Does Agricultural Worker Density Moderate the Relationship Between Physician Supply and Low Birth Weight? Evidence from U.S. Counties

Honors Thesis

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By

Melanie A. Brousseau
Department of Economics

Dr. Anita Alves Pena, Department of Economics
Graduate Student Instructor Benjamin Basow, Department of Economics

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Abstract

Migrant and seasonal farmworkers face disproportionate health risks due to occupational exposure, geographic isolation, and structural barriers to care, but the supply-side capacity of healthcare systems serving agricultural communities is understudied at the population level. This study addresses that gap by investigating whether primary care physician supply predicts low birth weight rates at the county level and whether agricultural worker density moderates that relationship across United States counties. Using a cross-sectional design, this study utilizes county-level data sourced from the 2025 County Health Rankings, the 2022 USDA Census of Agriculture, the Healthy Resources and Services Administration Federally Qualified Health Center site database, the 2021 American Community Survey, and Kaiser Family Foundation Medicaid expansion records. These datasets are linked through Federal Information Processing Standard codes and encompass approximately 2,700 counties. The primary analysis estimates a moderated linear regression model in which the percentage of low-birth-weight births serves as the outcome, primary care physicians per 100,000 population serves as the independent variable, and agricultural worker density serves as the moderating variable. Results indicate a statistically significant negative interaction between physician supply and agricultural worker density ($B_3 = -0.118$, $p < 0.01$), indicating that as agricultural worker concentration increases, the association between physician supply and low birth weight rates becomes steeper. These findings suggest that county-level physician supply measures alone may not fully capture effective healthcare access in agricultural communities.

Introduction

Migrant and seasonal farmworkers are foundational to the United States food supply, yet they remain among the most medically underserved populations in the country. Agriculture has been ranked one of the most hazardous industries in the United States for decades (National Safety Council, 2023), and the workers in the industry face a compounding set of health risks rooted in occupational exposure, housing conditions, economic poverty, and limited legal protection. The health burden by this population is both severe and well documented at the individual and community level. Farmworkers experience heat-related illness at four times the rate of workers in other industries, and agriculture's mortality rate from heat illness is 20 times greater than the broader workforce (Moyce & Schenker, 2017). Musculoskeletal injuries, pesticide exposure, respiratory illness, and chronic conditions, including diabetes, hypertension, and obesity, are disproportionately prevalent among this group (National Center for Farmworker Health [NCFH], 2022). Mental health challenges, including depression and anxiety tied to social isolation, discrimination, and fear of deportation, compound these physical risks (Bonney et al., 2025).

Access to care remains systemically constrained for this population even where providers are nominally available. Geographic distance, lack of transportation, limited English proficiency, and the opportunity cost of lost wages are all barriers to health utilization (Arcury & Quandt, 2007). Fear of deportation and employment retaliation further depress care-seeking among undocumented workers, who represented 42% of hired crop farmworkers nationally between 2020 and 2022 (Castillo, 2024). Only 28% of farmworkers receive employer-sponsored health insurance, and 41% of migrant and seasonal workers lived below the federal poverty line in 2021 to 2022 (Fung et al., 2023). The result is a population with concentrated health needs and suppressed demand for the care that could address them.

Throughout literature, a gap exists on quantifying the supply side of the healthcare market and whether it predicts measurable health outcomes in agricultural communities. Also, if the concentration of agricultural workers in a county affects these health outcomes. Although many studies have documented the barriers that farmworkers face in accessing care, few have used population-level outcome data to model the interaction between provider supply and worker density. This gap is significant: if physician supply matters more in high-ag counties than in low-ag counties, then targeted provider investment in agricultural areas represents a high-return policy opportunity that is still underutilized. Despite this, the bulk of published research on farmworker health has concentrated on high-density labor markets in California, Texas, Florida, and Washington (U.S. Bureau of Labor Statistics, 2023), leaving a significant geographic blind spot across the High Plains and Intermountain West. States like Montana, North Dakota, South Dakota, and Wyoming rank among the highest in the nation for farm employment as a share of total jobs (DePietro, 2021), yet the health infrastructure serving their agricultural workforce is far less studied.

This study attempts to address that gap using a county-level cross-sectional analysis of the U.S. Using cross-sectional data, this study estimates a moderated linear regression model in which the percentage of low-weight births serves as the outcome, primary care physician supply serves as the primary independent variable, and agricultural worker density serves as the moderating variable. The analysis includes a national sample of approximately 2,700 counties and a regional subgroup restricted to the six states: Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming. These six states correspond to the service area of the High Plains Intermountain Center for Agricultural Health and Safety (HICAHS), a National Institute for Occupational Safety and Health (NIOSH)-funded center, providing a regionally meaningful framework for analyzing agricultural worker health outcomes.

Methods and Materials

Data Sources

This study constructs a county-level cross-sectional dataset of the U.S. by linking six data sources using the five-digit Federal Information Processing Standard (FIPS) codes as the common join key. County analysis was chosen as it was the smallest geographic level at which all six sources report consistently and because county-level variables in both healthcare supply and agricultural worker concentration are substantial enough to identify the moderated relationship of interest.

The 2025 County Health Rankings (CHR), published annually by the University of Wisconsin Population Health Institute, serves as the backbone of the dataset. CHR was selected as it aggregates health outcome data and multiple socioeconomic variables into a single file, making it the most comprehensive publicly available source for the control variables needed to isolate the physician-supply effect. From CHR, this study draws the outcome variable (percentage of live births classified as low birth weight); the primary supply measure (primary care physicians per 100,000 population, converted from CHR's reported population-to-physician ratio); other primary care providers per 100,000; and socioeconomic controls, including median household income, percentage uninsured, percentage unemployed, the food environment index, adult smoking rate, obesity rate, teen birth rate, and percentage age 65 and older. Connecticut was excluded from the analytic sample because CHR 2025 reports planning region boundaries rather than county boundaries for that state, creating a geographic unit mismatch that cannot be reconciled with the FIPS-based merge.

Agricultural worker density, the moderating variable, is constructed from the 2022 USDA Census of Agriculture. The Census of Agriculture is conducted every five years and is a federal source that provides county-level hired farm labor counts with consistent methodology across all states. The latest section is 2022 and aligns well with the measurement window of CHR 2025, which measures roughly from 2021 to 2023. Raw worker counts from the USDA file are divided by total county population from CHR to form the agricultural density measure. Values that were suppressed by the USDA were too low for confidentiality rules and are coded as missing.

Federally Qualified Health Center (FQHC) site counts are taken from the HRSA Health Center site database, accessed in March 2026. Since the HRSA Health Center site database is a continuously updated administrative database rather than a periodic survey or fixed-vintage publication, the data is not tied to a specific date. FQHCs are included as a supply measure as they are the primary federally funded, serving uninsured and underinsured populations, and their distribution is not captured in the physician ratio reported by CHR. Only patient-care locations are retained from the HRSA file; sites classified as administrative-only are excluded. Counties absent from the HRSA file are assigned a count of zero on the assumption that absence reflects the genuine absence of a site. FQHC counts are then scaled to sites per 100,000 population using the CHR population denominator to ensure comparability with the physician supply measure.

The percentage of foreign-born residents is obtained from the 2021 American Community Survey (ACS) five-year estimates, specifically table B05003. The percentage of foreign-born residents is a theoretically appropriate proxy for immigration-related access barriers like fear of deportation, language barriers, and exclusions from federal insurance programs that literature identifies to suppress farmworkers' care-seeking. The 2021 five-year vintage (covering 2017 to 2021) is selected to align with the CHR outcome measurement period. Puerto Rico is excluded.

Rurality is captured using the 2023 USDA Rural-Urban Continuum Codes (RUCC), which classify counties on a nine-point scale from most urban (1) to most rural (9). RUCC is included because physician supply and birth outcomes both vary systematically with how urban or rural a place is. Two dummy variables are constructed from RUCC: metro (codes 1 to 3) and micropolitan (codes 4 to 5), with rural counties (codes 6 to 9) as the reference category. The 2023 vintage is the most recently available and ensures that rurality classifications reflect current county population structures.

Medicaid expansion status is coded as a binary indicator using Kaiser Family Foundation state-level records as of January 1, 2022. Medicaid expansion refers to a provision of the Affordable Care Act (ACA, passed in 2010) that gave states the option to expand their Medicaid programs to cover more low-income adults than were previously eligible. This variable is included because Medicaid expansion substantially increases insurance coverage for low-income adults, such as farmworkers. South Dakota and North Carolina are coded as non-expansion states as of the coding date, as neither had yet implemented expansion at that time.

Why Low Birth Weight Rates?

Low birth weight was selected as the outcome variable for both theoretical and methodological reasons. Theoretically, it captures a downstream consequence of the cumulative health burden that agricultural communities face, including occupational pesticide exposure, limited prenatal care access, and socioeconomic stress, making it well suited to the supply-side question this study addresses. Prenatal pesticide exposure in particular has been linked across multiple study populations to intrauterine growth restriction and reduced birth weight, providing a biologically plausible connection between agricultural worker density and the outcome of interest (Ma et al., 2025). Methodologically, low birth weight is fully administrative, drawn from birth certificate records rather than insurance claims or patient surveys, and is therefore least affected by the insurance-based exclusions and fear-based underreporting that suppress utilization measures among undocumented and uninsured farmworker populations (Arcury & Quandt, 2007). This matters particularly in high-ag-density counties, where a substantial share of residents may avoid formal healthcare contact due to immigration status, language barriers, or fear of employment retaliation (Moyce & Schenker, 2017; Fung et al., 2023). Together, these properties make low birth weight a reliable, meaningful, and population-appropriate signal of health burden in the counties most central to this analysis.

Sample Construction

The CHR files serve as the base. After joining both the CHR files and removing state and national summary rows, the base dataset contains 3,159 counties. All other merges with USDA, RUCC, HRSA, and ACS data were joined into the dataset. 125 counties missing the outcome variable (% low birth weight) are dropped from the analytic sample, leaving 3,034 counties. Hood River County, Oregon, is excluded from the primary analytic sample on the basis of high leverage (leverage = 0.487), the highest in the sample. The county reports 220 physicians per 100,000 people, a value attributable to American Medical Association attribution practices for physicians practicing near the Portland metropolitan area rather than a genuine local supply. Inclusion of Hood River County made the thesis interaction term non-significant. The final national analytic sample contains 2,679 counties. The HICAHS regional subgroup is defined as counties in Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming, yielding 184 counties.

Variables

The outcome variable is the percentage of live births classified as low birth weight (below 2,500 grams), drawn from birth certificate records via CHR 2025.

The primary independent variable is primary care physicians per 100,000 people (physicians_per_100k). Two additional supply measures are included as controls and robustness checks: other primary care providers per 100,000 and FQHC sites per 100,000. The moderating variable is agricultural worker density, defined as the ratio of agricultural workers to total county population. The thesis interaction term (B_3) is the product of physician supply and agricultural worker density.

Socioeconomic and demographic controls include median household income, percentage uninsured, percentage unemployed, the food environment index, percentage foreign born, percentage age 65 and older, adult smoking rate, obesity rate, teen birth rate, and a binary indicator for Medicaid expansion status. Rurality is captured through two dummy variables, as discussed earlier, and percentage Hispanic was considered but excluded from the final control set due to a Pearson correlation of 0.71 with percentage foreign-born; percentage foreign-born is retained as the theoretically grounded proxy for immigration-related access barriers. See Figure A1: Correlation Matrix, in the appendix for the full Pearson correlation matrix for each variable.

Empirical Strategy

The primary estimating equation is a moderated linear regression of the form:

% Low Birth Weight = B_0 + B_1(physicians) + B_2(ag density) + B_3(physicians x ag density) + B(controls) + error

The four continuous variables involved in interaction terms (physicians per 100k, other providers per 100k, FQHC sites per 100k, and agricultural worker density) are mean-centered prior to model estimation. The centering is applied across all models so that coefficients are easily comparable. Continuous control variables that are not involved in the interaction terms are not centered.

Each control variable was added sequentially, showing the stability of the physician supply coefficient as shown in Figure A2: The Physician Coefficient Path in the appendix. The primary interaction models are then estimated on the fully controlled specification, each testing a different supply-side moderator: physician supply by ag density, other providers by ag density, and FQHC sites by ag density. Heteroskedasticity-consistent standard errors (HC3) are used throughout, following detection of mild heteroskedasticity in the fully controlled model residual diagnostics. Variance inflation factors are computed for the model to verify that multicollinearity does not distort the interaction term estimates. See Figure A3: Fully Controlled Model Residual Diagnostics, in the appendix for the full diagnostics check.

Results

Descriptive Statistics

Descriptive statistics for the national analytic sample are presented in Table 1. The mean low birth weight rate is 8.42% (SD = 2.15), with values ranging from 3% to 23% across counties. The mean physician supply is 54.22 per 100,000 population (SD = 34.66, median = 47.37). Agricultural worker density averages 2.54% of county population (SD = 3.40%, median = 1.34%), with a maximum of 45.59%, indicating a right-skewed distribution. Approximately 3% of counties are missing agricultural worker density due to USDA confidentiality suppression, and 5% are missing physician supply or teen birth rate. Table 1 below shows the full descriptive statistics for each variable.

Table 1: Descriptive Statistics – National Analytic Sample

	N	Mean	SD	Min	Median	Max	PercentMissing
Low Birth Weight (%)	3034	8.42	2.15	3.00	8.00	23.00	0
Physicians per 100k	2873	54.22	34.66	3.44	47.37	581.40	5
Other Providers per 100k	3004	115.08	79.30	5.52	99.40	1923.08	1
FQHCs per 100k	3034	11.18	27.27	0.00	4.31	901.58	0
Ag Worker Density (%)	2948	2.54	3.40	0.00	1.34	45.59	3
Median Household Income ($)	3034	6.55	1.66	2.86	6.28	17.37	0
% Uninsured	3034	10.45	4.62	2.00	9.00	35.00	0
% Unemployed	3034	3.61	1.21	1.10	3.40	17.30	0
Food Environment Index	3002	7.49	1.15	0.00	7.60	10.00	1
% Hispanic	3034	10.54	13.94	0.20	5.25	97.00	0
% Foreign Born	3034	4.76	5.74	0.00	2.74	53.99	0
% Age 65+	3034	20.66	4.82	5.70	20.40	57.10	0
Adult Smoking Rate (%)	3034	18.06	3.90	6.00	18.00	38.00	0
Obesity Rate (%)	3034	38.05	4.65	18.00	39.00	53.00	0
Teen Birth Rate	2897	21.95	11.23	1.00	20.00	95.00	5

Bivariate Relationships

Figure 1: Bivariate Corrleations below present Pearson correlations between all analytic variables and the low-birth-weight outcome. Teen birth rate (r = 0.49), obesity rate (r = 0.37), and adult smoking rate (r = 0.35) show the strongest positive associations with low birth weight. Median income (r = -0.40), food environment index (r = -0.38), and Medicaid expansion (r = -0.28) show the strongest negative associations. Physicians per 100,000 and agricultural worker density are both negatively correlated with low birth weight in the bivariate case.

Figure 1: Bivariate Correlations

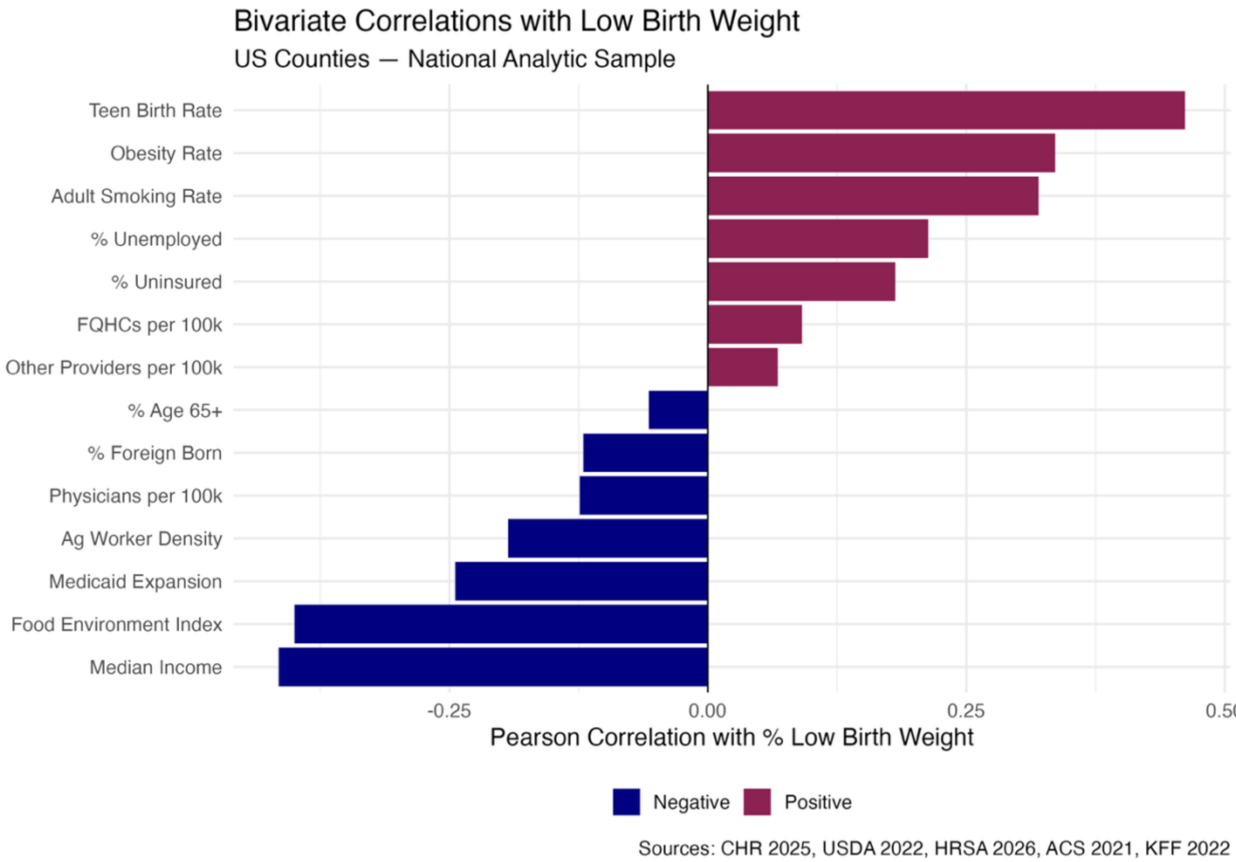


Figure 2: Physician Supply and Low Birth Weight and Figure 3: Agricultural Worker Density and Low Birth Weight are seen below display scatter plots of physician supply and agricultural worker density against low birth weight, respectively. Both show negative bivariate slopes, though with substantial dispersion around the fitted line in each case.

Figure 2: Physician Supply and Low Birth Weight

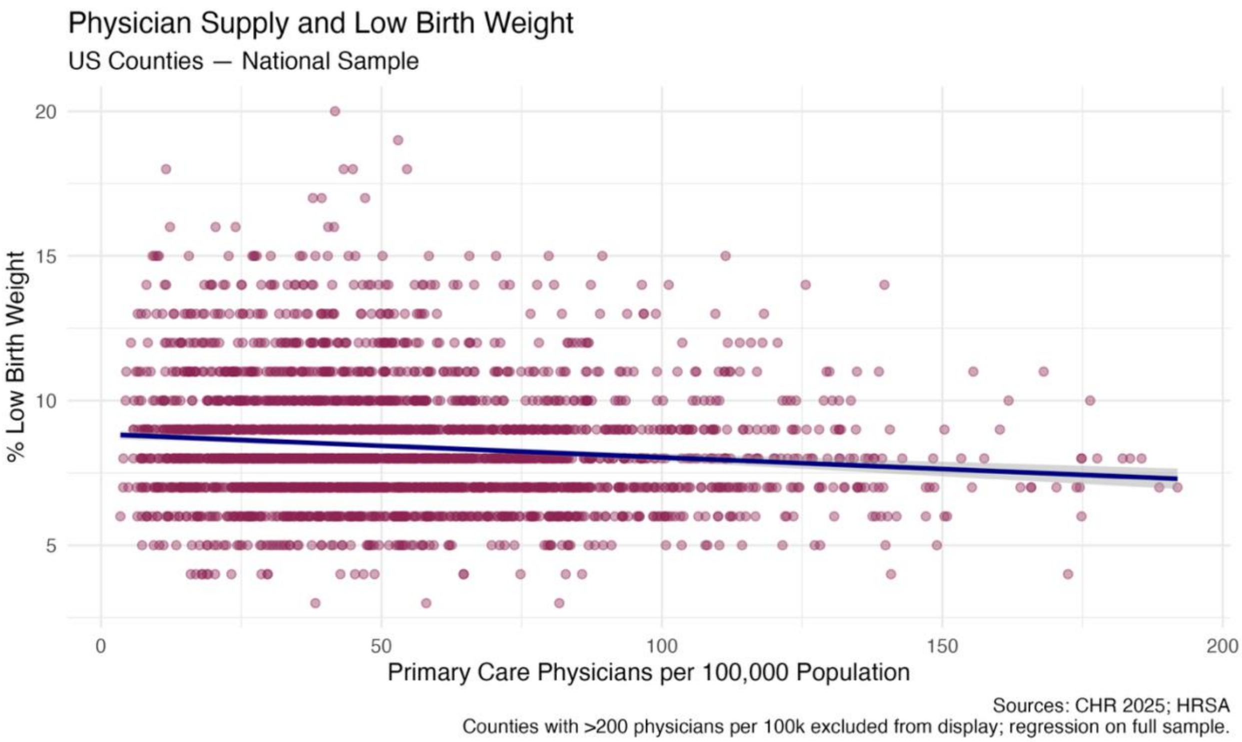
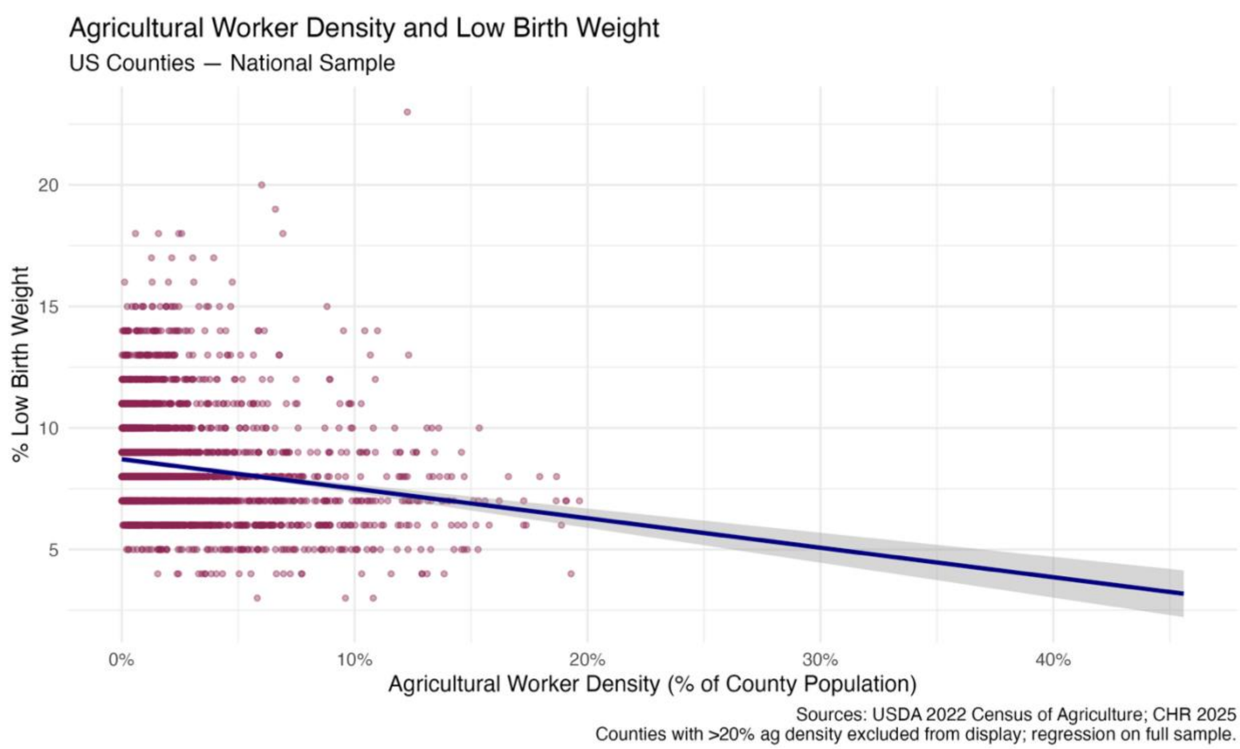


Figure 3: Agricultural Worker Density and Low Birth Weight



Primary Regression Results

Table 2: Primary Results - % Low Birth Weight below presents the four primary interaction models. In the full controls specification without an interaction term (column 1), physician supply is positively associated with low birth weight ($B1 = 0.004$, $SE = 0.002$, $p < 0.05$) and agricultural worker density is negatively associated with low birth weight ($B2 = -14.076$, $SE = 1.577$, $p < 0.001$). Medicaid expansion is associated with a reduction of approximately 1.05 percentage points in low-birth-weight rates ($B = -1.048$, $SE = 0.093$, $p < 0.001$), the largest coefficient among the policy variables. Teen birth rate ($B = 0.064$, $p < 0.001$) and obesity rate ($B = 0.028$, $p < 0.05$) are positively associated with low birth weight. Metro counties show significantly higher low birth weight rates than rural counties ($B = 0.405$, $SE = 0.090$, $p < 0.001$), while the micropolitan coefficient is not statistically significant.

Table 2: Primary Results - % Low Birth Weight

Table 2: Primary Results — % Low Birth Weight

	Full Controls	Physician x Ag Density	Provider x Ag Density	FQHC x Ag Density
(Intercept)	12.014***	11.965***	11.926***	11.971***
	(0.829)	(0.831)	(0.828)	(0.829)
Physicians per 100k (centered)	0.004*	0.003*	0.003*	0.004*
	(0.002)	(0.002)	(0.002)	(0.002)
Ag Worker Density (centered)	-14.076***	-14.510***	-14.494***	-13.660***
	(1.577)	(1.567)	(1.632)	(1.694)
Median Household Income	-0.296***	-0.303***	-0.290***	-0.301***
	(0.042)	(0.042)	(0.042)	(0.043)
% Uninsured	-0.081***	-0.080***	-0.081***	-0.082***
	(0.011)	(0.011)	(0.011)	(0.011)
% Unemployed	0.061	0.061	0.059	0.062
	(0.041)	(0.041)	(0.041)	(0.041)
Food Environment Index	-0.194**	-0.187**	-0.194**	-0.188**
	(0.059)	(0.059)	(0.059)	(0.060)
% Foreign Born	-0.010	-0.013	-0.011	-0.010
	(0.009)	(0.009)	(0.009)	(0.009)
% Age 65+	-0.026**	-0.026**	-0.025**	-0.025**
	(0.009)	(0.009)	(0.009)	(0.009)
Adult Smoking Rate	-0.053***	-0.054***	-0.053***	-0.052***
	(0.016)	(0.016)	(0.016)	(0.016)
Obesity Rate	0.028*	0.029*	0.028*	0.028*
	(0.013)	(0.014)	(0.013)	(0.013)
Teen Birth Rate	0.064***	0.064***	0.064***	0.064***
	(0.006)	(0.006)	(0.006)	(0.006)
Medicaid Expansion	-1.048***	-1.054***	-1.049***	-1.047***
	(0.093)	(0.094)	(0.093)	(0.094)
Micropolitan (ref: Rural)	-0.111	-0.113	-0.116	-0.120
	(0.114)	(0.113)	(0.114)	(0.114)
Metro (ref: Rural)	0.405***	0.398***	0.393***	0.395***
	(0.090)	(0.090)	(0.091)	(0.090)
Other Providers per 100k (centered)	-0.001	-0.001	-0.001	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)
FQHCs per 100k (centered)	0.010***	0.010***	0.011***	0.010**
	(0.003)	(0.003)	(0.003)	(0.003)
Physicians x Ag Density (B3)		-0.118**		
		(0.044)		
Other Providers x Ag Density (B3)			-0.036	
			(0.025)	
FQHC x Ag Density (B3)				0.149
				(0.120)
Num.Obs.	2679	2679	2679	2679
R2	0.379	0.381	0.380	0.380
R2 Adj.	0.376	0.377	0.376	0.376
AIC	10276.1	10269.7	10275.2	10274.5
BIC	10382.2	10381.7	10387.1	10386.5
Log.Lik.	-5120.049	-5115.843	-5118.588	-5118.261
F	77.763	74.078	72.881	73.637
RMSE	1.64	1.63	1.64	1.63
Std.Errors	HC3	HC3	HC3	HC3

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

HC3 robust standard errors. Rural (RUCC 6-9) is the reference category. + p<0.1, * p<0.05, ** p<0.01, *** p<0.001

The primary interaction model (column 2) adds the physician supply by agricultural worker density interaction term. The interaction coefficient is negative and statistically significant (B3 = -0.118, SE = 0.044, $p < 0.01$). The main effects of physician supply (B1 = 0.003, $p < 0.05$) and agricultural worker density (B2 = -14.510, $p < 0.001$) remain consistent in sign and magnitude with the full controls model. Model fit improves modestly with the addition of the interaction term ($R^2 = 0.381$ vs. 0.379).

The robustness interaction models (columns 3 and 4) substitute other primary care providers and FQHC sites as the interacting supply variable, respectively. Neither interaction term reaches statistical significance (other providers B3 = -0.036, SE = 0.025, p = 0.15; FQHC B3 = 0.149, SE = 0.120, p = 0.21). Main effects and control coefficients are stable across all four columns.

HICAHS Subgroup

Table 3: HICAHS Subgroup - % Low Birth Weight presents the HICAHS subgroup results alongside the National Model with the interaction term estimates. The analytic sample for the subgroup is 184 counties across Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming. The agricultural worker density main effect remains negative and significant in the subgroup (B2 = -13.441, SE = 6.294, $p < 0.05$), consistent in magnitude with the national estimate. The physician supply by agricultural worker density interaction term is not statistically significant in the subgroup (B3 = 0.106, SE = 0.200, p = 0.60). Several control variables that are significant in the national sample, including median income, percent uninsured, food environment index, and Medicaid expansion, are not significant in the subgroup. Standard errors are substantially larger in the subgroup across all coefficients.

Table 3: HICAHS Subgroup - % Low Birth Weight

	National Model	HICAHS Subgroup
(Intercept)	11.965***	12.511***
	(0.831)	(2.922)
Physicians per 100k (centered)	0.003*	-0.007
	(0.002)	(0.005)
Ag Worker Density (centered)	-14.510***	-13.441*
	(1.567)	(6.294)
Other Providers per 100k (centered)	-0.001	-0.003
	(0.001)	(0.003)
FQHCs per 100k (centered)	0.010***	0.041*
	(0.003)	(0.016)
Median Household Income	-0.303***	-0.076
	(0.042)	(0.124)
% Uninsured	-0.080***	-0.040
	(0.011)	(0.066)
% Unemployed	0.061	0.268
	(0.041)	(0.237)
Food Environment Index	-0.187**	0.117
	(0.059)	(0.278)
% Foreign Born	-0.013	0.067
	(0.009)	(0.054)
% Age 65+	-0.026**	-0.000
	(0.009)	(0.038)
Adult Smoking Rate	-0.054***	0.096+
	(0.016)	(0.051)
Obesity Rate	0.029*	-0.205***
	(0.014)	(0.043)
Teen Birth Rate	0.064***	0.031
	(0.006)	(0.024)
Medicaid Expansion	-1.054***	-0.366
	(0.094)	(0.367)
Micropolitan (ref: Rural)	-0.113	0.035
	(0.113)	(0.473)
Metro (ref: Rural)	0.398***	-0.164
	(0.090)	(0.400)
Physicians x Ag Density (B3)	-0.118**	0.106
	(0.044)	(0.200)
Num.Obs.	2679	184
R2	0.381	0.418
R2 Adj.	0.377	0.358
AIC	10269.7	712.9
BIC	10381.7	774.0
Log.Lik.	-5115.843	-337.454
F	74.078	7.521
RMSE	1.63	1.51
Std.Errors	HC3	HC3

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

HC3 robust standard errors. Rural (RUCC 6-9) is the reference category. + p<0.1, * p<0.05, ** p<0.01, *** p<0.001 HICAHS: CO, MT, ND, SD, UT, WY. Null B3 in subgroup likely reflects regional homogeneity and limited power (n≈185).

Sensitivity Analysis

When Hood River County is retained in the sample, the interaction coefficient attenuates from -0.118 ($p < 0.01$) to -0.051 ($p = 0.47$). The B2 main effect and all control coefficients are stable across both specifications. The FQHC per 100k coefficient, Medicaid expansion coefficient, and metro dummy are unchanged in sign and significance regardless of Hood River inclusion. Table A1 in the appendix presents the Hood River County sensitivity check.

Discussion

This study estimated the relationship between primary care physician supply and low birth weight rates at the county level and tested whether agricultural worker density moderated that relationship across a national sample of approximately 2,700 counties.

The Physician Supply Coefficient

The positive physician supply coefficient in the fully controlled models is unexpected given the direction of the bivariate relationship. The positive estimate may reflect residual confounding from unmeasured county-level characteristics rather than a true positive relationship between physician supply and low birth weight. Individual-level data would be better suited to isolate this relationship.

The Negative Ag Density Effect

The negative main effect of agricultural worker density (B2) is consistent across all specifications but should not be interpreted as evidence that farmworker populations experience better health outcomes than the general population. County-level averages obscure within-county distributions, and the negative coefficient likely reflects the composition of agricultural labor markets rather than a genuine health advantage for this population.

The Interaction Effect

The negative and significant interaction term (B3 = -0.118, $p < 0.01$) indicates that the association between physician supply and low birth weight varies with agricultural worker density, such that the negative slope between physician supply and low birth weight becomes steeper as agricultural worker concentration increases. Since the four continuous interaction variables are mean-centered, the conditional effect of physicians at any given level of ag density is expressed as: Effect = 0.003 + (-0.118)(ag density). At the sample mean, where the centered variable equals zero, each additional physician per 100,000 is associated with a 0.003 percentage point increase in low birth weight, reflecting the positive main effect B1. As ag density rises above the mean, however, the physician effect becomes progressively more protective. At one standard deviation above the mean (centered at 0.034), the conditional effect shifts to approximately -0.001 percentage points per physician, and at two standard deviations above the mean (centered at 0.068), it reaches -0.005, meaning that adding 20 physicians per 100,000 in a county at that level of ag density would be associated with roughly a 0.10 percentage point reduction in low birth weight. Interpreting B3 through a one-whole-unit increase in ag density would be misleading, because ag density is measured as a proportion and a one-unit increase would imply moving from a realistic value like 2.54% to over 100% of the county population working in agriculture. The meaningful variation occurs across hundredths, making the standard deviation the appropriate benchmark. The main effects remain stable in sign and magnitude with the addition of the interaction term, model fit improves modestly (R^2 = 0.381 versus 0.379), and given the cross-sectional design, causal interpretation is not warranted.

The HICAHS Subgroup

The interaction term is not statistically significant in the HICAHS subgroup (B3 = 0.106, p = 0.60). The subgroup contains 184 counties, and standard errors are substantially larger than in the national sample across all coefficients. The agricultural worker density main effect remains negative and directionally consistent with the national estimate. The null interaction result is most plausibly attributable to limited statistical power and reduced variation in the key variables within the six-state region.

Limitations

This study has several limitations. The cross-sectional design limits causal inference in this study. The county is a coarse unit of analysis that masks within-county variation in both provider access and population health risk. Agricultural worker counts from the USDA Census of Agriculture exclude undocumented workers, likely understating true farmworker density in many counties. Low birth weight captures only one dimension of health and is influenced by maternal characteristics not fully measured at the county level. Finally, CHR suppresses low birth weight rates in counties with small birth counts, which disproportionately affects high-ag-density counties and introduces a systematic missingness pattern into the analytic sample.

Policy Implications & Conclusions

County-level physician supply alone is insufficient to capture effective healthcare access in agricultural communities. Structural barriers including transportation, language, fear of deportation, and lack of insurance mean that even where physicians exist, farmworker populations may not be able to use them. Medicaid expansion is the strongest policy lever identified in this analysis, associated with a reduction of over one percentage point in low-birth-weight rates per county across all model specifications. The HICAHS region specifically requires more granular, worker-level data before the regional interaction can be properly evaluated. The null subgroup result reflects limited statistical power, not an absent mechanism.

This study demonstrates that agricultural worker density moderates the relationship between physician supply and low birth weight at the county level, with a negative and significant interaction term in the national sample. The choice of low birth weight as a fully administrative outcome proved appropriate for this population, capturing healthcare gaps without relying on utilization data that would be suppressed by the same barriers farmworkers face in seeking care. Taken together, the findings suggest that the geography of healthcare supply matters differently in agricultural counties than the raw counts imply and that future research pairing individual-level data with county-level supply measures would meaningfully advance understanding of this gap.

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Appendix

Table A1: Hood River Sensitivity Check

	Primary (Hood River Excluded)	Sensitivity (Hood River Included)
Physicians per 100k (centered)	0.003*	0.004*
	(0.002)	(0.002)
Ag Worker Density (centered)	-14.510***	-13.874***
	(1.567)	(1.638)
Physicians x Ag Density (B3)	-0.118**	-0.051
	(0.044)	(0.071)
Num.Obs.	2679	2680
R2	0.381	0.381
R2 Adj.	0.377	0.377
AIC	10269.7	10278.5
BIC	10381.7	10390.4
Log.Lik.	-5115.843	-5120.235
F	74.078	73.196
RMSE	1.63	1.63
Std.Errors	HC3	HC3

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Hood River County OR: leverage = 0.487, physicians per 100k = 220 (AMA attribution artifact).

Figure A1: Correlation Matrix

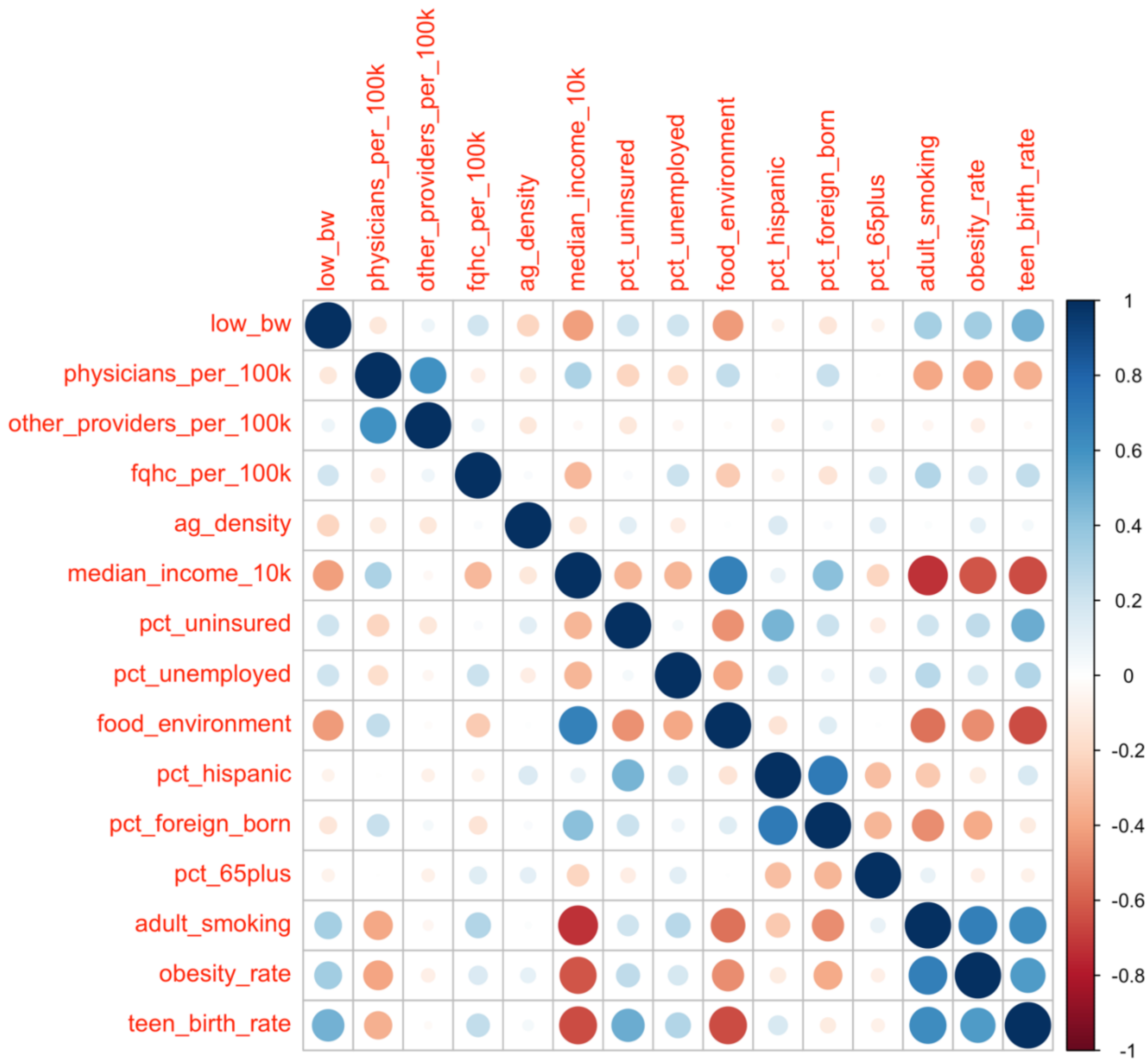

Figure A2: The Physician Coefficient Path

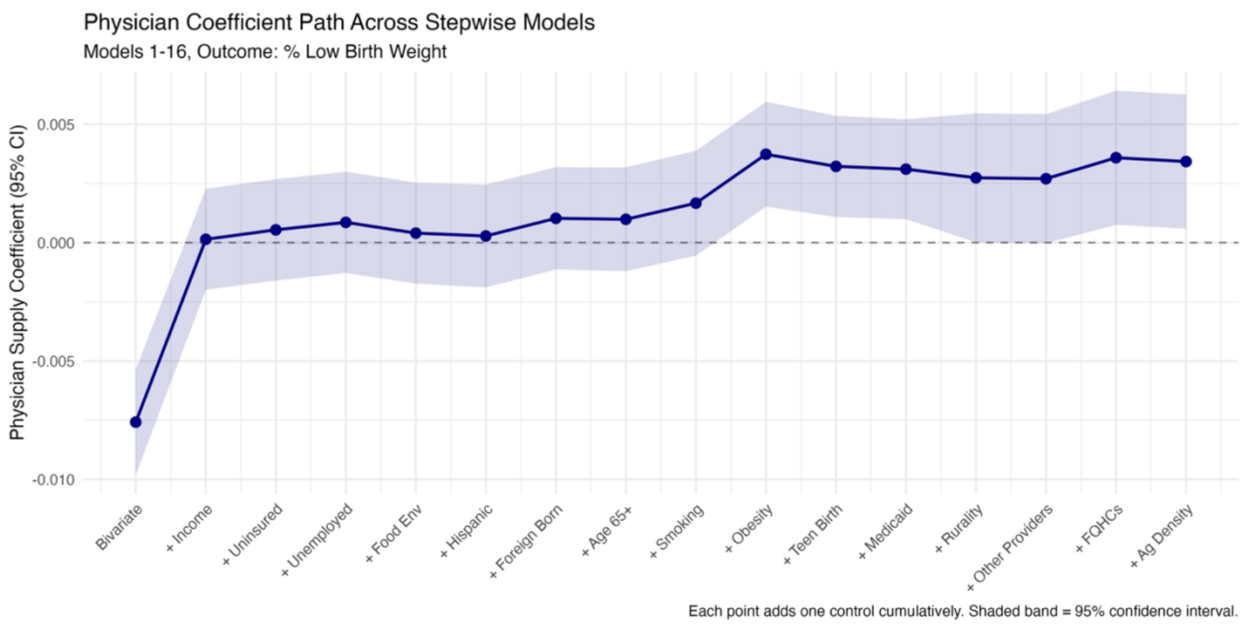

Figure A3: Fully Controlled Model Residual Diagnostics