate, we start by iteratively adding covariates to our regression model. For these tests, we include the share of procedures that occur in a hospital-based site of care, rather than the number of tests, to ease interpretability. As shown in Appendix Exhibits 3 and 4, our base specification (column 1) includes just year fixed effects. In column 2, we add month fixed effects, column 3 adds procedure (CPT code) fixed effects, and column 4 adds physician group fixed effects. For each outcome, the vertical integration coefficient is

similar in columns 1-3. However, adding the physician group fixed effects meaningfully reduces the magnitude of the estimated coefficients.

We next examine the association between vertical integration and each of our three outcomes separately for each procedure. When doing so, we include the full set of fixed effects, including the CPT code fixed effects for specific procedures. As shown in Appendix Exhibit 5, for imaging tests, we observe similar associations for each service. The primary exception is for head CT scans, where we do not find an association between vertical integration and site of care. For thorax CT scans, the association between vertical integration and Medicare spending is not statistically significant at conventional levels ($3.0, 95% CI: -$0.3 to $5.1). For laboratory tests, Appendix Exhibit 6, the individual procedure tests are also similar to the main results.

Our final regression sensitivity test estimates specifications similar to the main specification, but do not weight by provider volume. The unweighted results, in Appendix Exhibits 7 and 8, are also similar to the main results, but slightly larger in magnitude. For imaging tests, our preferred specification in column 4 indicates that physician vertical integration is associated with a 1.4 percentage point (95% CI: 1.1 to 1.8 percentage point) increase in the share of tests performed in a hospital and a $14.3 (95% CI: $12.7 to $15.9) increase in medical costs. For laboratory tests, the results imply that vertical integration is associated with a 3.0 percentage point (95% CI: 2.7 to 3.3 percentage point) increase in the share of tests performed in a hospital and a $1.33 (95% CI: $1.26 to $1.40) increase in medical costs. For our two primary outcomes, the unweighted results imply a 90,000 and 1.76 million increase in the number of imaging and laboratory tests performed in a hospital, respectively, and $90.1 and $76.8 increases in medical spending.

Finally, to test for changes in patient composition, we examined changes in the age and gender of Medicare fee-for-service beneficiaries attributed to each physician group following vertical integration. As shown in Appendix Exhibit 9, we do not find changes in mean beneficiary age. We do find a small, 1-percentage point, increase in the share of female beneficiaries.

4. APPENDIX TABLES AND FIGURES

Appendix Exhibit 1: Specific Procedures and Procedure Codes, and 2018 Medicare Site-Based Payments

Test	CPT Code	Description	Hospital Mean	Non-hospital Mean	Site of care price differential
Panel A: Imaging Tests					
1. CT head	70450	CT head/brain w/o dye	$181	$127	$54
	70460	CT head/brain w/ dye	$300	$155	$145
	70470	CT head/brain w/o & w dye	$329	$206	$123
2. MRI brain	70551	MRI brain stem w/o dye	$339	$228	$111
	70552	MRI brain stem w/ dye	$341	$220	$121
	70553	MRI brain stem w/o & w/ dye	$550	$332	$218
3. MRI lumbar	72148	MRI lumbar spine w/o dye	$315	$204	$111
	72149	MRI lumbar spine w/ dye	$303	$83	$220
	72158	MRI lumbar spine w/o & w/ dye	$472	$254	$218
4. CT thorax	71250	CT thorax w/o dye	$179	$125	$54
	71260	CT thorax w/ dye	$357	$236	$121
	71270	CT thorax w/o & w/ dye	$324	$203	$121
5. CT abdomen and pelvis	74176	CT abdomen & pelvis	$249	$132	$117
	74177	CT abdomen & pelvis w/ contrast	$341	$220	$121
	74178	CT abdomen & pelvis, 1/more regions	$403	$282	$121
Panel B: Laboratory Tests					
1. Complete CBC	85025	Complete CBC w/ auto differential WBC	$10.71	$10.35	$0.36
	85027	Complete CBC automated	$8.84	$8.64	$0.21
2. Metabolic panel	80047	Metabolic panel ionized calcium	$10.74	$11.21	-$0.47
	80048	Metabolic panel total calcium	$9.88	$11.21	-$1.33
	80053	Comprehensive metabolic panel	$12.25	$14.12	-$1.87
3. Lipid panel	80061	Lipid panel	$13.71	$17.78	-$4.07
4. Hgb A1C	83036	Glycosylated hemoglobin test	$13.37	$13.07	$0.30
	83037	Glycosylated hemoglobin home device	$13.19	$13.07	$0.12
5. Thyroid	84436	Assay of total thyroxine	$9.45	$9.17	$0.28
	84439	Assay of free thyroxine	$12.31	$12.10	$0.21
	84442	Assay of thyroid activity	$20.11	$19.54	$0.57
	84443	Assay thyroid stim hormone	$22.93	$22.89	$0.05

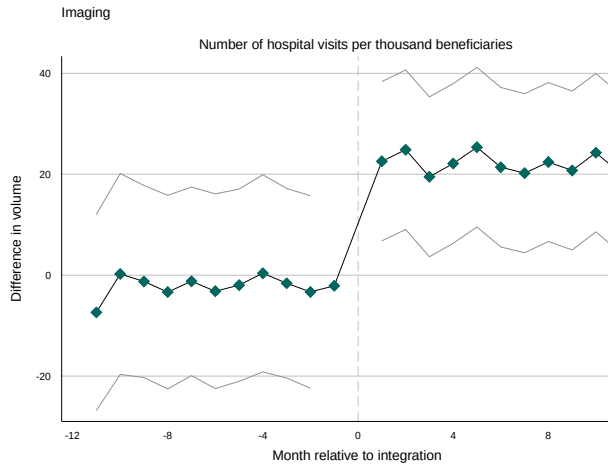
Appendix Exhibit 2: Site of Care Definitions

Code	Name	Definition of Site of Care	
		Imaging	Lab
Carrier file (Place of Service)			
11	Office	Non-hospital-based	Non-hospital-based
19	Off Campus-Outpatient Hospital	Hospital-based	Hospital-based
22	On Campus-Outpatient Hospital	Hospital-based	Hospital-based
81	Independent Laboratory	Non-hospital-based	Non-hospital-based
49	Independent Clinic	Non-hospital-based	NA
Outpatient (Facility Type, Service Type)			
12	Hospital, Inpatient or Home Health (covered on Part B)	Hospital-based	Hospital-based
13	Hospital, Outpatient (or HHA - covered on Part A)	Hospital-based	Hospital-based
71	Clinic or hospital-based renal dialysis facility, Rural Health Clinic (RHC)	Hospital-based	Hospital-based
77	Clinic or hospital-based renal dialysis facility, Federally Qualified Health Center (FQHC)	Hospital-based	Hospital-based
83	Special facility or ASC surgery, ASC in hospital outpatient department	Non-hospital-based	Non-hospital-based
85	Special facility or ASC surgery, Critical Access Hospital - Outpatient Services	Non-hospital-based	Non-hospital-based

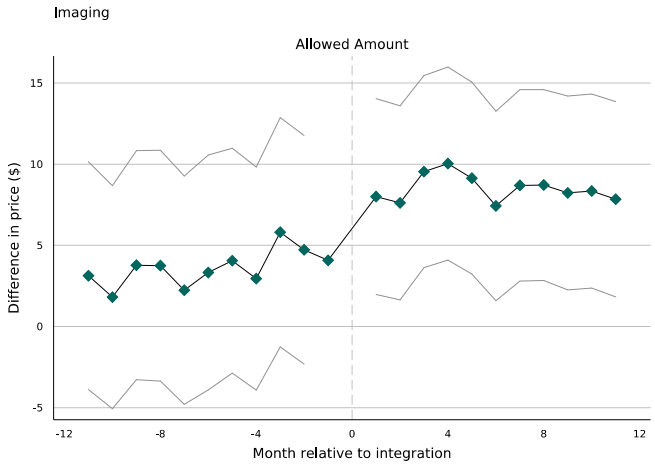
Appendix Exhibit 3: Regression-Adjusted Trends in Hospital-Based Sites of Care and Medicare Reimbursement for Imaging and Laboratory Tests

Imaging Tests

(a) Number of Hospital-Based Tests

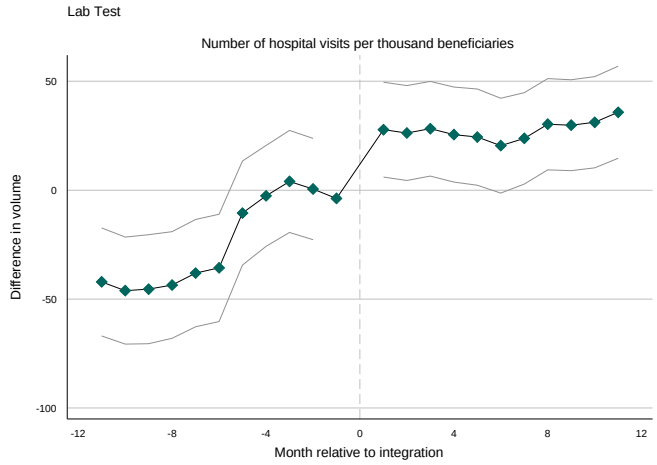


(b) Medicare Reimbursement Amount

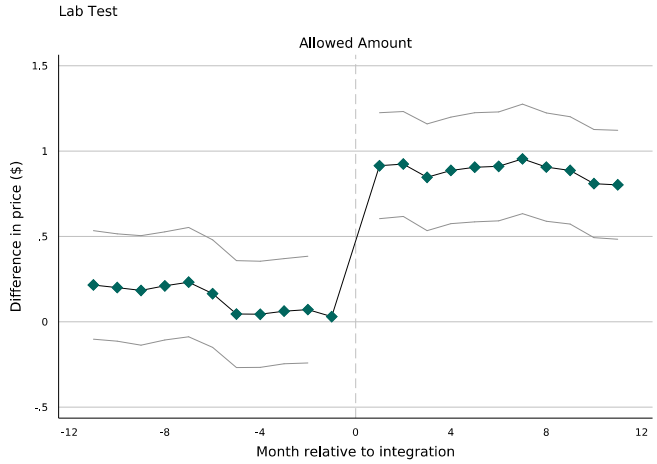


Laboratory Tests

(c) Number of Hospital-Based Tests



(d) Medicare Reimbursement Amount



Appendix Exhibit 4: Sensitivity Test that Examines the Importance of Included Controls—Imaging Tests

	(1)	(2)	(3)	(4)
Panel A: Probability of hospital vs. non-hospital site of care				
Vertically integrated physician group	0.0901*** (0.0886 - 0.0915)	0.0901*** (0.0886 - 0.0915)	0.0822*** (0.0810 - 0.0835)	0.0246*** (0.0212 - 0.0280)
R-squared	0.011	0.012	0.145	0.499
Baseline mean	66.4%	66.4%	66.4%	66.4%
Additional change due to vertical integration	567,117	567,117	517,392	154,840
Panel B: Medicare spending amount				
Vertically integrated physician group	19.79*** (19.06 - 20.51)	19.78*** (19.06 - 20.51)	16.69*** (16.23 - 17.14)	6.382*** (4.995 - 7.770)
R-squared	0.037	0.037	0.355	0.541
Baseline mean	$294.5	$294.5	$294.5	$294.5
Additional change due to vertical integration	124,564,296	124,501,353	105,051,950	40,170,255
Provider-procedure-month observations	9,019,641	9,019,641	9,019,641	9,016,684
Number of procedures	29,497,879	29,497,879	29,497,879	29,497,879
Number of procedures by vertically integrated physicians	6,294,305	6,294,305	6,294,305	6,294,305
Year FE	X	X	X	X
Month FE		X	X	X
Procedure FE			X	X
Group FE				X

This table presents regression results that measure the association between vertical integration and the probability of hospital vs. non-hospital sites of care (Panel A) and Medicare spending amounts (Panel B) for imaging tests. For each outcome, column 1 includes year fixed effects, column 2 adds month fixed effects, column 3 adds procedure (CPT code) fixed effects, and column 4 adds physician group fixed effects. Regression models were estimated using linear regressions, which are weighted by volume at the year-month-procedure-physician group level. Confidence intervals from heteroskedasticity-robust standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

Appendix Exhibit 5: Sensitivity Test that Examines the Importance of Included Controls—Laboratory Tests

	(1)	(2)	(3)	(4)
Panel A: Probability of hospital vs. non-hospital site of care				
Vertically integrated physician group	0.0741*** (0.0714 - 0.0768)	0.0739*** (0.0712 - 0.0766)	0.0692*** (0.0665 - 0.0719)	0.0362*** (0.0312 - 0.0412)
R-squared	0.011	0.012	0.145	0.499
Baseline mean	44.1%	44.1%	44.1%	44.1%
Additional change due to vertical integration	4,284,521	4,272,957	4,001,199	2,093,113
Panel B: Medicare spending amount				
Vertically integrated physician group	2.102*** (2.060 - 2.145)	2.103*** (2.060 - 2.145)	2.257*** (2.223 - 2.291)	0.569*** (0.500 - 0.637)
R-squared	0.037	0.037	0.355	0.541
Baseline mean	$14.4	$14.4	$14.4	$14.4
Additional change due to vertical integration	121,539,307	121,597,128	130,501,530	32,900,031
Observations	17,613,885	17,613,885	17,613,885	17,613,549
Number of procedures	341,365,722	341,365,722	341,365,722	341,365,722
Number of procedures by vertically integrated physicians	57,820,793	57,820,793	57,820,793	57,820,793
Year FE	X	X	X	X
Month FE		X	X	X
Procedure FE			X	X
Group FE				X

This table presents regression results that measure the association between vertical integration and the probability of hospital vs. non-hospital sites of care (Panel A) and Medicare spending amounts (Panel B) for laboratory tests. For each outcome, column 1 includes year fixed effects, column 2 adds month fixed effects, column 3 adds procedure (CPT code) fixed effects, and column 4 adds physician group fixed effects. Regression models were estimated using linear regressions, which are weighted by volume at the year-month-procedure-physician group level. Confidence intervals from heteroskedasticity-robust standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

Appendix Exhibit 6: Sensitivity Test that Examines Differences for Specific Diagnostic Imaging Tests

	(1) Head CT scan	(2) Brain MRI	(3) Lumbar MRI	(4) Thorax CT scan	(5) Abdomen/Pelvis CT scan
Panel A: Probability of hospital vs. non-hospital site of care					
Vertically integrated physician group	-0.00374* (-0.00799 - 0.000510)	0.0464*** (0.0376 - 0.0553)	0.0380*** (0.0279 - 0.0480)	0.0377*** (0.0297 - 0.0456)	0.0250*** (0.0195 - 0.0305)
R-squared	0.553	0.502	0.569	0.607	0.510
Baseline mean	83.3%	58.9%	45.3%	66.1%	69.8%
Panel B: Medicare spending amount					
Vertically integrated physician group	7.828*** (5.958 - 9.697)	8.963*** (6.057 - 11.87)	3.881*** (1.591 - 6.170)	2.398* (-0.317 - 5.112)	7.991*** (5.288 - 10.69)
R-squared	0.541	0.548	0.544	0.511	0.530
Baseline mean	$219.5	$421.8	$332.1	$260.0	$350.7
Provider-procedure-month observations	1,687,506	1,347,580	1,284,284	2,018,524	2,648,393
Number of procedures	7,189,792	3,407,970	3,640,574	6,740,520	8,519,022

This table presents regression results that measure the association between vertical integration and the probability of hospital vs. non-hospital sites of care (Panel A) and Medicare spending amounts (Panel B) for each specific diagnostic imaging procedure. Regression models were estimated using linear regressions and include fixed effect controls for year, month, procedure code, and physician group. Regression models were weighted by volume at the year-month-procedure-physician group level. Confidence intervals from heteroskedasticity-robust standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

Appendix Exhibit 7: Sensitivity Test that Examines Differences for Specific Diagnostic Laboratory Tests

	(1) Complete CBC	(2) Metabolic panel	(3) Lipid Panel	(4) HbA1C	(5) Thyroid test
Panel A: Probability of hospital vs. non-hospital site of care					
Vertically integrated physician group	0.0278*** (0.0186 - 0.0369)	0.0296*** (0.0201 - 0.0390)	0.0440*** (0.0301 - 0.0580)	0.0402*** (0.0268 - 0.0535)	0.0441*** (0.0334 - 0.0548)
R-squared	0.820	0.851	0.902	0.893	0.862
Baseline mean	51.4%	47.6%	38.3%	41.6%	38.0%
Panel B: Medicare spending amount					
Vertically integrated physician group	0.595*** (0.486 - 0.704)	0.965*** (0.805 - 1.126)	0.0646 (-0.0838 - 0.213)	0.325*** (0.221 - 0.429)	0.439*** (0.335 - 0.543)
R-squared	0.836	0.836	0.869	0.857	0.909
Baseline mean	$11.4	$13.4	$16.3	$14.6	$18.6
Provider-procedure-month observations	4,069,465	4,606,823	2,320,582	2,147,704	4,456,250
Number of procedures	94,393,113	103,615,982	54,056,752	33,312,376	55,987,498

This table presents regression results that measure the association between vertical integration and the probability of hospital vs. non-hospital sites of care (Panel A) and Medicare spending amounts (Panel B) for each specific diagnostic laboratory test procedure. Regression models were estimated using linear regressions and include fixed effect controls for year, month, procedure code, and physician group. Regression models were weighted by volume at the year-month-procedure-physician group level. Confidence intervals from heteroskedasticity-robust standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

Appendix Exhibit 8: Sensitivity Test Does Not Weight by Volume—Imaging Tests

	(1)	(2)	(3)	(4)
Panel A: Probability of hospital vs. non-hospital site of care				
Vertically integrated physician group	0.0564*** (0.0554 - 0.0574)	0.0564*** (0.0554 - 0.0575)	0.0677*** (0.0667 - 0.0688)	0.0143*** (0.0111 - 0.0175)
R-squared	0.001	0.001	0.093	0.359
Baseline mean	66.4%	66.4%	66.4%	66.4%
Additional change due to vertical integration	354,999	354,999	426,124	90,009
Panel B: Medicare spending amount				
Vertically integrated physician group	63.93*** (63.24 - 64.62)	63.94*** (63.25 - 64.62)	53.26*** (52.61 - 53.91)	14.31*** (12.72 - 15.89)
R-squared	0.031	0.031	0.247	0.405
Baseline mean	$294.5	$294.5	$294.5	$294.5
Additional change due to vertical integration	402,394,919	402,394,919	335,234,684	90,071,505
Provider-procedure-month observations	9,019,641	9,019,641	9,019,641	9,016,684
Number of procedures	29,497,879	29,497,879	29,497,879	29,497,879
Number of procedures by vertically integrated physicians	6,294,305	6,294,305	6,294,305	6,294,305
Year FE	X	X	X	X
Month FE		X	X	X
Procedure FE			X	X
Group FE				X

This table presents regression results that measure the association between vertical integration and the probability of hospital vs. non-hospital sites of care (Panel A) and Medicare spending amounts (Panel B) for imaging tests. Unlike the main regressions, these observations are not weighted by volume within each year-month-procedure-physician group cell. For each outcome, column 1 includes year fixed effects, column 2 adds month fixed effects, column 3 adds procedure (CPT code) fixed effects, and column 4 adds physician group fixed effects. Regression models were estimated using linear regressions. Confidence intervals from heteroskedasticity-robust standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

Appendix Exhibit 9: Sensitivity Test Does Not Weight by Volume—Laboratory Tests

	(1)	(2)	(3)	(4)
Panel A: Probability of hospital vs. non-hospital site of care				
Vertically integrated physician group	0.0802*** (0.0792 - 0.0812)	0.0803*** (0.0793 - 0.0813)	0.0703*** (0.0694 - 0.0713)	0.0304*** (0.0274 - 0.0334)
R-squared	0.023	0.026	0.061	0.554
Baseline mean	44.1%	44.1%	44.1%	44.1%
Additional change due to vertical integration	4,637,228	4,643,010	4,064,802	1,757,752
Panel B: Medicare spending amount				
Vertically integrated physician group	7.025*** (6.986 - 7.064)	7.025*** (6.986 - 7.064)	7.278*** (7.241 - 7.315)	1.328*** (1.259 - 1.396)
R-squared	0.025	0.025	0.252	0.639
Baseline mean	$14.4	$14.4	$14.4	$14.4
Additional change due to vertical integration	406,191,071	406,191,071	420,819,731	76,786,013
Observations	17,613,885	17,613,885	17,613,885	17,613,549
Number of procedures	341,365,722	341,365,722	341,365,722	341,365,722
Number of procedures by vertically integrated physicians	57,820,793	57,820,793	57,820,793	57,820,793
Year FE	X	X	X	X
Month FE		X	X	X
Procedure FE			X	X
Group FE				X

This table presents regression results that measure the association between vertical integration and the probability of hospital vs. non-hospital sites of care (Panel A) and Medicare spending amounts (Panel B) for laboratory tests. Unlike the main regressions, these observations are not weighted by volume within each year-month-procedure-physician group cell. For each outcome, column 1 includes year fixed effects, column 2 adds month fixed effects, column 3 adds procedure (CPT code) fixed effects, and column 4 adds physician group fixed effects. Regression models were estimated using linear regressions. Confidence intervals from heteroskedasticity-robust standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

Appendix Exhibit 10: Change in Attributed Beneficiary Age and Gender

Attributed Medicare FFS beneficiary characteristic	(1) age	(2) female
Change following vertical integration	0.0809	0.0105**
	(0.0827)	(0.00466)
Observations	285,193	285,193
R-squared	0.759	0.703
Mean	75.4	57.4%

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1