Operational efficiency, patient composition and regional context of U.S. health centers: Associations with access to early prenatal care and low birth weight

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Abstract

Community health centers (CHCs) provide comprehensive medical services to medically under-served Americans, helping to reduce health disparities. This study aimed to identify the unique compositions and contexts of CHCs to better understand variation in access to early prenatal care and rates of low birth weights (LBW). Data include CHC-level data from the Uniform Data System, and regional-level data from the US Census American Community Survey and Behavioral Risk Factor Surveillance System. First, latent class analysis was conducted to identify unobserved subgroups of CHCs. Second, data envelopment analysis was performed to evaluate the operational efficiency of CHCs. Third, we used generalized linear models to examine the associations between the CHC subgroups, efficiency, and perinatal outcomes. Seven classes of CHCs were identified, including two rural classes, one suburban, one with large centers serving poor minorities in low poverty areas, and three urban classes. Many of these classes were characterized by the racial compositions of their patients. Findings indicate that CHCs serving white patients in rural areas have greater access to early prenatal care. Health centers with greater efficiency have lower rates of LBW, as do those who serve largely white patient populations in rural areas. CHCs serving poor racial minorities living in low-poverty areas had particularly low levels of access to early prenatal care and high rates of LBW. Findings highlight that significant diversity exists in the sociodemographic composition and regional context of US health centers, in ways that are associated with their operations, delivery of care, and health outcomes. Results from this study highlight that while the provision of early prenatal care and the efficiency with which a health center operates may improve the health of the women served by CHCs and their babies, the underlying social and economic conditions facing patients ultimately have a larger association with their health.

Key words: community health centers; low birth weight; prenatal care; efficiency; latent class analysis; data envelopment analysis

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Background

Community health centers (CHCs) provide an organizational structure to address widespread health disparities in the United States, including outcomes relating to pregnancy and childbirth. In the United States, approximately 20% of low-income women of childbearing age are served by CHCs, providing for 10% of low-income births per year (Rosenbaum, 2015). Research consistently finds that low-income and racial minority women have higher rates of adverse birth outcomes (Blumenshine et al., 2010; Osterman et al., 2015). CHCs are well-equipped to provide wrap-around services to socially high-risk mothers by going beyond basic prenatal care and providing services such as language interpretation, family planning, mental health counseling, and social services that support maternal health (Shin et al., 2009). With wrap-around services, CHCs improve overall patient health and combat early contributions to poor birth outcomes.

Having access to a usual source of primary health care, such as at CHCs, increases women's prenatal care utilization (Starfield & Shi, 2004). Research suggests that expanding access to care for low-income women in particular improves their prenatal care utilization, which is typically lower than women from higher socioeconomic backgrounds (Dubay et al., 2001). This is important given that many studies find that access to primary health care generally, and prenatal care specifically, has been linked with a decrease in the rate of babies born with low birth weights (LBW) (Alexander & Korenbrot, 1995; Kotelchuck, 1994; Shi et al., 2004a), although reviews of research suggests that these effects are modest in size (Corman et al., 2018). Access to prenatal care within the first trimester enables early screening for maternal medical issues and initiates modifications to problematic behavior that can be consequential for the health of the fetus (e.g. medication and substance use, exposure to environmental toxins, etc.) (Phelan, 2008). However, while certain aspects of prenatal care have been linked with modest improvements in birth outcomes (e.g. smoking cessation programs), prenatal care alone may not be enough to reduce adverse birth outcomes without access to comprehensive and integrated health care for women across their life course (Lu et al., 2003). Therefore, providing prenatal health care at a medical home such as a CHC that provides wrap-around services for its patients may improve maternal and child health for at-risk groups.

Research finds that women living in communities served by CHCs have better perinatal outcomes – including lower rates of premature birth, infant mortality, and LBW – compared to those living in communities not served by CHCs (Kantayya & Lidvall, 2010; Mathis et al., 2013; Shi et al., 2004b; Shin et al., 2003). Examinations of differences in perinatal health outcomes and quality of care, however, have largely focused on differences between patients served by CHCs and national averages (Politzer et al., 2001; Regan et al., 2003; Shi et al., 2004b). While patients served by CHCs are more disadvantaged socioeconomically than the general population, there is variation across regions and individual CHCs. The characteristics of women served by CHCs and the sociodemographic context of the regions in which these centers are located may help to explain differences in birth outcomes across CHCs, to a greater extent than aspects of health center operations or access to prenatal care at CHCs. The limited research examining variation between CHCs finds that demographic characteristics of the CHC patient populations, such as higher percentages of low-income, racial minority and uninsured patients, are associated with poorer perinatal health outcomes and lower rates of prenatal care access (Paradise et al., 2013; Shi et al., 2012). Previous studies have not considered the regional context in much detail beyond simple urban/rural and regional classification (Shi et al., 2004b). This is an important oversight, given research that suggests aspects of the regional context are strongly linked with poorer birth outcomes, especially for disadvantaged women (Clayborne et al., 2017; Mehra et al., 2017; Kramer et al., 2010).

Ideally patient and regional characteristics should be considered simultaneously. By examining how several sociodemographic patient and regional characteristics interact, we can start to identify common, underlying compositional groupings of CHCs associated with different organizational and patient experiences. The intersection of sociodemographic compositions and regional contexts (e.g. a smaller rural CHC serving uninsured white patients vs. a large urban CHC serving minority patients on Medicaid) may be associated with health center performance, in terms of their return on resources, the quality of care, and the improvement in health outcomes. The question remains, how is the intersection of CHC patient sociodemographic characteristics and regional characteristics associated with access to prenatal care and the health outcomes of patients? It is hypothesized that CHCs characterized by a more disadvantaged patient population situated in more disadvantaged contexts will have poorer access to early prenatal care and higher rates of LBW (e.g. higher poverty, higher percent minority, and higher rates of uninsured patients).

Beyond the composition of patients, other operational characteristics of health centers may impact the quality of care they provide and patients' health outcomes. CHCs are run by governing boards composed of a majority of patient members representing the demographics of the patients served by the center (HRSA, 2018). This "community" nature of health centers enables greater insight into local needs and facilitates the tailoring of services to the unique needs of the local population. For example, CHCs in rural areas may increase transportation services due to the increased distance required to reach a health center (Swift, 2002).

Differences across health centers in staffing, resource allocation, and services provided may contribute to different operating environments and patient experiences. Measuring how efficiently health centers allocate resources provides insight into CHC operations. Efficiency is defined as the production of the maximum possible outputs from a given set of inputs (e.g., most patient visits from a given staff of healthcare providers and expenditures) (Giuffrida & Gravelle, 2001). Staffing mix decisions are linked to how well community health centers provide high-quality care in an efficient manner (Ku et al., 2015). For example, Daniels (2012) shows that higher transportation Full-Time Equivalents (FTEs) per 100 CHC patients was positively associated with women receiving early prenatal care. There lacks a consensus in the literature regarding the relationship between costs and quality, which may be due to total costs having two parts: the costs associated with the best use of resources and the costs that are inefficient (Clement et al., 2008; Deily & McKay, 2006). Improving the efficiency of CHCs would increase their capacity to serve more patients, thus increasing access to services and potentially improving patient outcomes. However, it is not known whether increased efficiency translates to increased access to early prenatal care or improved health outcomes (lower LBW).

Current Study

The current study draws upon data from multiple sources to examine the quality of prenatal care and birth outcomes of patients served at CHCs operating in the United States in 2015. Our approach involves three main analytic steps. First, we conduct a latent class analysis (LCA) to identify unobserved subgroups within the population of CHCs based on the sociodemographic characteristics of their patient populations and their regional settings. Second, we conduct a set of data envelopment analyses (DEAs) to examine the efficiency of CHCs, calculating the efficiency of an individual health center in reference to their peer organizations based on the previously identified latent classes. Finally, we conduct a set of generalized linear models estimating the proportion of CHC prenatal patients who had access to prenatal care in the first trimester and the proportion of LBW births born to CHC prenatal patients. In using LCA in conjunction with DEA, we empirically investigate the relationship between the sociodemographic composition of CHCs and the efficiency of health centers in order to understand how CHC demographics and efficiency are associated with both the numbers of patients served and patient health outcomes relating to pregnancy and childbirth. To the best of our knowledge, this is the first study to test the associations between perinatal health outcomes and both CHC typologies and efficiency.

Methods

Data

Our data come from several sources and include health center-level data and regional zip code tabulation area (ZCTA)-level data. The health center-level data come from the Uniform Data System (UDS) from 2015 and include data on patient demographics, health outcomes, quality of care indicators, costs, and revenues for all 1,375 federally-qualified health centers (FQHCs; HRSA, 2015a). We obtained regional ZCTA-level data from the US Census American Community Survey (ACS; 2010-2014) and Behavioral Risk Factor Surveillance System (BRFSS; 2009-2012). We obtained regional data associated with each CHC's service area by averaging the ZCTA-level data across all ZCTAs served by each CHC. Staffing data by major service category for each CHC was obtained from the UDS Mapper website (American Academy of Family Physicians, 2017).

Our sample for the LCA analyses excluded 44 FQHCs that were either outside of the 50 US states or served fewer than 100 patients. We limit all of our analyses to FQHCs funded by the

Community Health Center (CHC) Program, excluding an additional 79 health centers for a final LCA sample of n = 1,252. Additionally 187 CHCs were excluded from the DEA model, eliminating CHCs that served 5 or fewer total prenatal patients in 2015 or CHCs with zero Medical FTEs, reducing the sample to 1,065. This sample was used in regression models predicting access to early prenatal care. Finally, to deal with outliers, our sample for analyses predicting the proportion of births born at LBW excluded 24 CHCs who reported that 40% of births or higher were LBW (the 98^{th} percentile), resulting in a final sample for low birth weight analyses of 1,041. Supplementary analyses retaining these 24 CHCs in the sample indicated that these centers are influential outlier data points. Additional analyses indicated that these centers served a very small number of prenatal patients who delivered (mean = 10.83) compared to the general sample (mean = 220), rendering births at these centers particularly influential on the measure of LBW rate. Therefore we exclude these cases in final LBW models.

Measures

Two dependent variables were considered in the current study: proportion of prenatal patients with *access to early prenatal care* and proportion of births born at a *low birth weight* (LBW; < 2,500 grams) to prenatal care patients. Prenatal patients who received prenatal care within the first trimester, either directly from the CHC or via referral to another provider from the health center, are considered as having access to early prenatal care. In the models predicting LBW, standardized *access to early prenatal care* was also included as an independent variable.

For the latent class analysis, we included thirteen variables that describe characteristics of the CHC patient population as well as the regional population served by the CHC (see Table 2). Seven measures of CHC patient characteristics were included in the LCA model: patient age distribution, patient race (% of patients in 4 categories: Hispanic, Black, American

Indian/Alaskan Native, Asian/Pacific Islander), % of patients best served in another language, % of patients in poverty (at or below 100% of the federal poverty line), patient insurance status, the total number of patients served at the CHC, and the percentage of patients that are prenatal. Information on the demographic context of the CHC service region was captured with the following four measures: % of the population living in the CHC service region that were non-White, % living in poverty, insurance status of the regional population, and % of the service region population with no usual source of health care. In addition, two measures of urbanity were included: population density of the service region (population per square mile) and a binary indicator of the U.S. Census designation of urban/rural status of the service region (0 “rural” 1 “urban”). We note that, while the binary urban/rural index is limited by its coarseness, the combination of these two measures in the LCA gives a better measure of rurality than either measure by itself. To adjust for skewness, continuous measures for the total number of patients and population density were transformed by taking their natural log.

In our DEA model, we included two operational output measures, ten input measures, and two quality threshold measures. The two operational outputs were the annual number of prenatal patients served and the annual number of prenatal patients who delivered. The inputs for the DEA model were labor and total non-patient revenue. The revenue input is used as a proxy for inputs purchased using grants and contracts. The two quality threshold measures were the percentage of prenatal patients who receive care in the first trimester and the percentage of LBW births. These measures were used to eliminate cases from the reference set that were operationally efficient, but had low quality (described below). Descriptive information on the inputs and outputs of the DEA model are presented in Appendix 1.

In addition to our primary independent variables we also included a control for *Centers for Medicare and Medicaid Services (CMS) region* (Centers for Medicare and Medicaid Services, 2017) to account for variation in health care and health plan performance (Thompson et al., 1998; Thompson et al., 2003), as well as regulatory variation across the regions and other endogenous variability across place.

Analytic strategy

Our analytic strategy includes three methodologies: latent class analysis, data envelopment analysis, and generalized linear models with a fractional response. Next, we describe each of these methodologies.

To help identify unobserved subgroups of CHCs, a latent class analysis (LCA) was conducted, using Mplus version 6. This model-based clustering methodology identifies latent subgroups within populations based on observed indicators. To facilitate model selection, and determine the optimal number of latent classes, several measures of model fit were jointly considered, following the recommendation of simulation studies (Nylund et al., 2007), including information criteria (the Bayesian Information Criteria (BIC), the Sample-Adjusted Bayesian Information Criteria (SABIC), and the Akaike Information Criteria (AIC)) and likelihood-based tests (Lo-Mendell Rubin, LMR). Entropy, a measure of disambiguation between classes, aided model selection.

Data Envelopment Analysis (DEA) was conducted to evaluate the efficiency of CHCs, using the optimization software GAMS/CPLEX. Given a set of organizations to be evaluated, DEA computes an efficiency score for each organization based on the amount of inputs (e.g., number of staff) the organization utilizes and the amount and quality of the outputs (e.g., patient visits resulting in positive health outcomes) it generates (Sherman & Zhu, 2006). Inputs considered included financial resources, along with staffing for medical care and other health services (e.g. mental health care, dental care, substance use treatment, and enabling services, such as transportation), given their association with pregnancy outcomes (Corbella et al., 2016; Grote et al., 2010; Kelly et al., 2002; Zhang et al., 2013). Efficiency refers to the ability of an organization to produce a given set of outputs with a minimum set of resources, or inputs (Sherman & Zhu, 2006). Specifically, the DEA approach identifies a group of organizations on the efficient frontier, referred to as the efficient reference set (ERS), assigning them an efficiency score of 1. Relative to the optimal pattern of resource usage by members of the ERS, DEA computes an efficiency score between 0 and 1 for every other organization. One concern with efficiency scores is the potential for organizations to achieve high efficiency at the expense of quality. To mitigate the influence of such low-quality organizations on DEA efficiency scores we apply a variant of the Quality-Adjusted DEA approach (Sherman & Zhu, 2006). CHCs below a target quality threshold are excluded from the ERS that defines performance benchmarks. Specifically, all CHCs that did not meet HRSA standards for either access or LBW are removed from the ERS. For 2015, the HRSA target for prenatal patient access during the first trimester was 66%, and the target for LBW was "5% below national rate", or 7.67% (HRSA, 2017; CDC, 2017).

Research using DEA to calculate the efficiency of CHCs has largely drawn comparisons across the full sample of health centers when determining the efficient frontier (Amico et al., 2014). However, given the tremendous heterogeneity across CHCs' contextual environments (populations served, available resources), a comparison of efficiencies across all CHCs might systematically advantage some CHCs and disadvantage others. Given this heterogeneity, a classification strategy should first be used to partition the set of CHCs into a set of classes based on compositional and contextual characteristics. In our work, this classification is performed using LCA. DEA is then performed within each class to identify a CHC's efficiency relative to the other members of its class. McGarvey et al. (2018) show that calculating efficiency scores separately for groups of similar CHCs provides a more equitable and precise comparison of efficiency. It is important to note that DEA efficiency scores provide a relative metric; a high efficiency score does not imply that an organization is performing well from an absolute standpoint, it merely reflects the fact that this organization is performing comparably to the benchmark ERS for its class.

The goal of the current study is to examine how CHC typologies and efficiency are related to both the quality of care received by prenatal patients (Y_1, the proportion of patients with access to prenatal care in the first trimester) and their birth outcomes (Y_2, the proportion of patients' births born at a low birth weight). The generalized linear model (GLM) is specified as follows:

$$\mathrm{E}(Y_i) = g^{-1}(\beta \boldsymbol{X_i})$$

The dependent variables Y_1 and Y_2 are proportions ranging between zero and one, or fractional responses, thus we adopt this quasilikelihood regression approach specified with a logit-link function $g^{-1}(.)$. $\boldsymbol{X_i}$ represents a vector of independent variables including latent class indicators and efficiency scores. This approach enables us to model the bounded nature of our dependent variable without having to specify the functional form of its distribution (Kieschnick & McCullough, 2003; Papke & Wooldridge, 1996).

Results

Latent Class Analysis

Using measures of the CHC regional and patient population, solutions from two through eight classes were estimated. Information criteria, likelihood-based tests, and entropy were jointly considered to determine the optimal solution to latent class analyses, following established conventions (Collins & Lanza, 2013; Nylund et al., 2007). Entropy was highest for the eight class solution, but was high (> .9) for all but the three-class solution. The three information criteria measures declined as group number increased, and were lowest for the eight class solution. The Lo-Mendell Rubin (LMR) test was significant for the two through seven class solutions, indicating that the seven class solution was optimal (an improvement in model fit over the six class solution, with no improvement in fit with the eight class solution). Although the p-value for the LMR test dropped slightly below the conventional level of .05 for the five class solution, given how close this value was (p=.061) we estimated additional solutions and found improved model fit (declining AIC, BIC, and SABIC, increased entropy, significant LMR tests). Model comparisons led to the selection of the seven class solution, as it significantly improved model fit and had a clear substantive interpretation (see Table 1).

Table 1: Comparing Fit Statistics of different Latent Class solutions of CHCs

Number of Latent Classes	AIC	BIC	Adjusted BIC	Entropy	Lo-Mendell Rubin Adjusted LRT test	
					value	*p value*
2	-30118.663	-29795.316	-29995.433	0.906	2741.869	0.003
3	-31705.301	-31274.171	-31540.994	0.874	1617.837	0.000
4	-34107.459	-33568.546	-33902.074	0.902	1533.055	0.000
5	-35086.563	-34439.868	-34840.102	0.901	1014.332	0.061
6	-37394.981	-36640.504	-37107.443	0.914	2457.869	0.022
7	-37983.540	-37121.281	-37654.926	0.918	2468.277	0.025
8	-38646.778	-37676.736	-38277.087	0.921	2453.997	0.111

Table 2 presents descriptive information on the indicators of CHC regional and patient demographics used to generate the latent classes. The overall means of indicators for the full sample of CHCs are presented in the first column (n = 1,252). Indicator means for the seven classes are presented in subsequent columns, with subscript letters indicating significant differences in means according to Analysis of Variance (ANOVA) tests. Median values are presented for unbounded variables (population density and total number of patients), to facilitate interpretation given the skewed nature of these variables.

Class one (2.8% of the sample) consists of CHCs primarily located in rural areas (22% urban) characterized by low population density, with 63% residing in areas with less than 100 people per square mile (median = 21.7; mean = 448). The population living in the class one service region were generally more medically disadvantaged (higher proportion of the regional population on Medicaid, uninsured, and with no usual source of care) and more racially diverse compared to the other rural class of CHCs that emerged in the LCA (Class 2). Class one patients were also significantly more likely to be children, and either uninsured or on Medicaid compared to patients served by CHCs in Class 2. Class 1 was distinct for its high proportion of patients that were American Indian/Alaskan Natives (68.8%). We label this group *Very Rural American Indians*. Class two (23% of the sample) also served patients living in rural areas, but were more likely to serve older white patients on Medicare compared to all other classes. We label this group *Older Rural Whites*.

CHCs in Class 3 were situated in suburban areas (37.3% urban; population density mean = 373, median = 144 people/square mile). Class 3 served the second highest proportion of Black patients (35.8%) and the third highest proportion of Hispanics (18.2%), with the highest rate of uninsured patients (42.9%), therefore we label these centers *Suburban serving uninsured Blacks and Hispanics.* Class 4 (24.8% of the sample) was more urbanized than the rural and suburban classes but was not clearly distinguished by its urbanity (56.5% urban; population density mean = 933, median = 469 people/square mile). This class included CHCs serving a large number of patients (mean = 22,553, median =17,067), with a high proportion on Medicaid (57.8%), the majority of whom were poor (68.7%) and half of whom were racial minorities. The demographics of the Class 4 service region, however, do not mirror the population of its patients, with the lowest regional rate of poverty (15%), lowest regional rate of uninsured (9%), lowest rate at which the regional population has no usual source of care (15.7%), and a largely white regional population (78.3% white). We labeled this class *Large centers serving poor minorities in low-poverty area.*

Three urban classes emerged in the LCA. Class 5 CHCs (2.7% of the sample) were primarily set in urban areas (64.7% urban; population density mean = 4,013, median = 2,184 people/square mile) with a racially diverse regional population (54.7% non-white) that were fairly advantaged economically (15% in poverty, 9% uninsured). The majority of patients served by these centers were poor (67%) Asian or Pacific Islanders (72.3%), with many on Medicaid (52%) and a large proportion best served in a language other than English (43.7%). Class 5 was labeled *Urban serving poor Asians in low-poverty diverse areas.* Class 6 (19.5% of the sample) included CHCs set in less densely populated urban areas (62.7%; population density mean = 2,593, median = 1,213 people/square mile) with the highest percentage of the regional population with no usual source of care (25.1%). These centers were very large (total patients mean = 30,987) and served predominantly Hispanic patients (70%), many of whom were best served in a language other than English (43.6%), including a large percentage of children (32.6%), poor (73.3%), and uninsured patients (33.6%). Therefore we named Class 6 *Large urban serving poor uninsured Hispanics.* Finally, Class 7 (5.9% of the sample) included CHCs in densely populated urban areas (95.9% urban; population density mean = 15,634, median = 9,618 people/square mile) in which the regional population was majority racial minorities (59.4% non-white), with a high poverty rate (23.3%) and a high percentage of the population insured through Medicaid (36%). Patients at these centers were predominantly Black (63.7%) or Hispanic (25.5%), with the highest rate of poverty (77.4%) and highest rate of patients on Medicaid (61.6%). We label this class *Dense urban serving poor Blacks in a poor area.*

Table 2: Means of CHC Patient and Regional Demographics Indicators by Latent Class Membership

	Full Sample	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
Regional Information								
% non-white	0.273	0.365 bd	0.146	0.293 bd	0.217 b	0.547 abcdf	0.329 bcd	0.594 abcdf
% in poverty	0.176	0.175	0.172 d	0.190 bde	0.157	0.150	0.179 de	0.233 abcdef
% on Medicaid [i]	0.248	0.280 bcd	0.241 c	0.220	0.231	0.241	0.269 bcd	0.360 abcdef
% uninsured [i]	0.124	0.155 bde	0.114 de	0.148 bde	0.090	0.093	0.146 bde	0.144 bde
% with no usual source of care	0.199	0.220 bd	0.182 d	0.213 bd	0.157	0.185 d	0.251 abcdeg	0.216 bd
Population Density (pop/sq. mile)	1887.25	448.51	116.42	372.75	932.77	4013.06 abcd	2592.60 abcd	15634.02 abcdef
Median Population Density (pop/sq. mile) *	213.34	21.71	70.01	144.20	469.11	2183.95	1213.12	9618.28
Proportion Urban	0.431	0.229	0.045	0.373 b	0.565 abc	0.647 abc	0.627 abc	0.959 abcdef
Patient Information								
% patients who are children [ii]	0.273	0.297 b	0.219	0.233	0.326 bceg	0.212	0.326 bceg	0.256
% patients who are elderly [ii]	0.092	0.095 dfg	0.169 acdefg	0.077 dfg	0.060	0.130 acdfg	0.061	0.054
% Hispanic	0.258	0.092	0.073	0.182 abe	0.186 abe	0.095	0.700 abcdeg	0.255 abcde
% Black	0.222	0.027	0.060	0.358 abdef	0.286 abef	0.060	0.114	0.637 abcdef
% American Indian/ Alaskan Native	0.030	0.688 bcdefg	0.017	0.013	0.007	0.005	0.009	0.004
% Asian/Pacific Islander	0.047	0.016	0.009	0.017	0.042 bc	0.723 abcdfg	0.043 bc	0.041 bc

% of patients best served in another language	0.168	0.026	0.032	0.101 ab	0.134 ab	0.437 abcdg	0.436 abcdg	0.135 ab
% of patients in poverty	0.658	0.512	0.502	0.712 ab	0.687 ab	0.671 ab	0.733 abd	0.774 abde
% of uninsured patients [iii]	0.262	0.258 bd	0.163	0.429 abdefg	0.181	0.221	0.336 abdeg	0.182
% of patients on Medicaid [iii]	0.431	0.378 bc	0.299	0.284	0.578 abcf	0.520 abc	0.500 abc	0.616 abcef
% of patients on Medicare [iii]	0.103	0.082 e	0.189 acdefg	0.092 f	0.084 f	0.083 f	0.051	0.078 f
Total number of patients	18670.36	5157.31	11966.01	12677.84	22553.26 abc	13151.41	30986.63 abcdeg	18473.55 a
Median Total number of patients *	11374	3132	7537	9243	17067.5	7616.5	21773	10088
% prenatal patients	0.017	0.015	0.007	0.011	0.021 bc	0.016	0.030 abcde	0.016 b
N	1,252	35	292	263	310	34	244	74
Proportion	100%	2.8%	23.3%	21.0%	24.8%	2.7%	19.5%	5.91%

Notes: [i] % of the population on Medicare or private insurance is reference group; [ii] % of adult patients is reference group; [iii] % of patients with private insurance is reference group; [a-g] represents that the mean is significantly larger than the mean for another class at $p<0.05$ based on Bonferroni post hoc paired comparisons of Analysis of Variance (ANOVA) tests (classes 1-7 coded as *a-g*); * Median also reported due to skewness of distribution. **Class 1** “Very rural American Indians”, **Class 2** “Older rural Whites”, **Class 3** “Suburban serving uninsured Blacks and Hispanics”, **Class 4** “Large centers serving poor minorities in a low-poverty area”, **Class 5** “Urban serving poor Asians in a low-poverty diverse area”, **Class 6** “Large urban serving poor uninsured Hispanics”, **Class 7** “Dense urban serving poor Blacks in a poor area”

Efficiency of Health Centers – DEA Results

Using the Quality-Adjusted DEA approach, we calculated the efficiency of CHCs. We performed seven separate DEA procedures, so CHCs were only compared to their peer organizations. The mean efficiency scores were highest for classes 1, 6, and 7, and lowest for class 2 (Table 3). Recall that efficiency, as computed by DEA, refers to the ability of a CHC to produce outputs (here, annual number of prenatal patients served, annual number of prenatal patients who delivered) from a set of inputs (nine labor categories, total non-patient revenue), relative to the pattern of resource usage for the members of the LCA class ERS (i.e., those CHCs lying on the efficient frontier). It is important to emphasize that DEA efficiency is a *relative* metric; the fact that classes 1, 6, and 7 each has a high average efficiency implies that there is little heterogeneity in efficiency across class members within each class. One cannot make inferences about the efficiency of one class versus another class in any "absolute" sense. The low average efficiency for CHCs in class 2 indicates that this class has many CHCs that are considerably less efficient than the benchmark CHCs for class 2—this does not indicate anything regarding the efficiency of class 2 CHCs versus CHCs in other classes. While beyond the scope of the current paper, future research should examine what underlying factors contribute to varying efficiencies between groups of CHCs.

Table 3. Comparisons of Efficiency, Access to Early Prenatal Care, and Low Birth Weight by Latent Class (Analysis of Variance)

	Full Sample	**Class 1**	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**	**Class 7**
Efficiency	0.621	0.951^{bcdf}	0.430	0.639^{b}	0.627^{b}	0.962^{bcdf}	0.631^{b}	0.872^{bcdf}
Access to Early Prenatal Care	0.715	0.694	0.772^{cg}	0.649	0.733^{c}	0.727	0.711	0.669
Low Birth Weight	0.071	0.054	0.058^{cd}	0.084	0.078	0.068	0.065^{c}	0.072

Notes: Differences in means based on Bonferroni post hoc paired comparisons of ANOVA tests. $^{a\text{-}g}$ represents that the mean is significantly larger than the mean for another class at p<0.05 (classes 1-7 coded as *a-g*). **Class 1** "Very rural American Indians", **Class 2** "Older rural Whites", **Class 3** "Suburban serving uninsured Blacks and Hispanics", **Class 4** "Large centers serving poor minorities in a low-poverty area", **Class 5** "Urban serving poor Asians in a low-poverty diverse area", **Class 6** "Large urban serving poor uninsured Hispanics", **Class 7** "Dense urban serving poor Blacks in a poor area"

Access to Early Prenatal Care and Low Birth Weight

Descriptive statistics presented in Table 3 also illustrate that significant differences exist between latent classes in terms of access to early prenatal care and LBW. While HRSA sets a lower target for access to early prenatal care (66% in 2015; HRSA, 2017), according to objectives outlined by the U.S. Office of Disease Prevention and Health Promotion (ODPHP) *Healthy People 2020* initiative, nationally there is a goal for 77.9% of women delivering babies to receive prenatal care starting in the first trimester by 2020 (U.S. Department of Health and Human Services, 2017). As we see from Table 3, on average CHCs are not meeting this goal (71.5% average for the full sample), with significant variation across classes. Access to early prenatal care is highest for CHCs in Class 2 (*Older Rural Whites,* 77.2% of patients), while patients served by CHCs in Class 3 (*Suburban serving uninsured Blacks and Hispanics*, 64.9%) and Class 7 (*Dense urban serving poor blacks in poor area*, 66.9%) had significantly lower rates of access to early prenatal care.

Looking at birth weight, on average CHCs come close to the U.S. ODPHP's *Healthy People 2020* goal of less than 7.8% of live births born at a LBW (average 7.1%, range 5.4 to 8.4%). However, class 2 (*Older Rural Whites*, 5.8%) has significantly lower rates of LBW births compared to class 3 (*Suburban serving uninsured Blacks and Hispanics*, 8.4%) and class 4 (*Large centers serving poor minorities in low poverty area,* 7.8%). Patients served by centers in class 6 (*Large urban serving poor uninsured Hispanics*; 6.5%) also reported a lower rate of LBW than those served by centers in class 3. These descriptive patterns suggest that access to early prenatal care and LBW outcomes vary across CHC typologies.

Next we present results from bivariate and multivariate generalized linear regression models of the percentage of patients with access to early prenatal care (Table 4) and LBW births

(Table 5). We report average marginal effects (AMEs) which represent the amount of change in the dependent variable that results from a one-unit change in the predictor variable. Regression equations for all models are shown in Appendix 2. Similar to descriptive analyses, results from GLM models suggest that significant differences exist in the association between latent classes and access to prenatal care in the first trimester (Table 4). Multivariate results presented in model 4 of Table 4 indicate that the class of CHCs characterized by patients who are *Older Rural Whites* (Class 2) have the highest rate of access to prenatal care in the first trimester. Compared to classes 1, 3, 4, 5, 6 and 7, CHCs in Class 2 have 8%, 10.4%, 11.7%, 5.8%, 12.1% and 12.9% more prenatal patients who receive early prenatal care, respectively. Results rotating the latent class reference category (not shown) indicate that CHCs in *urban areas serving poor Asians in non-poor diverse areas* (Class 5) have significantly higher rates of access to early prenatal care for their patients relative to those at large centers serving poor minorities in non-poor areas (Class 4), and the other urban classes that serve predominantly poor Hispanics (Class 6) or poor Blacks (Class 7).

Results also highlight that the negative association between efficiency and access to care is partially mediated by latent class membership (Table 4, models 2 and 3). That is, while CHCs with higher levels of efficiency have lower rates of access to early prenatal care (one standard deviation increase in efficiency is associated with a 2.8% lower rate of early access to prenatal care; model 2), the size of this association is reduced by over 40% once we control for latent class differences between CHCs (models 3 & 4). This suggests that patient and regional sociodemographic compositional differences between health centers have a stronger association with access to early prenatal care and helps to partially explain the relationship between efficiency and lower access.

Table 4. Generalized Linear Models of the Proportion of Patients with Access to Prenatal Care in the First Trimester

	Change in Percentage of Patients with Prenatal Care in the First Trimester			
	Model 1	Model 2	Model 3	Model 4[a]
Latent Class (Class 2 ref)				
Class 1	-0.083**		-0.059*	-0.080*
	(0.03)		(0.03)	(0.03)
Class 3	-0.146***		-0.135***	-0.104***
	(0.02)		(0.02)	(0.02)
Class 4	-0.112***		-0.104***	-0.117***
	(0.01)		(0.01)	(0.01)
Class 5	-0.069*		-0.044	-0.058^
	(0.03)		(0.03)	(0.03)
Class 6	-0.129***		-0.121***	-0.121***
	(0.01)		(0.01)	(0.01)
Class 7	-0.137***		-0.114***	-0.129***
	(0.02)		(0.02)	(0.02)
Efficiency (std.)		-0.028***	-0.018***	-0.013**
		(0.00)	(0.00)	(0.01)

Note: ^ p < .1, * p < .05, ** p < .01, *** p < .001; The data reported in this table are average marginal effects. Delta-method standard errors are in parentheses; [a] Full multivariate model also controlling for Medicaid region. **Class 1** "Very rural American Indians", **Class 2** "Older rural Whites", **Class 3** "Suburban serving uninsured Blacks and Hispanics", **Class 4** "Large centers serving poor minorities in a low-poverty area", **Class 5** "Urban serving poor Asians in a low-poverty diverse area", **Class 6** "Large urban serving poor uninsured Hispanics", **Class 7** "Dense urban serving poor Blacks in a poor area"

Results also suggest there are differences in the association between latent class membership and the proportion of births born at low birth weight (LBW; Table 5). Results in the final multivariate model (Table 5, model 6) indicate that CHCs in Class 2 (*Older rural Whites*) have significantly lower rates of LBW among its patients than CHCs in most other classes. CHCs in classes 3, 4, 5, 6, and 7 have 1.8%, 2.8%, 2.6%, 1.1%, and 1.9% more of its births delivered at LBW compared to CHCs in class 2, respectively. Analyses rotating the reference group (not shown), indicate that the class of *large CHCs serving poor minorities in non-poor areas* (Class 4) also have statistically significantly higher rates of LBW relative to the class of *large urban CHCs serving poor uninsured Hispanics* (Class 6; 1.2% more births born at LBW).

These results illustrate the pervasive race disparities in LBW, with lower rates at CHCs with larger White and Hispanic populations relative to Blacks. Results also illustrate the association between exposure to racial and economic inequality and poor health, as centers serving poor Black patients in predominantly white and more affluent regions had the highest rates of LBW among its patients (Class 4).

Results in Table 5 also illustrate that, to a lesser extent, health centers with greater efficiency and higher levels of access to early prenatal care among its patients were associated with reduced rates of LBW births. A standard deviation increase in efficiency was associated with a decrease by half a percent in the rate of births to babies born at low birth weight (Table 5, model 6), controlling for latent class membership, access to early prenatal care, and Medicaid region. Results of the bivariate model examining the association between efficiency and LBW (Table 5, model 2) did not find a relationship, but stepwise regression models (not shown) indicate that this association is only clear after controlling for latent class membership. Given that CHCs in Class 2 have lower rates of efficiency (see Table 3), and CHCs in Class 2 have lower rates of LBW, controlling for LBW differences across latent classes helps to isolate the association between efficiency and LBW rates. Stepwise regression models illustrate that the association between access to early prenatal care and rates of LBW is mediated in part by patient and regional sociodemographic compositional differences across latent typologies of CHCs. Comparing the bivariate association between access to early prenatal care and LBW (model 3) to models controlling for latent class membership (model 4), suggests that the association between access to early prenatal care and rates of LBW becomes smaller and only marginally significant after we account for latent class differences (reduced by 33%).

CHCs with a higher rate of access to care in the first trimester were associated with lower rates of births born at LBW; a one standard deviation increase in access to care is associated with a decrease of almost 1 percentage point of births born at LBW (model 3). However, CHCs with the highest rates of access to early prenatal care among their patients are also more likely to have a sociodemographic patient composition and regional context that is linked with improved birth outcomes (e.g. the class of rural whites; class 2). Therefore, the association between early prenatal care access and lower LBW is partially explained by other sociodemographic composition differences across health centers. After controlling for geographic differences in the final multivariate model (model 6; controlling for Medicaid region), there is no longer a statistically significant association between a health center's rate of patient access to early prenatal care and LBW rate.

A comparison of effect sizes in the multivariate model illustrates the relative size of the association between factors and LBW rates. Differences in the size of marginal effects indicates that latent typologies of CHC sociodemographic composition have a larger average association with rates of LBW than either access to early prenatal care or efficiency. This suggests that patient and regional sociodemographic factors, and their related determinants of maternal and infant health, are more strongly associated with lower or higher rates of LBW at health centers than either patient access to early prenatal care or the relative efficiency with which these centers operate. Moreover, this same model suggests that efficiency is more strongly associated with LBW rates than is access to early prenatal care.

Table 5. Generalized Linear Models of the Proportion of Low Birth Weight (LBW) Births

	Change in Percentage of LBW Births					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6[a]
Latent Class (Class 2 ref)						
Class 1	-0.004			-0.005	-0.000	0.008
	(0.01)			(0.01)	(0.01)	(0.01)
Class 3	0.025***			0.022**	0.024***	0.018*
	(0.01)			(0.01)	(0.01)	(0.01)
Class 4	0.020***			0.018**	0.020***	0.023***
	(0.01)			(0.01)	(0.01)	(0.01)
Class 5	0.010			0.008	0.016	0.026^
	(0.01)			(0.01)	(0.01)	(0.02)
Class 6	0.006			0.004	0.006	0.011*
	(0.01)			(0.01)	(0.01)	(0.01)
Class 7	0.013^			0.011	0.017*	0.019*
	(0.01)			(0.01)	(0.01)	(0.01)
Efficiency (std.)		-0.003			-0.005**	-0.005**
		(0.00)			(0.00)	(0.00)
Access to Early Prenatal Care (std.)			-0.009**	-0.006^	-0.007*	-0.004
			(0.00)	(0.00)	(0.00)	(0.00)

Note: ^ p < .1, * p < .05, ** p < .01, *** p < .001; The data reported in this table are average marginal effects. Delta-method standard errors are in parentheses.[a] Full multivariate model also controlling for Medicaid region. **Class 1** "Very rural American Indians", **Class 2** "Older rural Whites", **Class 3** "Suburban serving uninsured Blacks and Hispanics", **Class 4** "Large centers serving poor minorities in a low-poverty area", **Class 5** "Urban serving poor Asians in a low-poverty diverse area", **Class 6** "Large urban serving poor uninsured Hispanics", **Class 7** "Dense urban serving poor Blacks in a poor area"

Discussion

Federally-funded health centers play an important role in the U.S. healthcare system, providing care to over 24 million Americans (HRSA, 2015b), serving a wide-range of populations in a variety of geographic contexts. This study contributes to the literature by identifying and classifying diversity among health centers in terms of their patient populations and regional contexts. Results suggest that this variation matters when performing a relative evaluation of the operation of health centers, access to early care, and the health of their patients. Results provide empirical evidence that particular combinations of patient composition and regional context are associated with the degree of access to early prenatal care for patients and the health outcomes of prenatal patients and their babies (i.e., rates of LBW births). Scholars and practitioners interested in improving maternal and child health through the CHC system should consider this diversity in patient composition and context across centers. Further, given that federal funding for section 330 grants is allocated on a competitive basis, the unique compositional characteristics of CHCs should be considered when calculating how efficiently these health centers operate.

The efficiency with which a health center operates is related to its potential reach. Efficient health centers are those that use the fewest resources, in terms of labor and financing, to serve the largest number of patients. As CHCs are charged with extending health care to underserved populations, measures of efficiency illustrate the capacity of centers to reach these populations. However, findings suggest that many CHCs characterized as *Older Rural Whites* (Class 2) have fairly low levels of efficiency compared to the Class 2 benchmarks. This suggests that the patient and regional characteristics of certain rural contexts may be associated with a more limited ability of health centers to efficiently translate resources into patients served. It is possible that a causal association exists in the other direction, that is, that a CHC's resource allocation decisions are influenced by characteristics of its served patient population, and that these decisions determine a CHC's efficiency score. For this to be true, there would need to be sufficient heterogeneity between members of a single LCA class with respect to factors influencing DEA efficiency scores. Future research should explore what factors contribute to the relatively lower efficiency of these *Older Rural Whites* health centers and the greater heterogeneity among them.

Despite the relatively lower levels of efficiency with which CHCs in rural contexts serving older white patients operate, these CHCs provide the highest level of access to prenatal care in the first trimester to their patients compared to other types of health centers. This finding makes an important contribution to the literature about the necessary and valuable role of CHCs in rural communities for providing prenatal care, in light of recent research that finds rural areas of the U.S. are losing access to obstetric services, with more than half of all rural counties in the U.S. without hospital obstetric services (Hung et al., 2017). Given the unique challenges of providing prenatal and perinatal health care in rural communities, findings from the current study suggest that CHCs play a pivotal role in providing such care. Future research should examine what unmeasured aspects of life in rural communities and rural health center service delivery might support women living in rural areas to obtain early prenatal care.

Results also point to persistent racial inequalities in prenatal care and birth outcomes. Health centers that serve predominantly white patients had the highest rates of early access to prenatal care among their prenatal patients and the lowest rates of LBW births among patients that delivered. CHCs serving a larger share of American Indian, Asian, and especially Black and Hispanic patients had significantly lower rates of early access to prenatal care. Centers serving more Black, and to a lesser extent Hispanic, patients had the highest rates of LBW. These findings fit within a large literature that suggests Black and Hispanic women are less likely to receive adequate prenatal care relative to Whites and are less likely to enter prenatal care in the first trimester (Frisbie, et al., 2001; Mayberry, et al., 2000). Further, research has consistently found elevated rates of premature and LBW births among Blacks, while rates among Hispanics tend to be more similar to Whites (Osterman, et al., 2015). Scholarship on racial disparities in healthcare and birth outcomes is expansive but inconclusive, with scholars pointing to a myriad of factors including stress (Jackson, et al., 2012), discrimination (Braverman et al., 2017), and maternal behaviors (Kramer et al., 2000) to help explain disparities. Experiences in pregnancy alone do not explain differences in birth outcomes, however, as the accumulation of disadvantages over the life course of Black women impact their health and the health of their children (Lu & Halfon, 2003). Further, issues of systemic racism within the US healthcare system may contribute to implicit bias and discrimination in health clinics when women of color seek care (Feagin & Bennefield, 2014). Together this suggests that when health centers serve more Hispanic and especially Black patients in their clinics, access to early prenatal care and birth outcomes are poorer.

Beyond the racial composition of the patient population, the sociodemographics of the clinic's regional setting also matters. The poorer outcomes of women served by CHCs primarily serving poor, racial minorities located in more affluent, white areas (Class 4) supports research that finds any positive benefit minority women have of living in better socioeconomic contexts is offset by the adverse effects of racism, more commonly experienced when women of color live in racially segregated neighborhoods where they are a racial minority (Pickett, et al., 2005; Vinikoor et al., 2008). Similarly, the quality of care in prenatal settings and patient satisfaction with care is lower when there is discordance in provider-patient race, especially when there is less continuity in the patient-provider relationship (Nimbal et al., 2016). The large nature of the health clinics in Class 4 may contribute to less continuity in care for minority patients, who are likely being served by predominantly white providers given the more affluent and white regional population from which providers are drawn. The intersection of these characteristics may help explain why this group of CHCs were associated with lower rates of early access to prenatal care, as well as the highest rates of LBW. Future research should examine how the intersection of patient characteristics within particular regional settings of healthcare are associated with patient engagement in care and ultimately health outcomes.

Differences in access to early prenatal care did not explain differences in rates of low birth weight across health centers. Providing prenatal care has been widely touted as a means of improving the health and wellbeing of mothers and their children, including reducing rates of LBW births. While there is variation in the nature and utilization of prenatal health care, public health guidelines recommend beginning prenatal care in the first trimester (Phelan, 2008; U.S. Department of Health and Human Services, 2018). The research literature on the association between prenatal care and LBW is large and findings are often ambiguous, with studies finding that early (Kotelchuck, 1994) or even delayed prenatal care (Hueston et al., 2003), is associated with a reduced risk of delivering a LBW baby. However, neither the timing nor adequacy of prenatal care alone can explain differences in birth outcomes (Lu et al., 2003). Results of the current study are consistent with these findings, and suggest that CHCs that have greater access to prenatal care in the first trimester are associated with lower rates of LBW births. However, the association between early access to prenatal care and LBW is partially mediated by the sociodemographic composition of the patient population and regional setting. That is, higher rates of early access to prenatal care is linked with reduced rates of LBW in part because those patients and settings that are most likely to have early prenatal care are also those that have lower rates of LBW, namely CHCs serving white patients in rural areas.

Finally, greater efficiency at health centers is not associated with improved access to early prenatal healthcare, but is associated with lower rates of LBW, even controlling for the sociodemographic composition of CHC patients and regional context, suggesting that whatever reductions in expenditures (financial or staff) are associated with increases in efficiency, these economies are not occurring at the expense of worsened health outcomes. Further research is necessary to explore the mechanisms behind this association.

We note several limitations of the current study. First, our measure of prenatal care is operationalized by the timing of initiation of care and does not capture other dimensions of prenatal care quality. There are several other aspects of prenatal care, however, including the number and spacing of appointments, content of visits, and the use of various medical and social intervention services (Alexander & Korenbrot, 1995; Beeckman et al., 2011). As our measure of access to early prenatal care does not capture utilization of care, we are unable to test any mechanisms of why CHCs that have a higher percentage of patients with access to early prenatal care also have a lower percentage of patient births born at LBW. Future research should continue to explore the mechanisms underlying this association, including measures on the quality of prenatal care. Second, we are unable to identify and separate what share of the labor and financial inputs to our DEA model are being used specifically for pregnancy-related services. Therefore, our efficiency metric should be viewed as a measure of how all resources (labor and expenditures) are used by the center to produce the most prenatal patients and deliveries. Third, one of our output measures in the DEA model captures the total number of prenatal patients, not total patient encounters. Thus, our efficiency measure does not capture engagement with patients in terms of distinct visits, but rather the total prenatal patient population. Therefore, a CHC might not have many prenatal patients, given the resources it is using, but each of those patients might have more encounters. This might help to explain why class 2, which has a high rate of early prenatal health care access, has a low efficiency. Their prenatal patients might have more encounters, in part because they serve fewer prenatal patients. Additional research and data on patient encounters at CHCs are needed to explore these questions. Another limitation is that UDS data are reported at the grantee level rather than the service delivery site level. Many grantees have multiple delivery sites over which their staff is dispersed. This may obscure the relationship between staffing and outcomes at the level of the delivery site. Finally, our binary rural/urban index is limited due to its coarseness which may hide important differences. This issue is compounded by the lack of UDS data disaggregation by service delivery sites, since a CHC may operate multiple service delivery sites over different types of geographic settings. We account for this limitation by supplementing our analysis with a variable representing population density of the CHC service region.

Conclusion

CHCs provide an institutional structure to target underserved populations and improve the health of marginalized populations. Access to early prenatal care remains an important metric of maternal and child health during the prenatal and perinatal period, but the provision of early prenatal care varies across CHCs. In particular, CHCs in rural areas provide a higher proportion of their prenatal patients with early prenatal care. Therefore, despite low access to obstetrics care in rural areas (Hung et al., 2017), CHCs in these communities may provide much-needed care for pregnant women. The racial composition of the patient population, and its contrast with the larger regional setting, is an important component of variation in access to prenatal care and LBW across health centers, with centers serving poor Black patients – especially those served by centers located in more affluent, white areas – having the highest rates of LBW and the lowest rates of early prenatal care. Finally, while the efficiency with which a health center operates, and to a lesser extent the provision of early prenatal care, may be linked with improved health for women served by CHCs and their babies, the underlying social and economic conditions facing patients at CHCs ultimately have a larger association with their health.

References

Alexander, G. R., & Korenbrot, C. C. (1995). The role of prenatal care in preventing low birth weight. *Future Child, 5*(1), 103-120.

American Academy of Family Physicians. (2017). UDS Mapper. Retrieved from www.udsmapper.org

Amico, P. R., Chilingerian, J. A., & Van Hasselt, M. (2014). Community health center efficiency: the role of grant revenues in health center efficiency. *Health Services Research, 49*(2), 666-682.

Beeckman, K., Louckx, F., Masuy-Stroobant, G., Downe, S., & Putman, K. (2011). The development and application of a new tool to assess the adequacy of the content and timing of antenatal care. *Bmc Health Services Research, 11*(1), 213.

Blumenshine, P., Egerter, S., Barclay, C. J., Cubbin, C., & Braveman, P. A. (2010). Socioeconomic Disparities in Adverse Birth Outcomes A Systematic Review. *American Journal of Preventive Medicine, 39*(3), 263-272.

Braverman, P., Heck, K., Egerter, S., Dominguez, T.,P., Rinki, C., Marchi, K.,S., & Curtis, M. (2017). Worry About Racial Discrimination: A Missing Piece of the Puzzle of Black-White Disparities in Preterm Birth? *PlOs ONE* 12, 1-17.

Centers for Disease Control. (2017). National Center for Health Statistics, Birthweight and Gestation. Retrieved from https://www.cdc.gov/nchs/fastats/birthweight.htm

Centers for Medicare and Medicaid Services. (2017). CMS Regional Offices. Retrieved from https://www.cms.gov/Medicare/Coding/ICD10/CMS-Regional-Offices.html

Clayborne, Z. M., Giesbrecht, G. F., Bell, R. C., & Tomfohr-Madsen, L. M. (2017). Relations between neighbourhood socioeconomic status and birth outcomes are mediated by maternal weight. *Social Science & Medicine, 175*, 143-151.

Clement, J., Valdmanis, V. G., Bazzoli, G. J., Zhao, M., & Chukmaitov, A. (2008). Is more better? An analysis of hospital outcomes and efficiency with a DEA model of output congestion. *Health Care Management Science*, 11, 67-77.

Collins, L. M., & Lanza, S. T. (2013). *Latent class and latent transition analysis: With applications in the social, behavioral, and health sciences* (Vol. 718): John Wiley & Sons.

Corbella, S., Taschieri, S., Del Fabbro, M., Francetti, L., Weinstein, R., & Ferrazzi, E. (2016). Adverse pregnancy outcomes and periodontitis: A systematic review and meta-analysis exploring potential association. *Quintessence international, 47*(3).

Corman, H., Dave, D. M., & Reichman, N. (2018). *Effects of Prenatal Care on Birth Outcomes: Reconciling a Messy Literature* (No. w24885). National Bureau of Economic Research.

Daniels, F. A. (2012). *Are enabling services in federally qualified health centers associated with women receiving prenatal care in the first trimester?* (Unpublished doctoral dissertation). The University of Alabama at Birmingham.

Deily, M., & McKay, N. L. (2006). Cost inefficiency and mortality rates in Florida hospitals. *Health Economics*, 15, 419-431.

Dubay, L., Joyce, T., Kaestner, R., & Kenney, G. M. (2001). Changes in prenatal care timing and low birth weight by race and socioeconomic status: implications for the Medicaid expansions for pregnant women. *Health Services Research, 36*(2), 373.

Feagin, J., & Bennefield, Z. (2014). Systemic racism and US health care. *Social science & medicine.* 103, 7-14.

Frisbie, W. P., Echevarria, S., & Hummer, R. A. (2001). Prenatal care utilization among non-Hispanic whites, African Americans, and Mexican Americans. *Maternal and child health journal*, 5(1), 21-33.

Giuffrida, A., & Gravelle, H. (2001). Measuring performance in primary care: econometric analysis and DEA. *Applied Economics, 33*(2), 163-175.

Grote, N. K., Bridge, J. A., Gavin, A. R., Melville, J. L., Iyengar, S., & Katon, W. J. (2010). A meta-analysis of depression during pregnancy and the risk of preterm birth, low birth weight, and intrauterine growth restriction. *Archives of general psychiatry, 67*(10), 1012-1024.

Health Resources and Services Administration. (2015a). 2015 Health Center Data - Health Center Program Grantee Data. Retrieved from https://bphc.hrsa.gov/uds/datacenter.aspx?year=2015

Health Resources and Services Administration. (2015b). Data by Geography - Nationwide. Retrieved from https://datawarehouse.hrsa.gov/Tools/DataByGeographyResults.aspx?geoTyp=National&geoCd=00

Health Resources and Services Administration. (2017). FY 2017 Annual Performance Report. Retrieved from https://www.hrsa.gov/about/budget/fy17annualperformancereport.pdf

Health Resources and Services Administration. (2018). What is a Health Center? Retrieved from https://bphc.hrsa.gov/about/what-is-a-health-center/index.html

Hueston, W. J., Gilbert, G. E., Davis, L., & Sturgill, V. (2003). Delayed prenatal care and the risk of low birth weight delivery. *J Community Health, 28*(3), 199-208.

Hung, P., Henning-Smith, C. E., Casey, M. M., & Kozhimannil, K. B. (2017). Access To Obstetric Services In Rural Counties Still Declining, With 9 Percent Losing Services, 2004-14. *Health Aff (Millwood), 36*(9), 1663-1671.

Jackson, F., M., Rowley, D., I., & Owens, T., C. (2012). Contextualized Stress, Global Stress, and Depression in Well-Educated Pregnant, African-American Women. *Women's Health Issues*. 22,329-326

Kantayya, V. S., & Lidvall, S. J. (2010). Community health centers: disparities in health care in the United States 2010. *Disease-a-month: DM, 56*(12), 681.

Kelly, R. H., Russo, J., Holt, V. L., Danielsen, B. H., Zatzick, D. F., Walker, E., & Katon, W. (2002). Psychiatric and substance use disorders as risk factors for low birth weight and preterm delivery. *Obstetrics & Gynecology, 100*(2), 297-304.

Kieschnick, R., & McCullough, B. D. (2003). Regression analysis of variates observed on (0, 1): percentages, proportions and fractions. *Statistical Modelling, 3*(3), 193-213.

Kotelchuck, M. (1994). The Adequacy of Prenatal Care Utilization Index: its US distribution and association with low birthweight. *American Journal of Public Health, 84*(9), 1486-1489.

Ku, L., Frogner, B. K., Steinmetz, E., & Pittman, P. (2015). Community health centers employ diverse staffing patterns, which can provide productivity lessons for medical practices. *Health Affairs*, 34(1), 95-103.

Kramer, M. S., Seguin, L., Lydon, J., & Goulet, L. (2000). Socio-economic disparities in pregnancy outcome: why do the poor fare so poorly?. *Paediatric and perinatal epidemiology*, 14(3), 194-210.

Kramer, M. R., Cooper, H. L., Drews-Botsch, C. D., Waller, L. A., Hogue, C. R. (2010). Metropolitan isolation segregation and Black-White disparities in very preterm birth: A test of mediating pathways and variance explained. *Social Science & Medicine*, 71(12), 2108-2116.

Lu, M. C., & Halfon, N. (2003). Racial and ethnic disparities in birth outcomes: a life-course perspective. *Maternal and child health journal*, *7*(1), 13-30.

Lu, M.,C., Tache, V., Alexander, G.,R., Kotelchuck, M., & Halfon, N. (2003). Preventing Low Birth Weight: Is Prenatal Care the Answer? *The Journal of Maternal-Fetal and Neonatal Medicine.* 13:362-380

Mathis, A., Barnes, P. A., & Shah, G. H. (2013). Assessing Gaps in the Maternal and Child Health Safety Net. *Population health management, 16*(4), 270-275.

Mayberry, R. M., Mili, F., & Ofili, E. (2000). Racial and ethnic differences in access to medical care. *Medical Care Research and Review*, 57(1_suppl), 108-145.

McGarvey, R. G., Thorsen, A., Thorsen, M. L., Reddy, R. M. (2018). Measuring efficiency of community health centers: a multi-model approach considering quality of care and heterogeneous operating environments. *Health Care Management Science*, 1-23.

Mehra, R., Boyd, L. M., & Ickovics, J. R. (2017). Racial residential segregation and adverse birth outcomes: A systematic review and meta-analysis. *Social Science & Medicine*, 191, 237-250.

Nimbal, V. C., Zhao, B., Pu, J., Romanelli, R. J., Palaniappan, L., & Chung, S. (2016). Does Patient-Provider Racial/Ethnic and Language Concordance Impact Patient-Reported Experience of Care?. *Journal of Patient-Centered Research and Reviews*, 3(3), 198.

Nylund, K. L., Asparouhov, T., & Muthén, B. O. (2007). Deciding on the number of classes in latent class analysis and growth mixture modeling: A Monte Carlo simulation study. *Structural equation modeling, 14*(4), 535-569.

Osterman, M.J.K., Kochanek, K.D., MacDorman, M.F., Strobiono, D.M., & Guyer, B. (2015). Annual summary of vital statistics: 2012-2013. *Pediatrics*, 135(6), 1-12.

Papke, L. E., & Wooldridge, J. M. (1996). Econometric methods for fractional response variables with an application to 401(k) plan participation rates. *Journal of Applied Econometrics, 11*(6), 619-632.

Paradise, J., Shin, P., Sharac, J., & Rosenbaum, S. J. (2013). Quality of care in community health centers and factors associated with performance.

Phelan, S. T. (2008). Components and timing of prenatal care. *Obstetrics and gynecology clinics of North America, 35*(3), 339-353.

Pickett, K. E., Collins Jr, J. W., Masi, C. M., & Wilkinson, R. G. (2005). The effects of racial density and income incongruity on pregnancy outcomes. *Social science & medicine*, 60(10), 2229-2238.

Politzer, R. M., Yoon, J., Shi, L., Hughes, R. G., Regan, J., & Gaston, M. H. (2001). Inequality in America: the contribution of health centers in reducing and eliminating disparities in access to care. *Medical Care Research and Review, 58*(2), 234-248.

Regan, J., Schempf, A. H., Yoon, J., & Politzer, R. M. (2003). The role of federally funded health centers in serving the rural population. *The Journal of Rural Health, 19*(2), 117-124.

Rosenbaum, S. (2015). Will health centers go over the "funding cliff"? *The Milbank Quarterly, 93*(1), 32-35.

Sherman, H. D., & Zhu, J. (2006). *Service productivity management: improving service performance using Data Envelopment Analysis (DEA)*: Springer science & business media.

Shi, L., Lebrun, L. A., Zhu, J., Hayashi, A. S., Sharma, R., Daly, C. A., . . . Ngo-Metzger, Q. (2012). Clinical quality performance in US health centers. *Health Services Research, 47*(6), 2225-2249.

Shi, L., Macinko, J., Starfield, B., Xu, J., Regan, J., Politzer, R., & Wulu, J. (2004a). Primary care, infant mortality, and low birth weight in the states of the USA. *Journal of Epidemiology & Community Health, 58*(5), 374-380.

Shi, L., Stevens, G. D., Wulu Jr, J. T., Politzer, R. M., & Xu, J. (2004b). America's Health Centers: reducing racial and ethnic disparities in perinatal care and birth outcomes. *Health Services Research, 39*(6p1), 1881-1902.

Shin, P., Jones, K., & Rosenbaum, S. J. (2003). Reducing racial and ethnic health disparities: Estimating the impact of high health center penetration in low-income communities.

Shin, P., Ku, L., Jones, E., Finnegan, B., & Rosenbaum, S. (2009). Financing community health centers as patient- and community-centered medical homes: A primer. Washington, DC: The Commonwealth Fund, The George Washington University Department of Health Policy Geiger Gibson Program in Community Health Policy

Starfield, B., & Shi, L. (2004). The medical home, access to care, and insurance: a review of evidence. *Pediatrics, 113*(Supplement 4), 1493-1498.

Swift, E.K. (2002). Guidance for the National Healthcare Disparities Report.Washington, D.C.: National Academies Press.

Thompson, J. W., Bost, J., Ahmed, F., Ingalls, C. E., & Sennett, C. (1998). The NCQA's Quality Compass: Evaluating Managed Care In The United States: A brief look at the NCQA's comparison of health plan performance. *Health Affairs, 17*(1), 152-158.

Thompson, J. W., Pinidiya, S. D., Ryan, K. W., McKinley, E. D., Alston, S., Bost, J. E., . . . Simpson, P. (2003). Health plan quality-of-care information is undermined by voluntary reporting. *American Journal of Preventive Medicine, 24*(1), 62-70.

U.S. Department of Health and Human Services. (2017). Prenatal Care and Tests. Retrieved from https://www.womenshealth.gov/pregnancy/youre-pregnant-now-what/prenatal-care-and-tests

U.S. Department of Health and Human Services. (2018). Maternal, Infant, and Child Health. Retrieved from https://www.healthypeople.gov/2020/topics-objectives/topic/maternal-infant-and-child-health/objectives

Vinikoor, L. C., Kaufman, J. S., MacLehose, R. F., & Laraia, B. A. (2008). Effects of racial density and income incongruity on pregnancy outcomes in less segregated communities. *Social science & medicine*, 66(2), 255-259.

Zhang, S., Cardarelli, K., Shim, R., Ye, J., Booker, K. L., & Rust, G. (2013). Racial disparities in economic and clinical outcomes of pregnancy among Medicaid recipients. *Maternal and child health journal, 17*(8), 1518-1525.

Appendix 1. Descriptive statistics on inputs and outputs in the DEA model

	Mean	Standard Deviation	Min	Max
Inputs				
Total non-patient related revenue [a]	6041650	8285418	0	158000000
Labor Full-Time-Equivalencies (FTEs)				
Medical (e.g., nurse, other medical personnel)	58.20	69.59	1.95	771.97
Primary care physicians	9.78	13.39	0	153.65
Non-primary care physicians	0.34	3.62	0	109.12
Nurse practitioners/Physician assistants/Certified nurse-midwife	8.83	8.90	0	64.40
Dental	12.65	17.90	0	176.45
Mental health	6.35	15.13	0	217.77
Substance abuse	0.69	3.43	0	73.57
Vision	0.46	1.85	0	29.10
Enabling (e.g., case manager, patient education specialist)	15.61	21.03	0	203.99
Operational outputs				
Total prenatal patients served	499.54	844.98	6	7631
Number of prenatal patients who delivered	263.26	436.47	0	3343
Quality threshold measures				
Access to prenatal care in first trimester	0.76	0.154	0	1
Percentage of low-birth weight births	0.08	0.108	0	1

Notes: All information is for the DEA sample n = 1,065. [a] includes other federal grants, non-federal grants, and other non-patient related revenue; Full information on staffing categories available online

Appendix 2: Formulae for GLM models

*Note: LCA Class 2 is the reference group in all models with dependent variables "Latent Class" that were reported in Tables 3 and 4

Models of the Proportion of Patients with Access to Prenatal Care in the First Trimester:

$\ln\left[\frac{P1}{1-P1}\right] = \beta_0+\beta_1(\text{LATENT CLASS}_1) + \sum_{i=3}^{7}\beta_i(\text{LATENT CLASS}_i)$

$\ln\left[\frac{P2}{1-P2}\right] = \beta_0+\beta_1(\text{EFFICIENCY})$

$\ln\left[\frac{P3}{1-P3}\right] = \beta_0+\beta_1(\text{LATENT CLASS}_1) + \sum_{i=3}^{7}\beta_i(\text{LATENT CLASS}_i)+\beta_8(\text{EFFICIENCY})$

$\ln\left[\frac{P4}{1-P4}\right] = \beta_0+\beta_1(\text{LATENT CLASS}_1) + \sum_{i=3}^{7}\beta_i(\text{LATENT CLASS}_i) +\beta_8(\text{EFFICIENCY})$

$+\sum_{i=9}^{18}\beta_i(\text{MEDICAID REGION}_{i-8})$

Models of the Proportion of Low Birth Weight (LBW) Births:

$\ln\left[\frac{P1}{1-P1}\right] = \beta_0+\beta_1(\text{LATENT CLASS}_1) + \sum_{i=3}^{7}\beta_i(\text{LATENT CLASS}_i)$

$\ln\left[\frac{P2}{1-P2}\right] = \beta_0+\beta_1(\text{EFFICIENCY})$

$\ln\left[\frac{P3}{1-P3}\right] = \beta_0+\beta_1(\text{EARLY ACCESS})$

$\ln\left[\frac{P4}{1-P4}\right] = \beta_0+\beta_1(\text{LATENT CLASS}_1) + \sum_{i=3}^{7}\beta_i(\text{LATENT CLASS}_i) +\beta_8(\text{EARLY ACCESS})$

$\ln\left[\frac{P5}{1-P5}\right] = \beta_0+ \beta_1(\text{LATENT CLASS}_1) + \sum_{i=3}^{7}\beta_i(\text{LATENT CLASS}_i)+\beta_8(\text{EARLY ACCESS})$

$+\beta_9(\text{EFFICIENCY})$

$\ln\left[\frac{P6}{1-P6}\right] = \beta_0+ \beta_1(\text{LATENT CLASS}_1) + \sum_{i=3}^{7}\beta_i(\text{LATENT CLASS}_i) +\beta_8(\text{EARLY ACCESS})+$

$\beta_9(\text{EFFICIENCY})+\sum_{i=10}^{19}\beta_i(\text{MEDICAID REGION}_{i-9})$