Maternity Ward Deserts in Wisconsin, 2011 and 2017

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Received: 06/20/2021
Accepted: 08/08/2021

Abstract

Distance to a maternity ward is correlated with adverse health effects for mothers and infants, motivating this study of maternity ward deserts in Wisconsin. Absolute distance from census tracts is used, as well as a multidimensional measure incorporating income/poverty and low rates of vehicle access, and each are compared to medically-underserved areas (MUAs). Absolute distance places deserts outside of urban areas relative to the multidimensional measure, with different patterns for race/ethnicity, and all are correlated with MUAs. Between 13% (multidimensional measure) and one-fifth (10 mile measure) of the population were in deserts as of 2017. Deserts defined by the 10 mile measure are positively correlated with rates of household vehicle access. A net reduction of 5 maternity wards between 2011 and 2017 resulted in a surprisingly reduced prevalence of maternity deserts (distance measure), although continued reductions in maternity wards may generate more adverse outcomes.

1 Introduction

For expectant mothers, distance from a maternity ward can represent a threat to their health and that of their child due to unplanned out-of-maternity deliveries (OMD). For example, a study in France found significant increases in OMDs for distances to a maternity ward greater than 15 kilometers (9.3 miles) (Combier et al., 2020). Unplanned OMDs are in turn significantly related to fetal polycythemia (excess red blood cells), hypothermia, and perinatal mortality (i.e., infant mortality within 24 hours) (Nguyen et al., 2015; Pasternak et al., 2018). Any OMD is significantly related to premature birth, admission to neonatal care units, hypothermia, perinatal mortality, and severe postpartum hemorrhage for the mother (Ovaskainen et al., 2015; Thornton and Dahlen, 2018), and even planned OMD is associated with perinatal mortality (Snowden et al., 2015).

Distance to a maternity ward has increased in many rural areas due to hospital closures. In the U.S., the percentage of rural counties having maternity wards decreased from 54.0% in 2004, to 45.7% in 2014, with a decline in Wisconsin from 76.1% to 69.6% over the same time period (Hung et al., 2017).

Taken together, the well-documented dangers of long distance to a maternity ward, and reduction in coverage in rural areas, call for research on maternity ward deserts. The notion of maternity ward deserts is drawn from earlier research on food deserts (Walker et al., 2010), bank deserts (Hegerty, 2016, 2020; Kashian et al., 2018) and pharmacy deserts (Qato et al., 2014). Food deserts are defined as areas "without access to fresh, healthy, and affordable food", and lack of access is a key defining feature in studies of commodity or service deserts.[1]

[1] See `https://www.ers.usda.gov/data-products/food-access-research-atlas/documentation/`.

The present study concerns maternity ward deserts in Wisconsin for 2011 and 2017. Wisconsin is relevant for the following reasons. The decline in rural hospitals mentioned above was countered by expanded Medicaid coverage under the Affordable Care Act, which took effect in 2014 in states choosing to participate.[2] Research found that rates of rural and urban hospital closures declined significantly in states that adopted the Medicaid expansion, compared to those which did not (Lindrooth et al., 2018). Wisconsin did not adopt the expansion (Commonwealth Fund, 2021), so further decline from 2011 to 2017 might be expected. In fact, the number of functioning maternity wards in the state declined from 118 to 113 over the period. That decline in turn may have expanded the prevalence of maternity ward deserts.

Below, we review studies of various types of deserts, and particularly methodological issues, before discussing research directly relevant to maternity ward deserts and the Wisconsin setting. An important methodological issue involves differences between rural and urban areas. Individuals in urban areas may often have lower incomes and lesser access to automobiles, which effectively reduces access for any given distance to a maternity ward. In response, two measures are applied to census tract level data from the state of Wisconsin: one is absolute distance, as in Combier et al. (2020), with the other using a combination of distance, income, and vehicle access, as in Qin et al. (2018).

The purpose of the analysis below is to identify relevant populations in Wisconsin which are likely experiencing unnecessary OMDs due to a lack of access to maternity wards. Prior research from abroad, detailed below, establishes a direct link between distance to a maternity ward and OMDs, justifying use of the absolute measure. Less direct research suggests poverty is linked to OMDs, and while no prior research tests for any association between vehicle access and OMDs, it is highly plausible to suggest that a positive correlation will exist, thereby justifying use of the multidimensional measure.

Following Guadamuz et al. (2021), for a relevant contrast, we compare the locations of maternity ward deserts with "medically underserved areas" (MUAs), which the U.S. Health Resources and Services Administration defines as areas with relatively few primary care providers, high rates of infant mortality, high poverty rates or disproportionate representation of the elderly.[3] Although it is not expected that MUAs will be perfectly correlated with maternity deserts, there should be some positive correlation.

2 Background

The US Department of Agriculture defines food deserts using the base criterion of absolute distance to a supermarket, adjusted for urban/rural location, which is supplemented with absolute measures of poverty and vehicle-less households.[4] Studies of food deserts have used a combination of absolute distance and poverty (Thomsen et al., 2016), or absolute distance, poverty, and high or low priced supermarkets (Jiao et al., 2012). In a summary of food desert measures, Ver Ploeg et al. (2015), note that measures include multiple criteria, ranging from absolute to relative distance, poverty, vehicle access, grocery store prices, grocery store square footage per unit of population, and grocery story provision of fresh fruits and vegetables, with absolute distance allowed to be further for rural areas.

Qato et al. (2014) studied Chicago, IL, and categorized census tracts as pharmacy deserts using a multidimensional indicator (as in the U.S.D.A. approach): a) at least a 20% poverty rate or b) median household income below 80% of median income for the entire area, and either c) 33% of the population live more than 1 mile from the nearest pharmacy, or d) at least 33% of the population lives more than .5 miles from a pharmacy (i.e. walking distance) and at least 100 households in the tract do not own a vehicle. Using this multidimensional measure, Qato et al. (2014) found that pharmacy deserts were more often located in segregated African-American and Hispanic communities. This approach yields a multidimensional measure.

Qin et al. (2018) also studied pharmacy deserts and used a similar measure, except condition c) is ignored, such that low vehicle access and the walking distance criteria are uniformly applied. That approach is considered here as relevant to understanding urban maternity ward deserts.

Other research has addressed bank deserts as areas with limited access to bank offices (Hegerty, 2016,

[2]See `https://www.medicaid.gov/about-us/program-history/index.html`.
[3]See `https://data.hrsa.gov/data/download`.
[4]See `https://www.ers.usda.gov/data-products/food-access-research-atlas/documentation/`.

2020; Kashian et al., 2018). Kashian et al. (2018) develop a relative measure of bank deserts such that the 95th percentile distance from the centroid of each census tract to the nearest bank office is used as a cut-off for defining deserts, separately for urban, suburban, and rural areas. The rationale for treating the three areas separately is that residents may expect and plan for greater bank distances where population is relatively less dense. This approach yields a relative measure.

Hegerty (2016) studied the cities of Milwaukee, WI and Buffalo, NY, and applied two measures of bank deserts. The first identified the centroids of census blocks with one or fewer bank or credit union offices within one mile, and the second identified groups of such census blocks, a process which involves some degree of arbitrariness. Somewhat differently, Hegerty (2020) studied bank deserts in Chicago, IL, again using the centroids of census blocks and the one or fewer criteria within one mile, but also added deserts defined as five or fewer offices within a 2-mile radius.

Viewing the food, pharmacy, and bank deserts research in totality, three types of desert measures have been used: the multidimensional measure commonly used in food or pharmacy deserts research (Qato et al., 2014; Qin et al., 2018; Ver Ploeg et al., 2015), and either absolute or relative distance measures for bank deserts (Hegerty, 2016, 2020; Kashian et al., 2018). Some judgement is required as to which measure to apply for maternity ward deserts.

Maternity ward deserts are distinct from food deserts across several important dimensions. First is frequency of utilization. If fresh food is desired, then visits to a grocery store are required multiple times per month, while childbirth is a far less frequent event. Second is the potential for planning. While plans could be made far in advance for grocery store visits, plans for childbirth are likely more common, but unlike plans for the grocery store, there is an ever-present potential for unplanned emergencies with pregnancy, and hence unplanned OMDs. In the latter case, the lives of the mother and infant may be at risk if a maternity ward is not accessible nearby. By way of contrast, lives are typically not placed in immediate risk by food deserts, much less pharmacy deserts (with some possible exceptions for emergencies), or bank deserts.

Turning to aspects of distance, relative distance may be sensible for banks, as indicators of relative deprivation. Maternity ward deserts are less about relative deprivation and more about safety, suggesting the importance of absolute distance measures. Further, multiple studies of maternity wards and geography use absolute distance or an absolute cut-off in terms of travel time. Combier et al. (2020) found OMDs rising consistently and significantly for distances of 15 km or less, to 16-30 km, 31-45 km, and 46-90 km in France, as did Blondel et al. (2011) for distances of at least 30 km. Ovaskainen et al. (2015) found OMDs in Finland were significantly related to distance of at least 35 km. Renesme et al. (2013) found significantly higher unplanned OMDs in France for hospital distances greater than 45 minutes, compared to less than 15 minutes. Diana et al. (2018) found distances of at least 30 km associated with unplanned OMDs in neighborhoods around Rio Di Janeiro, Brazil. Ravelli et al. (2011) found distance to hospital of at least 20 minutes associated with neonatal mortality and other adverse outcomes in the Netherlands (irrespective of OMDs).

In food deserts absolute distance criteria are sometimes lengthened for rural areas (Ver Ploeg et al., 2015). This does not make sense in terms of maternity ward deserts because OMDs are often related to absolute distance regardless of rural status (Combier et al., 2020). Therefore, one measure of maternity wards used below applies cut-offs of 10, 20, or 30 miles; those distances are approximately 16km, 32km, and 48km, so even the smallest cut-off is significantly related to OMDs (Combier et al., 2020).

This absolute distance measure ignores two facets of food deserts used by the US Department of Agriculture: poverty or low income, and a lack of vehicle access. Lack of vehicle access effectively limits maternity ward access unless the ward is within .5 miles, applying the walking distance criterion from Qato et al. (2014), and Qin et al. (2018). Therefore, an alternative indicator includes this criterion.

Are low income and poverty also relevant to maternity ward deserts? Two studies suggest poverty is associated with pharmacy deserts in terms of higher prices or being out of stock for commonly prescribed drugs (Amstislavski et al., 2012; Wolf and Becker, 2018). More directly, Thornton and Dahlen (2018) found low socio-economic status associated with OMDs in Australia, while Renesme et al. (2013) found maternal unemployment contributing to OMDs in France, independent of distance. In the U.S., Bateman et al. (1994) found OMDs correlated with a lack of health insurance coverage in Harlem, New York. Most directly, poverty associated with low vehicle access may limit alternative transportation resources available (e.g., limousine

or taxicab services).

More broadly, Amstislavski et al. (2012) reference Hart (1971) inverse care law, which states that medical care is available in inverse proportion to need where (and because) market forces operate on the health care system. Hart found evidence for the operation of this law in the U.K. where, even though the National Health Service is nationalized, market incentives nonetheless exist which yield better access to care in wealthier communities, a finding recently confirmed (Watt, 2018). It is plausible to suggest that the inverse care law will be operational in terms of maternity ward deserts, as hospitals may find wealthier communities more financially viable, given a higher proportion of patients are likely to be insured.

Therefore, there is a strong case for an alternative measure of maternity ward deserts that incorporates poverty/low income and vehicle access. For that purpose, the multidimensional measure used by Qin et al. (2018) is applied to maternity ward deserts: a) at least a 20% poverty rate or b) median household income below 80% of median income for the entire area, and at least 33% of the population lives more than .5 miles from a maternity ward (i.e. walking distance) and at least 100 households in the tract do not own a vehicle.

It is expected that the absolute distance measure will more often identify rural maternity ward deserts, while the multidimensional measure will find more deserts in urban areas. On the one hand, relative to rural areas, drawing a 10 or 20 mile radius from any point in an urban area, particularly a dense urban area, is likely to include a hospital with a maternity ward. On the other hand, the multidimensional measures for other types of deserts were typically designed for and applied to urban areas (Jiao et al., 2012; Qato et al., 2014; Qin et al., 2018).[5] More generally, Alkire et al. (2015) note that multidimensional measures of poverty often diverge substantially from unitary measures.

In Wisconsin, the total number of functioning maternity wards declined from 117 as of 2011, to 112 as of 2017. The net change involved the closure of 12 facilities, and the opening of 7 new facilities. To get a notion of relevant size, the mean number of births per facility as of 2007 was 514, with a mean of 46 for the 12 facilities which closed. However, one facility, Burlington Memorial Hospital in the city of Burlington, was responsible for 296 births in 2011[6]; removing that outlier yields a mean number of 2011 births of 23 for other facilities which closed. As of 2017, the overall mean was 535, with an average of 530 in the 7 new facilities.

3 Data and Methods

3.1 Data

Data on all maternity wards in Wisconsin for 2011 and 2017 was obtained from the Wisconsin Department of Health Services.[7] Inspection of these data revealed sparse coverage near the northern Wisconsin border of the Upper Penninsula of Michigan, and near the city of Duluth, Minnesota. In response, data on maternity wards in those areas were geocoded and included in the data.[8] The inclusion of the Michigan and Minnesota data reduced the measured prevalence of maternity ward deserts, supporting their inclusion.[9] The street addresses were geocoded using the Arc 10.6 software. That software includes the geocodes for all census tracts in Wisconsin, and the minimum distance in miles to a maternity ward was calculated using Stata version 15.1, which comprises the distance measure for both the absolute and multidimensional desert measures.

Demographic data on all 1,409 census tracts in Wisconsin are available from the U.S. Bureau of the Census (http://data.census.gov/cedsci), with all figures derived from the 2018 5-year American Community Survey data. A total of 17 of those tracts are on bodies of water, and have no population, leaving a sample of 1,392

[5] See also `https://www.ers.usda.gov/data-products/food-access-research-atlas/documentation/`.

[6] Burlington was purchased by Aurora Health Care, which already had a birthing center 11 miles away in Geneva, so this closure is not surprising.

[7] Specifically, the data are for the location of all health care provider births (which includes mid-wives, particularly in rural areas). See `https://www.dhs.wisconsin.gov/stats/births/index.html`.

[8] For Michigan, data on midwives were obtained from a business directory (https://michiganmidwives.org/business-directory/), with data on other facilities from the state (`https://www.michigan.gov/documents/infantmortality/BirthHospitalList-1_3_2013_430473_7.pdf`). Data on birth locations for Minnesota were provided by the state (`https://www.health.state.mn.us/people/vitalrecords/birthreg/index.html`).

[9] The number of deserts using the 10 mile cut-off fell from 290 to 281, from 51 to 35 with the 20 mile cut-off, and from 19 to 3 with a 30 mile cut-off, with the multidimensional measure unchanged at 203.

census tracts for analysis. The demographic data collected include measures of race by proportion, including non-Hispanic African-Americans (Black), Hispanics, Native American non-Hispanics, and the proportion living under the official poverty line (Poverty). Additionally, to utilize the multidimensional measure, the number of households without access to a motor vehicle (NoVehicle) is included.

To understand the distribution of deserts using the two measures, tracts are split into those which are urban, which includes tracts within Metropolitan counties with either fewer or greater than 250,000 in population, suburban, for non-Metropolitan counties which are contiguous with metropolitan counties, and rural for the remainder.

Descriptive statistics for each type of tract are provided in Table 1. Note that the sample sizes for suburban and particularly rural areas are small because census tracts are designed to capture approximately 4,000 individuals in each. As is reasonable, for both 2011 and 2017, the distance to the nearest maternity ward almost doubles between urban and suburban areas, then nearly doubles again in rural areas. Surprisingly, average distance declined slightly from 2011 to 2017 in suburban and rural areas, even with a net loss of service. Minorities tend to be concentrated in urban areas, excepting Native Americans who tend to reside in rural areas. Poverty is slightly more concentrated in urban areas, and lack of access to a vehicle is concentrated in urban areas, but still occurs elsewhere.

Table 1: Descriptive Statistics

Variables	Urban	Suburban	Rural
Distance 2017 (mi.s)	4.45	7.81	13.2
Distance 2011 (mi.s)	4.24	8.32	14.2
Poverty	14.3%	11.3%	12.9%
Black	11.3%	0.9%	0.8%
Hispanic	8.4%	4.0%	2.4%
Native American	0.6%	0.7%	5.5%
NoVehicle	8.7%	5.3%	4.8%
N	999	291	102

MUA data are drawn from the Health Resources and Services Administration, with the latest update as of this analysis from March 2021.[10] A total of 381 census tracts (27.4%) are classified as MUAs.

3.2 Methods

Maternity deserts are initially defined using an absolute measure, with cut-offs of either 10 or 20 miles; a 30 mile cut-off was considered but yielded only 3 maternity deserts. For policy purposes these tracts may warrant attention (noting that all 3 are both rural and MUAs),[11] but the group is too small for statistical testing purposes, so not discussed further. Next the multidimensional measurement method, including income and poverty measures, distance, and household automobile access, is applied.

Each of the two absolute measures are compared to the multidimensional measure for overlap. All three are compared to the distribution of MUAs. χ^2 statistics are used to gauge the significance of any correlation.

4 Results

For 2017, the Desert10 measure yields 281 maternity ward deserts, while the Desert20 measure yields only 35 such deserts. The Multidimensional measure generates 203 deserts. There is minimal overlap, with 5 overlapping tracts for the Desert10 and Multidimensional measure[12] (i.e., less than 3% of either category) with a total population of 24,057. There is no overlap for the Desert20 and Multidimensional measure.

[10] See `https://data.hrsa.gov/data/download`.

[11] The tracts are 1001 in Door County, 1003 in Oconto County, and 9502 in Forest County.

[12] These include single tracts in Chippewa (108), Eau Claire (1), Sawyer (9400), Waupaca (1011), and Waushara (9608) counties.

However, each of the three measures is positively and significantly correlated with MUAs: over half of the Desert10 tracts (157 of 281) are also MUAs ($\chi^2 143.9, p < .01$), almost all of the Desert20 tracts (33 of 35) are MUAs ($\chi^2 80.9, p < .01$), and a plurality of Multidimensional tracts (89 of 203) are MUAs ($\chi^2 32.4, p < .01$).

Characteristics of maternity ward deserts (and their non-desert counterparts) for 2017 are described in Table 2, along with the MUAs. Using the 10 mile cut-off for the Desert10 measure, poverty, African Americans, Hispanics, and lack of vehicle access are negatively correlated with the deserts, while Native Americans are positively associated. Those results are not surprising given that Desert10 captures less than one-fifth of urban tracts, but almost two-thirds of rural tracts (with the suburban distribution being intermediate), with the overall difference between the three geographic groups being significant. Although weaker, the same patterns hold using the Desert20 measure.

Table 2: Characteristics of Maternity Ward Deserts 2017, and MUAs (non-deserts in parentheses)

Variables	Desert10	Desert20	Multidimensional measure	MUAs
Poverty	9.89%***	12.2%	31.2%***	19.0%***
	(14.5%)	(13.6%)	(10.6%)	(11.5%)
Black	0.90%***	0.55%**	34.6%***	14.4%***
	(10.2%)	(8.55%)	(3.87%)	(6.08%)
Hispanic	3.00%***	2.29%**	16.2%***	9.21%***
	(8.10%)	(7.20%)	(5.52%)	(6.27%)
Native American	2.03%***	2.57%**	0.94%	1.73%***
	(0.68%)	(0.91%)	(00.96%)	(0.66%)
NoVehicle	0.20%***	0.06%***	100%***	0.44%
	(0.47%)	(0.43%)	(0.32%)	(0.41%)
Urban	118	8	183	185
	(881)	(991)	(816)	(814)
Suburban	98	10	19	121
	(193)	(281)	(272)	(170)
Rural	65	17	1	75
	(37)	(85)	(101)	(27)
Affected population	1,129,000	104,110	739,000	1,319,000
	(4,650,000)	(5,674,000)	(5,039,000)	(4,460,000)
N	281	35	203	381
	(1,111)	(1,357)	(1,189)	(1,011)

Notes: Non-deserts in parentheses. * p<.10, ** p <.05, *** p<.01 in 2-tailed t-test for difference in means.

Considering the multidimensional measure, here positive correlations are found for poverty, African Americans, Hispanics, and lack of vehicle access, noting that both poverty and the lack of vehicle access are correlated by design. No correlation is found for Native Americans. The vast majority of maternity ward deserts using this measure are urban, in contrast to the mile cut-off criteria.

As expected, the multidimensional measure is more relevant to urban areas. Less than half of the Desert10 deserts are found in urban areas (118 of 281), while above 90% of the multidimensional measure deserts are in those areas (183 of 203). A closer look at the data revealed that Milwaukee county accounts for only 21 of the Desert10 deserts, with a majority of the multidimensional deserts appearing there (123 of 203).

The Desert10 and Desert20 tracts, along with MUAs, are mapped in Figure 1, while the Multidimensional deserts and MUAs are mapped in Figure 2. In each case, a cut-out highlights the city of Milwaukee, which is the largest population center in the state. That cut-out reveals the mainly urban character of the Multidimensional measure, and the suburban and particularly rural character of the Desert10 and Desert20 tracts, with the MUAs being intermediate.

It is possible that the negative correlation between lack of household access to vehicles and Desert10 and Desert20 is an artifact of the relatively high representation of rural communities for those measures (see Table 2). As a check, the mean number of households in each tract was calculated for the three types of

Figure 1: Maternity ward deserts using Desert10 and Desert20 measures, compared to Medically Underserved Areas (MUAs), with cut-out for Milwaukee

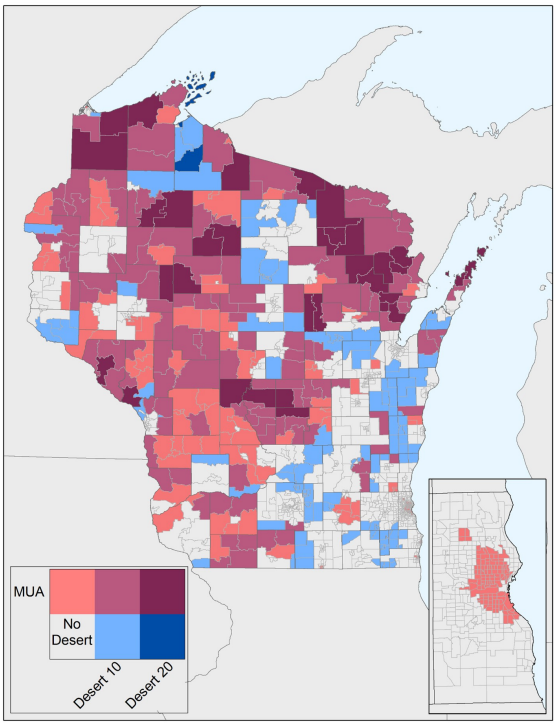
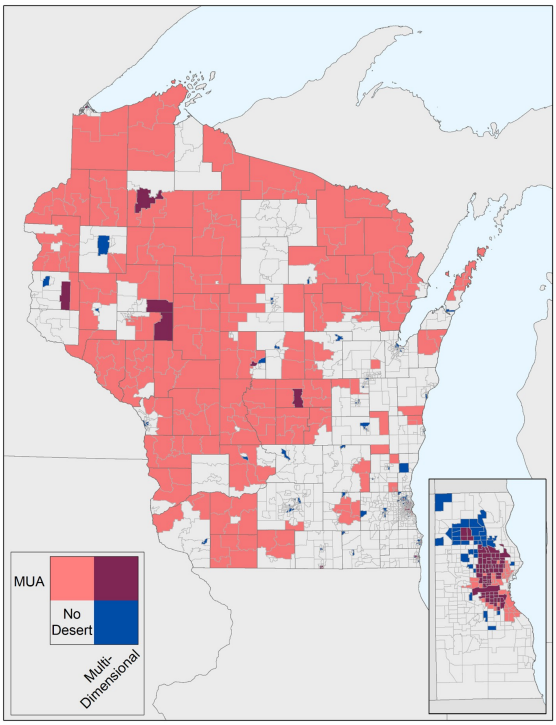


Figure 2: Maternity ward deserts using the Multidimensional measure, compared to Medically Underserved Areas (MUAs), with cut-out for Milwaukee



deserts, and the MUAs, separately for urban, suburban and rural areas. The results are shown in Table 3. By construction, the Multidimensional measure is positively correlated with no vehicle access, as are urban MUAs. However, the Desert10 measure is negatively and significantly correlated in all three areas, as are MUAs in suburban areas. These findings are discussed later.

Table 3: Households with No Vehicle Access Across, by Geography and Deserts plus MUAs

Variables	Desert10	Desert20	Multidimensional measure	MUAs
Urban	68.4***	41.5*	245.3***	171.9***
	(132.5)	(125.6)	(97.9)	(114.3)
Suburban	68.5***	58.6	159.7***	83.9*
	(106.5)	(94.9)	(89.1)	(100.6)
Rural	53.4*	50.4	174	57.9
	(70.4)	(61.4)	(58.5)	(64.2)
N	281	35	203	381
	(1,111)	(1,357)	(1,189)	(1,011)

Notes: Non-deserts in parentheses. * p<.10, ** p <.05, *** p<.01 in 2-tailed t-test for difference in means.

For changes in maternity ward deserts from 2011 to 2017, 17 tracts were filled between 2011 and 2017 using the Desert10 measure, while 10 new deserts appeared (see Table 4). Given there was a net loss of 5 maternity wards over this time, a net gain in coverage is surprising. Indeed, considering the population affected, more than 70,000 people gained coverage from 2011 to 2017. In only one comparison is a significant difference found, and that suggests that coverage of Native Americans expanded as well. Considering the Desert20 measure, there is also a net expansion of 8 tracts covered, with approximately a net of 20,000 people gaining coverage. Note that there were no changes using the multidimensional measure.[13]

Table 4: Characteristics of Maternity Ward Deserts filled 2011 to 2017

Variables	Desert10	Desert20
Poverty	10.30%	11.20%
	(8.09%)	(7.76%)
Black	0.47%	1.22%
	(0.46%)	(0.38%)
Hispanic	2.46%	5.60%
	(5.93%)	(1.28%)
Native American	1.39%***	2.12%
	(0.27%)	(0.14%)
NoVehicle	0.40%	0.23%
	(0.17%)	(0.00%)
Urban	0.00%	0.00%
	(69.6%)	(60.0%)
Suburban	80.00%	69.20%
	(21.7%)	(20.0%)
Rural	20.00%	30.80%
	(8.70%)	(20.0%)
Affected population	101,199	38,671
	(28,102)	(18,896)
N	23	13
	(10)	(5)

Notes: New deserts as of 2017 in parentheses. * p<.10, ** p <.05, *** p<.01 in 2-tailed t-test for difference in means.

[13]This is not surprising given the same 5-year ACS demographic/household data were applied to the 2011 and 2017 measures.

These results are somewhat surprising given most recent hospital closures in the U.S. have been in rural areas (Hung et al., 2017). Yet, the measures of maternity ward deserts that mainly capture rural areas (Desert10 and Desert20) show greater coverage. As a check, we identified the zip codes for maternity wards closed between 2011 and 2017, and those newly opened, and found the percentage of the population in each classified as rural or urban.[14] Of the 12 closures, seven were in areas with 100% rural populations, one was in an area with half the population being rural (Oconto Falls), and four were in predominantly urban areas (Menomonee, Menomonee Falls, Middleton, and Rochester). Of the seven new facilities, one was in a rural area, two in areas that were predominantly rural, three in areas that were predominantly urban (Black River Falls, Baldwin, and Ashland), and one which is urban (Wauwatosa). On net, Wisconsin fits the national story of hospitals (or at least maternity wards) mainly closing in rural areas.

This pattern helps to explain why there were no changes in the multidimensional measure of maternity ward deserts: urban areas on net were relatively unaffected by closures and openings. It cannot, however, explain the contraction in people covered by maternity ward deserts using the distance measure.

5 Discussion

Maternity deserts in Wisconsin pose serious risks to expectant mothers, and large numbers are affected. Using 2017 data, the 10-mile cut-off where Combier et al. (2020) found significant increases in OMDs suggests heightened risk for above 1 million Wisconsin residents, and the multidimensional measure suggests more than 700,000 residents are affected (see Table 2).

Comparing 2011 and 2017 data found no change using the multidimensional measure, but a net reduction in maternity desert coverage of more than 70,000 individuals (see Table 4) using the Desert10 measure. That beneficial outcome occurred simultaneous with a net reduction of 5 maternity wards in the state, mainly in rural areas. Taken together, reduced service with improved coverage suggests the health care market functioned efficiently in this case.

For policy-makers, the results provided here may be viewed as somewhat reassuring, and for two reasons. First, using the Desert10 measure, the lack of vehicle access is significantly lower in maternity ward deserts (see Table 3). Although no prior study of maternity ward deserts addressed vehicle access directly, two found that travel time to a maternity ward was positively correlated with OMDs (Ravelli et al., 2011; Renesme et al., 2013), and no access to a vehicle likely increases travel time. Second, the net closure of maternity wards from 2011 to 2017 improved population coverage. Both findings suggest that Hart (1971) inverse care law was not operating, otherwise, low vehicle access would be concentrated in maternity deserts, and population coverage would likely have declined, particularly in low income/high poverty areas.

These generally optimistic findings do not negate three important policy conclusions. First, given the strong evidence from elsewhere linking maternity ward distance and OMDs, it is highly likely that unnecessary OMDs are already occurring in maternity ward deserts. Efforts to improve transportation options for expectant mothers in those areas are therefore warranted. Second, the five tracts which were identified as maternity ward deserts under both the 10-mile and multidimensional measure may warrant special attention. Although the 28,000 people affected may not be sufficiently large to justify new maternity wards, the improvements in transportation options just mentioned could be targeted in these deserts. Third and finally, if rural hospital closures continue in Wisconsin, at some point an expansion of maternity ward deserts will occur. That expansion – and the unnecessary OMDs that will follow – is entirely preventable if policy-makers ensure that future closures do not expand these deserts.

The major limitation of this study is that the multidimensional measure of maternity ward deserts was borrowed from research on food and pharmacy deserts (Qin et al., 2018),[15] so we cannot know for certain that the measure predicts OMDs. That is not the case for the absolute distance measures, which are based upon fairly extensive research on distance to maternity ward and OMDs (Blondel et al., 2011; Combier et al., 2020; Diana et al., 2018; Ovaskainen et al., 2015). However, given the close association between the multidimensional measure and disadvantaged communities of color, it is at least plausible to suggest that maternity ward deserts identified using this measure would be positively associated with OMDs. Only

[14] See https://*www.city − data.com*

[15] See also `https://www.ers.usda.gov/data-products/food-access-research-atlas/documentation/`.

future research, perhaps focusing directly on Milwaukee county, could establish such a connection. The only relevant prior study in the U.S. (Bateman et al., 1994) established that a shortfall of health insurance in Harlem was associated with OMDs, but did not study the effects of distance, poverty, or lack of vehicle access. Given the high stakes in terms of maternal and infant health, such research is clearly warranted.

References

Alkire, S., Roche, J. M., Ballon, P., Foster, J., Santos, M. E., and Seth, S. (2015). *Multidimensional Poverty Measurement and Analysis*. Oxford University Press, Cambridge, MA.

Amstislavski, P., Matthews, A., Sheffield, S., Maroko, A. R., and Weedon, J. (2012). Medication deserts: Survey of neighborhood disparities in availability of prescription medications. *International Journal of Health Geographics*, 11(1):1–13.

Bateman, D. A., O'Bryan, L., Nicholas, S. W., and Heagarty, M. C. (1994). Outcome of unattended out-of-hospital births in Harlem. *Archives of Pediatrics & Adolescent Medicine*, 148(2):147–152.

Blondel, B., Drewniak, N., Pilkington, H., and Zeitlin, J. (2011). Out-of-hospital births and the supply of maternity units in France. *Health & Place*, 17(5):1170–1173.

Combier, E., Roussot, A., Chabernaud, J.-L., Cottenet, J., Rozenberg, P., and Quantin, C. (2020). Out-of-maternity deliveries in France: A nationwide population-based study. *PloS One*, 15:e0228785.

Commonwealth Fund (2021). *Status of Medicaid Expansion and Work Requirement Waivers*. Commonwealth Fund, New York, NY.

Diana, L., Glaucia, L., Adriana, C., and Israel Jr, F. (2018). Out-of-hospital deliveries: A case-control study. *Turkish Archives of Pediatrics/Türk Pediatri Arşivi*, 53(2):87–95.

Guadamuz, J. S., Wilder, J. R., Mouslim, M. C., Zenk, S. N., Alexander, G. C., and Qato, D. M. (2021). Fewer pharmacies in black and hispanic/latino neighborhoods compared with white or diverse neighborhoods, 2007–15: Study examines pharmacy "deserts" in black and hispanic/latino neighborhoods compared with white or diverse neighborhoods. *Health Affairs*, 40(5):802–811.

Hart, J. T. (1971). The inverse care law. *The Lancet*, 297(7696):405–412.

Hegerty, S. W. (2016). Commercial bank locations and "banking deserts": A statistical analysis of Milwaukee and Buffalo. *Annals of Regional Science*, 56(1):253–271.

Hegerty, S. W. (2020). "Banking deserts," bank branch losses, and neighborhood socioeconomic characteristics in the city of Chicago: A spatial and statistical analysis. *The Professional Geographer*, 72(2):194–205.

Hung, P., Kozhimannil, K., Casey, M., and Henning-Smith, C. (2017). *State Variability in Access to Hospital-based Obstetric Services in Rural US Counties*. University of Minnesota Rural Health Research Center, Minneapolis, MN.

Jiao, J., Moudon, A. V., Ulmer, J., Hurvitz, P. M., and Drewnowski, A. (2012). How to identify food deserts: Measuring physical and economic access to supermarkets in King County, Washington. *American Journal of Public Health*, 102(10):e32–e39.

Kashian, R. D., Tao, R., Drago, R., et al. (2018). Bank deserts in the USA and the Great Recession: Geography and demographics. *Journal of Economic Studies*, 45(4):691–709.

Lindrooth, R. C., Perraillon, M. C., Hardy, R. Y., and Tung, G. J. (2018). Understanding the relationship between Medicaid expansions and hospital closures. *Health Affairs*, 37(1):111–120.

Nguyen, M., Lefèvre, P., and Dreyfus, M. (2015). Maternal and neonatal outcomes of unplanned deliveries. *Journal de Gynecologie, Obstetrique et Biologie de la Reproduction*, 45(1):86–91.

Ovaskainen, K., Ojala, R., Gissler, M., Luukkaala, T., and Tammela, O. (2015). Out-of-hospital deliveries have risen involving greater neonatal morbidity: Risk factors in out-of-hospital deliveries in one university hospital region in Finland. *Acta Paediatrica*, 104(12):1248–1252.

Pasternak, Y., Wintner, E. M., Shechter-Maor, G., Pasternak, Y., Miller, N., and Biron-Shental, T. (2018). Perinatal outcomes of unplanned out-of-hospital deliveries: A case–control study. *Archives of Gynecology and Obstetrics*, 297(4):871–875.

Qato, D. M., Daviglus, M. L., Wilder, J., Lee, T., Qato, D., and Lambert, B. (2014). 'Ppharmacy deserts' are prevalent in Chicago's predominantly minority communities, raising medication access concerns. *Health Affairs*, 33(11):1958–1965.

Qin, J. Z., Diniz, C. P., and Coleman, J. S. (2018). Pharmacy-level barriers to implementing expedited

partner therapy in Baltimore, Maryland. *American Journal of Obstetrics and Gynecology*, 218(5):504–e1.

Ravelli, A., Jager, K., De Groot, M., Erwich, J., Rijninks-van Driel, G., Tromp, M., Eskes, M., Abu-Hanna, A., and Mol, B. (2011). Travel time from home to hospital and adverse perinatal outcomes in women at term in the Netherlands. *BJOG: An International Journal of Obstetrics & Gynaecology*, 118(4):457–465.

Renesme, L., Garlantézec, R., Anouilh, F., Bertschy, F., Carpentier, M., and Sizun, J. (2013). Accidental out-of-hospital deliveries: A case–control study. *Acta Paediatrica*, 102(4):e174–e177.

Snowden, J. M., Tilden, E. L., Snyder, J., Quigley, B., Caughey, A. B., and Cheng, Y. W. (2015). Planned out-of-hospital birth and birth outcomes. *New England Journal of Medicine*, 373(27):2642–2653.

Thomsen, M. R., Nayga Jr, R. M., Alviola IV, P. A., and Rouse, H. L. (2016). The effect of food deserts on the body mass index of elementary schoolchildren. *American Journal of Agricultural Economics*, 98(1):1–18.

Thornton, C. E. and Dahlen, H. G. (2018). Born before arrival in NSW, Australia (2000–2011): A linked population data study of incidence, location, associated factors and maternal and neonatal outcomes. *BMJ open*, 8(3):e019328.

Ver Ploeg, M., Dutko, P., and Breneman, V. (2015). Measuring food access and food deserts for policy purposes. *Applied Economic Perspectives and Policy*, 37(2):205–225.

Walker, R. E., Keane, C. R., and Burke, J. G. (2010). Disparities and access to healthy food in the United States: A review of food deserts literature. *Health & Place*, 16(5):876–884.

Watt, G. (2018). The inverse care law revisited: A continuing blot on the record of the National Health Service. *The British Journal of General Practice*, 68(677):562–563.

Wolf, B. L. and Becker, M. (2018). Pharmacy deserts and healthcare impediment zones. *Journal of Allergy and Clinical Immunology*, 141(2):AB166.