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A Place-Based Approach to Health: The Effect of Rhode Island's Health Equity Zones on Maternal and Neonatal Health

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An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
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Abstract

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Health capital, a measure of an individual's level of general health and wellbeing, is positively associated with productivity, income, and workforce participation, among other economic metrics. Establishing a foundation of good health during early development is critical in achieving good health in adulthood; therefore, policies that promote health in early life stages can manifest as positive economic returns in later life stages. In 2015 the Rhode Island Department of Health (RIDOH) implemented Health Equity Zones (HEZs), a public health initiative in which RIDOH identified nine geographically-delineated areas demonstrating health disparities within the zone and/or compared to the rest of the state. Each HEZ represents one of these regions in which a team, led by a backbone agency, utilizes a grassroots approach to implement a series of projects and initiatives intended to improve the health of HEZ residents. In this paper I employ a difference-in-differences analytical approach, comparing births of HEZ residents to those of non-HEZ residents pre- and post-HEZ implementation, to examine the effects of HEZs on maternal and neonatal health. Using data from birth certificates between the years 2005 and 2017, I perform regression analysis to determine the average impact of HEZs and the impact of individual HEZs on birthweight, the month prenatal care began, rates of smoking during pregnancy, and gestational age. Although I detect several statistically significant effects of HEZs on these health outcomes, confounding factors, including the HEZs' varying degrees of maturity and tenuous satisfaction of the parallel trends assumption, make it difficult to decisively conclude the magnitude of the HEZs' impacts on maternal and neonatal health. However, the trends in health outcomes within HEZs generally move in a direction of improvement, suggesting a positive net effect of the initiative. Given these promising results, the effects of HEZs on health warrant further examination, especially as more years of data become available and HEZs achieve a greater degree of maturity.

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Abstract

Health capital, a measure of an individual's level of general health and wellbeing, is positively associated with productivity, income, and workforce participation, among other economic metrics. Establishing a foundation of good health during early development is critical in achieving good health in adulthood; therefore, policies that promote health in early life stages can manifest as positive economic returns in later life stages. In 2015 the Rhode Island Department of Health (RIDOH) implemented Health Equity Zones (HEZs), a public health initiative in which RIDOH identified nine geographically-delineated areas demonstrating health disparities within the zone and/or compared to the rest of the state. Each HEZ represents one of these regions in which a team, led by a backbone agency, utilizes a grassroots approach to implement a series of projects and initiatives intended to improve the health of HEZ residents. In this paper I employ a difference-in-differences analytical approach, comparing births of HEZ residents to those of non-HEZ residents pre- and post-HEZ implementation, to examine the effects of HEZs on maternal and neonatal health. Using data from birth certificates between the years 2005 and 2017, I perform regression analysis to determine the average impact of HEZs and the impact of individual HEZs on birthweight, the month prenatal care began, rates of smoking during pregnancy, and gestational age. Although I detect several statistically significant effects of HEZs on these health outcomes, confounding factors, including the HEZs' varying degrees of maturity and tenuous satisfaction of the parallel trends assumption, make it difficult to decisively conclude the magnitude of the HEZs' impacts on maternal and neonatal health. However, the trends in health outcomes within HEZs generally move in a direction of improvement, suggesting a positive net effect of the initiative. Given these promising results, the effects of HEZs on health warrant further examination, especially as more years of data become available and HEZs achieve a greater degree of maturity.

Introduction

According to the Organisation for Economic Co-operation and Development (OECD), healthcare spending per capita in the United States has increased from $3,748 in 1996 to $10,209 in 2017, almost a three-fold increase in two decades. This increase is reflected in the share of GDP spent on healthcare: 12.46% in 1996 to 17.15% in 2017 (OECD 2018). Researchers from the Centers for Medicare and Medicaid Services (CMS) project 5.5 percent annual growth in national health spending in America from 2017-2026, representing 19.7 percent of total GDP in 2026 (Cuckler et al. 2018). Given this trend of increasing healthcare costs in America, policy makers-municipal, state, and federal governments; insurers; and the public have vested interests in policies that mitigate these costs, including those that improve public health. A systematic review of 52 studies found that public health interventions in industrialized countries yield a median return on investment of 14.3 to one and a cost-benefit ratio of 8.3 (Masters et al. 2017). It is also the case that individuals who demonstrate risky health behaviors, such as smoking and excessive alcohol consumption, have significantly higher lifetime healthcare costs than individuals who do not, despite the shorter lifespan associated with these risky behaviors (Yen, Edington, and Witting 1991; Wetzler and Cruess 1985; Fries et al. 1993). Therefore, effecting behavior change as a preventative measure for reducing illness and disease (and the associated treatment costs) represents a promising target for public health interventions. To achieve widespread behavioral change, many researchers and policy makers have turned to community-based interventions that rely on principles from the field of behavioral economics. Given the nascency of this field of study, novel applications of behavioral economics to public health are constantly being developed, and there exists a paucity of research into these new applications. Rhode Island's Department of Health (RIDOH) took such a novel approach in its implementation of Health Equity Zones (HEZs), geographically delineated areas with traditionally underserved populations and poor health relative to the rest of the state. In each HEZ, community stakeholders implemented a series of diverse interventions and initiatives in an effort to improve the health of those communities (Alexander-Scott et al. 2017). In this paper, I will analyze the impact of RIDOH's HEZ initiative on maternal and neonatal (i.e. infants ≤28 days of age) health. Using a unique dataset obtained from information reported to RIDOH via birth certificates, I employ a difference-in-differences regression analysis that exploits the strict geographic delineation of HEZs and their 2015 implementation to assign treatment (HEZ residents) and non-treatment (non-HEZ residents) groups, as well as a pre- and post-treatment period. I use birthweight, the month prenatal care began, rates of smoking during pregnancy, and gestational age as outcome variables. Although analysis detects several significant effects of the HEZs, confounding factors make it difficult to conclusively determine the magnitude of these effects. However, the detected effects trend generally towards improved health metrics, suggesting HEZs represent a promising low-cost public health strategy that warrants continued study, particularly as the HEZs continue to develop and mature. I will begin with a brief overview of the social impact strategies and behavioral economic principles which serve as the foundation for the HEZs, followed by a comprehensive explanation of the HEZ initiative. The following section explores relevant literature, after which I describe the data used in this analysis and explain my methodology. The next section provides results, followed by a discussion of the results and my conclusion. Included in the appendix are a map of Rhode Island overlaid by the HEZs, a description of each of the nine HEZs, the results and discussion of two robustness tests, and selected results from a difference-in-differences analysis of different disease and birth complication-related outcome variables, obtained from a different dataset of hospital discharge data, *Social Impact Strategies*

Community-based interventions have proven particularly appealing to public health officials and economists, who are interested in their potential to effect meaningful changes in community health for relatively low costs. In recent years the principle of "Collective Impact" has gained traction in policy circles. Collective impact describes a strategy for addressing societal problems in which stakeholders from different sectors unify efforts in pursuit of a common agenda. These stakeholders coalesce around a centralized structure or organization and work in collaboration, with mutually reinforcing activities, to achieve the agreed upon agenda (Kania and Kramer 2011). The collective impact model of cross-sector coordination relies on the theory that "the whole is greater than the sum of its parts." This stands in contrast to a model of "isolated impact," which focuses on the unilateral implementation of a single intervention or strategy (Kania and Kramer 2011). For decades the isolated impact model has dominated social intervention efforts, the funding of which has often relied on individual organizations vying against one another for access to grants. It is only recently, largely within the past decade, that the collective impact model has become more prominent, especially in the field of public health. Given its recency, literature on the efficacy of collective impact is limited; however, several studies into collective impact-based health interventions have demonstrated the model's promise in effecting positive changes in community health (Kania and Kramer 2011; Flood et al. 2015; Economos et al. 2007; Mabachi and Kimminau 2012; Breckwich Vásquez et al. 2007). Many of these intervention strategies rely on "nudges" that promote behavior change; such nudges have become a popular topic in the field of behavioral economics.

Behavioral economics, pioneered by such economists as Kahneman and Tversky, Thaler, and Simon, applies psychological principles and behavioral trends to economic models. In doing this, behavioral economists seek to develop models that more accurately reflect human behavior, and therefore act as better economic models than neoclassical models that rely on erroneous assumptions of perfect rationality. Economists and policy makers have recognized the applications of behavioral economics in designing and implementing effective policies. The concept of "nudges," small environmental or architectural changes that encourage a predictable behavior without significantly changing economic incentives, have been championed largely by economists Richard Thaler and Cass Sunstein and have become a popular tool in public policy (Chetty 2015; Thaler and Sunstein 2008, 2003). Since the introduction of nudges into the field of public policy, researchers have analyzed their applications to public health. Much of this research has focused on nudges that encourage healthy eating behaviors; for example, displaying fruit near grocery stores or cafeteria check outs increased incidence of fruit consumption, and using smaller plates, bowls, and utensils decreased total food consumption even when participants were served the same quantity of food (Liu et al. 2014; Marteau et al. 2011; Thorgeirsson and Kawachi 2013; Arno and Thomas 2016). However, little research has been done on the cumulative effect of nudges applied in different contexts and environments all targeting a single goal or purpose, e.g., improving community health.

Rhode Island's Health Equity Zones

In 2015 the Rhode Island Department of Health (RIDOH) embarked on an ambitious project called the Health Equity Zone Initiative. The mission of the initiative is "To eliminate health disparities using place-based strategies to promote healthy communities" (Rhode Island Department of Health n.d.). Nine health equity zones, or HEZs, were chosen based on a combination of factors outlined in community health assessments, which identified contiguous geographic areas in which residents were struggling with particular health challenges (e.g. lack of access to healthy food; unsafe parks and recreation centers; high levels of diabetes, obesity, and other chronic diseases) that contributed to significant health disparities between these areas and the rest of the state (Patriarca and Ausura 2016). Each HEZ is a geographic area in which a team, led by a backbone agency, utilizes a grassroots approach, working with local businesses, nonprofits, and residents to implement a series of projects and initiatives intended to improve the health of the community. Although RIDOH provides some funding and oversees the HEZs, each HEZ team is granted significant autonomy, and each implements projects and initiatives addressing its community's unique needs and resources (Patriarca and Ausura 2016). Each HEZ submitted to RIDOH an action plan identifying what health issues it hoped to address, projects it would implement, organizational partners, and a timeline. The teams are required to file annual reports with updates about their projects and initiatives (Alexander-Scott et al. 2017). This first iteration of the HEZ initiative started in 2015 and spans a three- or four-year period (depending on the zone), meaning that many of the zones are in the final stages of their projects and RIDOH will be receiving (or has received) final reports (Patriarca and Ausura 2016).

Given the importance of maternal and child health on long-term health outcomes, the potential of community-based public health interventions, and the paucity of research on the efficacy of these interventions in developed countries, I am interested in studying the effects of Rhode Island's Health Equity Zones on maternal and neonatal health, the improvement of which several HEZs identified as an explicit goal (Olneyville Health Equity Zone n.d.; JSI Healthy Communities 2017; West Warwick Health Equity Zone 2018; Providence Children & Youth Cabinet n.d.; Healthy Communities Office 2018; Bristol Health Equity Zone n.d.; Local Initiatives Support Corporation 2016; Woonsocket Health Equity Zone n.d.; Newport Health Equity Zone

2016). My interest in focusing on maternal and child health is also motivated by the difficulty of effecting and observing significant health improvements of the kind that HEZs promote (e.g. lower obesity, better diabetes management/lower diabetes rates, lower rates of chronic diseases) in the short time period the HEZ initiatives occupy (3-4 years). While the hope is that these projects and initiatives will flourish into sustaining, long-term community staples, it will take many years for those outcomes to be realized. It is a far more feasible for short-term (3-4 year) projects such as those in HEZs to have a significant, appreciable, and detectable impact on the health of pregnant mothers and neonates. The nine-month gestation of a fetus is a critical period for mother and child, and any decisions or actions made or taken during that period can potentially have lasting effects on the health of the mother and/or child. Therefore, this nine-month period, as well as the time immediately preceding and following it, represent a prime opportunity for public health interventions to significantly affect health outcomes in a relatively short period of time. Also important is that these effects on health outcomes (at least any immediate effects, which are the type targeted by the projects and initiatives on which I will focus) present within and/or immediately following the gestational period, such that data regarding the efficacy of the initiatives is available shortly after their introduction.

HEZs also represent a relatively low-cost public health strategy; although exact figures were not made available, RIDOH supports every HEZ with a grant, institutional support, and access to resources, and each HEZ is responsible for meeting its remaining funding needs through external (i.e. non-RIDOH) grants. This funding structure ensures RIDOH bears only a portion of the total required financial burden and allows each HEZ to tailor its funding sources to its unique set of initiatives and projects. Additionally, HEZ strategy employs a grass-roots approach, utilizing pre-existing community infrastructure, both physical (community centers, walking paths, etc.) and social (meeting groups, school communities, etc.). Capitalizing on pre-existing infrastructure serves as a cost-saving strategy, further reducing the financial needs of the HEZs and contributing to their designation as a low-cost approach to improving public health.

Importance of Good Health

Improving health outcomes results in many direct and indirect benefits, beyond money saved vis-à-vis the lower healthcare costs associated with better health. Extensive research has demonstrated the positive associations between health and human capital, labor productivity, and income. On a macro scale, economists using an expanded Solow growth model estimated that 30 percent of the transition growth rate of per-capita income in OECD countries is due to human health capital, i.e. an individual's level of health, and therefore improved population health results in higher steady-state income (Gyimah-Brempong and Wilson 2004). Similar estimates of production function models further substantiate this finding; even when controlling for education/experience (traditionally considered the primary component of human capital), good health is associated with significantly higher growth rates of aggregate output (Arora 2001; Bloom, Canning, and Sevilla 2004). Good health also has positive implications on a more micro level; researchers found that employees who received telephonic health management training and subsequently improved their health enjoyed 10.3 hours of additional productive time per year, compared with eligible employees who did not receive health management training (Mitchell, Ozminkowski, and Serxner 2013). In an analysis of lifestyle-related health behaviors, Katz et. al. found that employees, aged 18 to older than 60, who engaged in healthy lifestyle behaviors (e.g. high fruit and vegetable intake, regular physical activity), similar to those targeted by HEZs, experienced significantly less productivity loss than those who did not (Katz, Pronk, and Lowry

2014). This increased labor productivity is associated with higher real wages and living standards for workers, and higher levels of GDP for countries with high labor productivity (Fisher and Hostland 2002; Bloom and Canning 2000).

Good health during childhood is critical in establishing a foundation for good health in adulthood, which is consistently associated with positive economic metrics; therefore, childhood health represents a powerful determinant of an individual's economic outcomes. Because poor childhood health may be a product of limited parental resources, which also affect a child's ability to develop his or her human capital, it is difficult to isolate the effect of poor health from these other variables. However, researchers have documented the impact of environmental factors during an individual's in-utero and early life stages on his or her adult health, and have consistently demonstrated the association between poor infant and childhood health and increased probability of disease in adulthood (Gluckman et al. 2008; Barker 1990; Bateson et al. 2004). These effects are extensive in their physiological mechanistic impacts and manifest in a wide range of health outcomes; adverse events experienced in-utero can affect a fetus' kidney development, resulting in an increased risk of hypertension, proteinuria, and kidney disease, and poor fetal and infant growth resulting from poor nutrition highly correlates with type II diabetes and metabolic syndrome later in life (Hales and Barker 2001; Luyckx et al. 2013). Johnson and Schoeni found that low birthweight (an indicator of poor neonatal health) decreases potential for accumulating human capital, reflected in lower labor force participation by five percentage points and reduced earnings by 15 percentage points (Johnson and Schoeni 2011). Lower birth weight and childhood undernutrition were also cited as risk factors for high serum glucose concentrations (an indicator of diabetes and pre-diabetes), high blood pressure, and harmful lipid profiles in adulthood (Victora et al. 2008). Similarly, in a review of current literature, Currie found strong evidence that child health is significantly linked to educational attainment and labor market outcomes (Currie 2009). Using longitudinal panel data that include observations from siblings, thereby allowing control of unmeasured family and background effects, Smith analyzed the impact of childhood health on adult labor market outcomes and demonstrated a significant correlation with poor health during childhood and several important socioeconomic metrics, including ability to earn in the labor market, total family income, and wealth (Smith 2009). Collectively, these findings support the strategy of targeting infant and childhood health to improve adult economic outcomes; by extension, a program such as the HEZ initiative that positively affects neonatal and infant health indirectly has the potential to substantially improve a child's chances of achieving better economic outcomes as an adult.

Maternal, Neonatal, and Child Health

Maternal health is increasingly recognized as a sector that represents a promising target for health interventions. Focusing on maternal health provides an opportunity for public health experts and healthcare providers to target the earliest possible stages of development (i.e. in-utero gestation). Because the health of a gestating fetus is inextricably reliant on the health of its mother, improvements in maternal health translate to an increased probability of good fetal and neonatal health. The principle of compounding returns applies to investments in these early life stages, such that a relatively small investment targeting a person's early life stages may yield significantly greater effects on a desired outcome than a comparable investment targeting later life stages. A meta-analysis including studies of low- and middle-income countries found that maternal undernutrition led to poor fetal growth and lower birthweight, resulting in irreversible damage that affected the offspring's medical, social, and economic wellbeing; the progeny of mothers who experienced undernutrition suffered increased incidence of certain chronic diseases, shorter adult height, less schooling, and reduced economic productivity and human capital (Victora et al. 2008). Haddow et al. found that hypothyroidism in pregnant women is associated with lower intelligence quotient (IQ) scores in their offspring (Haddow et al. 1999). Even a mother's mental health can affect the health of her offspring; chronic stress in a mother (i.e. chronic maternal distress) can precipitate preterm labor, reduced birthweight, and slow offspring growth rate, and maternal depression is associated with low child health ratings and higher rates of child hospitalization (Casey et al. 2004; Patel et al. 2004; Rahman et al. 2004; Weinstock 2005). In a separate study, Leiferman suggested that this latter correlation may be an indirect result of depressed mothers engaging in certain adverse health behaviors that more directly affect their children's health, such as smoking and alcohol consumption (Leiferman 2002). Targeting maternal health and health behaviors provides policymakers the opportunity to affect health during its earliest stages, thereby building a solid foundation for good health throughout an individual's life.

Adopting community-based strategies for health interventions represents a particularly promising method for targeting improvements in maternal and child health. Many of the highest-risk individuals in these critical life stages (i.e. mothers and young children) interact only sporadically and infrequently with traditional healthcare institutions and providers (a paradox termed the "inverse care law"), such that interventions based in or administered in traditional healthcare settings, such as hospitals and clinics, are less likely to reach these high-risk individuals (Ahmed et al. 2010; Hart, Centre, and Talbot 1971). In a comparison of different maternal-health interventions, Barros et al. found community-based interventions were more equally distributed among socio-economic classes than those administered in healthcare facilities (Barros et al. 2012). Community-based approaches to public health also help address issues of scale, which can prove prohibitively complicating for interventions that rely on individually delivering services to people (Rosato et al. 2008). Rosato et al.'s study of community-based health programs in World Health Organization (WHO) member countries determined that community mobilization (i.e. employing community-based public health approaches) is a cost-effective strategy for reducing mortality and improving the health of newborn infants, children, and mothers (Rosato et al. 2008).

Gaps in the Literature

Despite the demonstrated potential of community-based health programs for improving health during critical early life stages, the efficacy of specific interventions and the logistics of scaling up these interventions to reach larger communities are areas of study that deserve more research. Most of the research regarding community-based strategies for improving maternal and neonatal health focuses on middle- and low-income countries. Since these countries experience a disproportionate (according to population size) burden of maternal and neonatal death and disease when compared to higher-income countries, focusing on these countries is rational from a global-health perspective (Bhutta and Black 2013). Because of this, many of the interventions studied are those that address very basic needs (e.g. under- and malnutrition, access to sterile birthing environments) associated with rudimentary healthcare systems. These interventions do not readily translate to countries with more developed healthcare systems, in which public health initiatives seek to address more complex issues. A group of researchers publishing in the journal *Pediatrics* reviewed published and unpublished data on community-based strategies and interventions targeting improved maternal and neonatal health. The researchers identified a series of interventions that offered clear evidence of benefit. However, most of these interventions lacked relevance in developed countries; for example, highlighted interventions included those that addressed malaria prevention and the presence of a skilled birthing attendant during delivery (Bhutta et al. 2005). Studies of initiatives such as the HEZ initiative are therefore necessary to ameliorate these gaps in knowledge and inform public health policy in developed countries.

Data

RIDOH collects and curates health data through a variety of reporting mechanisms and sources; among them, birth certificates and hospital discharge reports for all Rhode Island residents with some exceptions. RIDOH stores these and other child health data in Kidsnet(Rhode Island Department of Health n.d.). The data used in this analysis were provided by RIDOH from birth certificates and hospital discharge reports and span the years 2005 to 2017. The first set of data includes information reported on birth certificates; Rhode Island mandates reporting of all births of Rhode Island residents to RIDOH via a birth certificate reporting form, such that my data set includes all births of Rhode Island residents from 2005 to 2017. The following variables were obtained from birth certificate data: birth year, birth weight, gestational age, maternal gestational diabetes, mother's type of insurance at delivery (public or private), mother's age, mother's race, mother's ethnicity (Hispanic, non-Hispanic, unknown), smoking during pregnancy, mother's city/town of residence, mother's zip code of residence, and the month prenatal care began (i.e. number of months into pregnancy that mother began receiving prenatal care).

The hospital discharge dataset includes information about an individual's diagnosed medical condition(s) during a hospital course. RIDOH and the Centers for Disease Control and Prevention (CDC) mandate the reporting of certain birth defects, abnormalities, and complications, which are recorded in the hospital discharge data. The incidence of the diagnoses for which I requested data is low, and the low prevalence among my study population failed to provide meaningful power to the analytical techniques I employ in this paper. These data and their associated regression analyses are included in the appendix.

All variables from the hospital discharge dataset were knitted to the observations from the birth certificate dataset by an epidemiologist in RIDOH's Division of Maternal and Child Health, and the resulting dataset was provided for this study. The zip code of residence allows me to classify an observation as "HEZ" or "non-HEZ," and to classify observations in the former category in their respective HEZs. Descriptive statistics for the study population are provided in *Tables 1A* and *1B* on the following pages.

Table 1A. Descriptive Characteristics of Study Population

		Age, year					Race						
	n *Percent*	<20	20-29	30-39	40-49	≥50	White	Black	Asian	Native Hawaiian/ Other Pacific Islander	American Indian/ Alaskan Native	Other	Unknown
Not in HEZ	79374	3961	33979	38517	2904	13	62261	5843	3800	12	529	6323	606
	67.75	*3.38*	*29.00*	*32.88*	*2.48*	*0.01*	*53.14*	*4.99*	*3.24*	*0.01*	*0.45*	*5.40*	*0.52*
Providence	6153	670	3316	2038	129	0	2667	1211	283	4	116	1794	78
	5.25	*0.57*	*2.83*	*1.74*	*0.11*	*0.00*	*2.28*	*1.03*	*0.24*	*0.00*	*0.10*	*1.53*	*0.07*
Pawtucket/ Central Falls	3651	540	2096	930	85	0	1636	410	27	1	30	1498	49
	3.12	*0.46*	*1.79*	*0.79*	*0.07*	*0.00*	*1.40*	*0.35*	*0.02*	*0.00*	*0.03*	*1.28*	*0.04*
Newport	883	27	315	487	52	2	729	76	14	1	13	35	15
	0.75	*0.02*	*0.27*	*0.42*	*0.04*	*0.00*	*0.62*	*0.06*	*0.01*	*0.00*	*0.01*	*0.03*	*0.01*
Olneyville	8820	1136	5020	2465	199	0	3298	1240	509	3	155	3516	99
	7.53	*0.97*	*4.28*	*2.10*	*0.17*	*0.00*	*2.82*	*1.06*	*0.43*	*0.00*	*0.13*	*3.00*	*0.08*
Southside, Elmwood, West End	5780	841	3264	1531	143	1	1663	1155	504	3	84	2291	80
	4.93	*0.72*	*2.79*	*1.31*	*0.12*	*0.00*	*1.42*	*0.99*	*0.43*	*0.00*	*0.07*	*1.96*	*0.07*
Washington County	539	28	207	275	29	0	515	4	3	0	5	7	5
	0.46	*0.02*	*0.18*	*0.23*	*0.02*	*0.00*	*0.44*	*0.00*	*0.00*	*0.00*	*0.00*	*0.01*	*0.00*
West Warwick	4243	307	2291	1559	86	0	3781	113	147	0	19	136	47
	3.62	*0.26*	*1.96*	*1.33*	*0.07*	*0.00*	*3.23*	*0.10*	*0.13*	*0.00*	*0.02*	*0.12*	*0.04*
Woonsocket	6168	759	3667	1631	109	2	4247	542	519	3	34	750	73
	5.26	*0.65*	*3.13*	*1.39*	*0.09*	*0.00*	*3.63*	*0.46*	*0.44*	*0.00*	*0.03*	*0.64*	*0.06*
Bristol	1543	61	604	815	63	0	1461	18	37	0	2	19	6
	1.32	*0.05*	*0.52*	*0.70*	*0.05*	*0.00*	*1.25*	*0.02*	*0.03*	*0.00*	*0.00*	*0.02*	*0.01*
Total	117154	8330	54759	50248	3799	18	82258	10612	5843	27	987	16369	1058
	100.00	*7.11*	*46.74*	*42.89*	*3.24*	*0.02*	*70.21*	*9.06*	*4.99*	*0.02*	*0.84*	*13.97*	*0.90*

Table 1B. Descriptive Characteristics of Study Population, continued

	Ethnicity			Smoked during Pregnancy		Insurance	
	Non-Hispanic	Hispanic	Unknown	Yes	No	Public	Private
Not in HEZ	63530	10402	5442	5747	73627	29020	50354
	54.23	*8.88*	*4.65*	*4.91*	*62.85*	*24.77*	*42.98*
Providence	2918	3015	220	406	5747	4364	1790
	2.49	*2.57*	*0.19*	*0.35*	*4.91*	*3.73*	*1.53*
Pawtucket/Central Falls	1102	2476	73	248	3403	3132	519
	0.94	*2.11*	*0.06*	*0.21*	*2.90*	*2.67*	*0.44*
Newport	724	131	28	60	823	312	571
	0.62	*0.11*	*0.02*	*0.05*	*0.70*	*0.27*	*0.49*
Olneyville	2768	5816	236	568	8252	7261	1559
	2.36	*4.96*	*0.20*	*0.48*	*7.04*	*6.20*	*1.33*
Southside, Elmwood, West End	1952	3680	148	285	5495	4760	1020
	1.67	*3.14*	*0.13*	*0.24*	*4.69*	*4.06*	*0.87*
Washington County	458	15	66	44	495	140	399
	0.39	*0.01*	*0.06*	*0.04*	*0.42*	*0.12*	*0.34*
West Warwick	3417	349	477	657	3586	1924	2319
	2.92	*0.30*	*0.41*	*0.56*	*3.06*	*1.64*	*1.98*
Woonsocket	4287	1396	485	1058	5110	4177	1991
	3.66	*1.19*	*0.41*	*0.90*	*4.36*	*3.57*	*1.70*
Bristol	1423	40	80	96	1447	448	1095
	1.21	*0.03*	*0.07*	*0.08*	*1.24*	*0.38*	*0.93*
Total	82579	27320	7255	9169	107985	55538	61617
	70.49	*23.32*	*6.19*	*7.83*	*92.17*	*47.41*	*52.59*

Methodology

Analytical Model

I use a standard difference-in-differences (DD) model to estimate the effect of HEZ implementation on maternal and neonatal health using a model similar to that used by Evans and Garthwaite in their analysis of the impact of higher earned income tax credit payments on maternal health (Evans and Garthwaite 2014). DD methodology compares pre- and post-treatment outcomes between a group affected by the treatment or shock (treatment group) and a group unaffected by the treatment/shock (control group) (Evans and Garthwaite 2014; Dimick and Ryan 2014). In the case of my analysis, the treatment/shock is HEZ implementation in 2015, the control group comprises individuals not living in a HEZ, and the treatment group comprises individuals living in a HEZ. The simplest DD model involves a comparison of means between groups for each period; in my results, this is reported as the "simple" DD estimate. A more robust analysis requires additional information and computation; to perform a more robust analysis, I use the following equation, which includes covariates to control for individual characteristics and time effects:

$$(1)\ y_i = \alpha + HEZ_i\phi + Post_t\pi + X_i\gamma + (HEZ_iPost_t)\delta_{DD} + \varepsilon_i$$

Where y_i is the outcome of interest for person i; HEZ_i is an indicator variable for living in a HEZ; X_i is a set of explanatory variables; $Post_t$ is a time indicator variable that equals 1 for all years after 2015; and ε_i is idiosyncratic error. δ_{DD} captures the effect of HEZs on the outcome of interest. The results from (1) are reported as "regression-adjusted" DD estimates.

I perform two regressions for each of the analyses described below; the first regression does not include controls (i.e. $X_i\gamma = 0$) and is reported as "no controls;" the second includes a set of explanatory variables and is reported as "controls." The following variables are used as explanatory variables in the latter analyses: Race (American Indian/Alaskan Native, Asian, Black, Native Hawaiian/Other Pacific Islander, White, Other, and Unknown), Ethnicity (Hispanic, Non-Hispanic, Unknown), Mother's age at birth, Insurance type (Public or Private), and Smoking status (Smoker or Non-Smoker). Each race is represented by a binary variable that equals 1 if i^{th} individual belongs to that race and 0 otherwise. Ethnicity equals 1 if i^{th} individual is Hispanic and 0 otherwise. Mother's age at birth is a discrete numeric variable. Insurance type equals 1 if i^{th} individual had public insurance at the time of birth and 0 otherwise. Insurance type acts as a loose proxy for income; because the maximum age in the sample is 56, none of the mothers in the sample qualify for public insurance (i.e. Medicaid or Medicare) on the basis of age, as the minimum qualification for age alone is 65 (Centers for Medicare & Medicaid Services n.d.). Therefore, those individuals with public insurance qualify either as a result of disability or, more likely, because they classify as "low income" or "very low income." In Rhode Island public insurance is available for pregnant women with incomes up to 253% of the federal poverty level, which depends on household size (State of Rhode Island 2019). Therefore, I employ the "Insurance type" variable as a proxy for income, such that if the variable equals 1 (i.e. i^{th} individual has public insurance) i^{th} individual is likely "low-" or "very low income." Smoking status equals 1 if i^{th} individual smoked at any time during pregnancy and 0 otherwise. When performing analyses in which rates of smoking during pregnancy is the outcome variable, smoking status is not used as a control.

The first regression analysis, reported as the "pooled" analysis, measures the mean effects of HEZs, such that all HEZs are grouped together. In this analysis, HEZ_i represents a dummy variable that equals 1 if i^{th} individual lives in a HEZ and 0 if i^{th} individual lives outside of a HEZ. The second regression analysis, reported as the "separated" analysis, measures the effect of each individual HEZ. In this second analysis, each HEZ is represented by a dummy variable that equals 1 if i^{th} individual lives in that HEZ and 0 otherwise. This second analysis will allow me to identify specific HEZs that significantly affected health outcomes.

Parallel Trends Assumption

A DD model relies on the assumption that the control group serves as an indication of the trend the treatment group would follow if not for the intervention. Although it is impossible to test this counterfactual directly, demonstrating parallel trends between the treatment and control groups before implementation of the treatment supports this assumption, and therefore the validity of the DD analysis. To demonstrate parallel trends, I rely on visual analysis of graphs plotting the trends of HEZs versus those of non-HEZs. For the pooled analyses, one trendline represents the pooled HEZs while another represents non-HEZs. For the separated analyses, I present graphs only for the HEZs for which I detect a significant effect by regression analysis. In such cases, one trendline represents pooled HEZs, including the HEZ in question; one trendline represents non-HEZs; and a third trendline represents the specific HEZ that is the subject of analysis, independent of all other HEZs. Including these three trendlines allows me to evaluate individual HEZs in comparison with non-HEZs and the general HEZ program, thereby providing the opportunity to identify HEZs that over- or under-perform program averages. I also test for parallel trends using the Stata command "dqd" developed by Mora and Reggio. This command tests the parallel trends assumption and reports the p-value under the null hypothesis H_0: Common pre-dynamics (i.e. parallel trends in the pre-treatment period) (Mora and Reggio 2014).

No Differential Shocks Assumption

Another important assumption for a valid DD model is that the treatment of interest is the only shock that differentially affected treatment and control groups. Any exogenous shock that affected the groups asymmetrically could skew the results, as the effect of this shock would be included in δ_{DD}, which is meant to measure exclusively the effect of the treatment. Given the geography of HEZs and Rhode Island's small size, individuals living inside HEZs live in relatively close proximity to those living outside HEZs. Due also to its small size, Rhode Island has a single department of health (RIDOH) that serves the entire state; this is dissimilar to other states, which have a hierarchy of departments of health including those on municipal, county, and/or regional levels, in addition to a state-wide department of health. Therefore, health-related policies or initiatives instituted by RIDOH affect all individuals, both HEZ and non-HEZ residents, with the exception of HEZ-specific policies. Similarly, municipal and regional governments in Rhode Island are small, such that most significant legislation or policy changes (even those not associated with health) occur at the state level, and therefore affect control and treatment groups alike. These factors allow me to conclude that this second DD assumption, that no exogenous shocks differentially affected treatment and control groups, is true, and therefore the results of my DD analysis are valid.

Data Cleaning and Coding

Before beginning analysis, the data require preliminary cleaning. I generate dummy variables to describe ethnicity, race, mother's insurance type, and mother's smoking status. Observations with missing, unknown, or unclear values (e.g. "2nd floor") for "mother's zip code" are dropped, as are observations with missing values for "gestational age" and/or "month prenatal care began." Observations not linked to hospital discharge data are dropped; any record with no information from hospital discharge data signifies that the Rhode Island-resident birth certificate record did not match to a hospital discharge record. The most common reasons for unmatched records include Rhode Island-resident births occurring outside of Rhode Island and adoptions-Kidsnet, the state's child health information system database, includes only in-state hospital records and does not include records for children given up for adoption. Unmatched records may also be a result of data entry error for newborn's medical record number in the Kidsnet table; the epidemiologist at RIDOH providing the data reports that this type of data entry error represents just under five percent of unmatched birth records. Although I do not use hospital discharge data in my primary analysis, I drop unmatched observations to ensure my sample includes only in-state births. I discuss this decision in the "*Discussion*" section.

To assign observations to specific HEZs, I generate nine HEZ dummy variables, each representing a different HEZ. I use the mother's zip code and a map of the HEZs overlaying a zip code map to categorize observations (Rhode Island Department of Health 2016). In some cases a HEZ contains only part of the region delineated by a zip code; in such instances I consider the zip code as contained by the HEZ to help mitigate spillover effects. The Southside, Elmwood, West End (all one HEZ) and Olneyville HEZs are both contained within the larger Providence HEZ. I include these smaller HEZs in the Providence HEZ in addition to assigning them each their own HEZ variable. I also generate a pooled HEZ dummy variable that is equal to 1 if i^{th} individual resides in any HEZ and equal to 0 otherwise. Finally, I generate a time variable to interact with the HEZ variables. The time variable equals 1 if i^{th} observation's year of birth is 2015 or later (i.e. post-treatment) and 0 otherwise.

Results

I present my results using a 95% confidence level for significance (i.e. α=0.05). Two robustness checks are included in the appendix; one includes all observations and changes the date of implementation from 2015 to 2016, and the other drops all 2015 observations and uses 2016 as the date of implementation. Neither of these checks differ significantly from the following results. Simple difference-in-differences estimates, both pooled and separated, are presented in *Table 2*.

Table 2. Simple Difference-in-Differences Estimate by Health Equity Zone

	Birthweight (grams)*		**Month Prenatal Care Began***		**Smoking during Pregnancy†**		**Gestational Age (weeks)***	
	Pre-2015	Post-2015	Pre-2015	Post-2015	Pre-2015	Post-2015	Pre-2015	Post-2015
Separated								
Not in HEZ	3329.28 *585.07*	3330.23 *569.37*	2.55 *0.99*	2.82 *0.99*	0.0760 *0.2651*	0.0607 *0.2388*	38.60 *2.03*	38.71 *1.85*
Providence	3257.38 *607.08*	3242.52 *577.06*	2.81 *1.22*	3.04 *1.20*	0.0686 *0.2528*	0.0572 *0.2323*	38.55 *2.24*	38.63 *2.02*
Pawtucket/Central Falls	3298.85 *567.13*	3266.32 *583.20*	2.74 *1.25*	2.98 *1.17*	0.0758 *0.2647*	0.0405 *0.1972*	38.67 *1.94*	38.59 *1.96*
Newport	3029.63 *818.19*	3264.38 *569.17*	2.44 *0.95*	2.74 *1.09*	0.0601 *0.2381*	0.0723 *0.2592*	37.49 *3.39*	38.69 *1.99*
Olneyville	3233.83 *583.13*	3231.15 *577.79*	2.92 *1.26*	3.07 *1.10*	0.0705 *0.2561*	0.0423 *0.2013*	38.54 *2.09*	38.52 *1.99*
Southside, Elmwood, West End	3234.32 *580.59*	3244.82 *577.13*	2.89 *1.28*	3.07 *1.13*	0.0551 *0.2283*	0.0296 *0.1695*	38.57 *2.11*	38.60 *2.04*
Washington County	3374.12 *611.26*	3397.45 *578.92*	2.52 *0.96*	2.73 *0.99*	0.0925 *0.2900*	0.0469 *0.2122*	38.62 *2.15*	38.89 *1.65*
West Warwick	3326.57 *574.83*	3361.18 *535.55*	2.65 *1.09*	2.77 *1.01*	0.1600 *0.3667*	0.1362 *0.3432*	38.66 *1.97*	38.78 *1.62*
Woonsocket	3234.04 *570.47*	3249.88 *599.15*	2.68 *1.21*	3.11 *1.13*	0.1791 *0.3835*	0.1405 *0.3476*	38.47 *2.02*	38.61 *2.12*
Bristol	3321.44 *583.92*	3336.08 *551.34*	2.53 *0.96*	2.84 *0.87*	0.0701 *0.2554*	0.0362 *0.1871*	38.73 *2.02*	38.81 *1.75*
Pooled								
Not in HEZ	3329.28 *585.07*	3330.23 *569.37*	2.55 *0.99*	2.82 *0.99*	0.0760 *0.2651*	0.0607 *0.2388*	38.60 *2.03*	38.71 *1.85*
In HEZ	3258.01 *587.17*	3263.83 *576.55*	2.78 *1.22*	2.99 *1.12*	0.0972 *0.2963*	0.0681 *0.2520*	38.56 *2.10*	38.63 *1.97*

*Mean
Standard Deviation

†Frequency
Standard Deviation

Parallel Trends

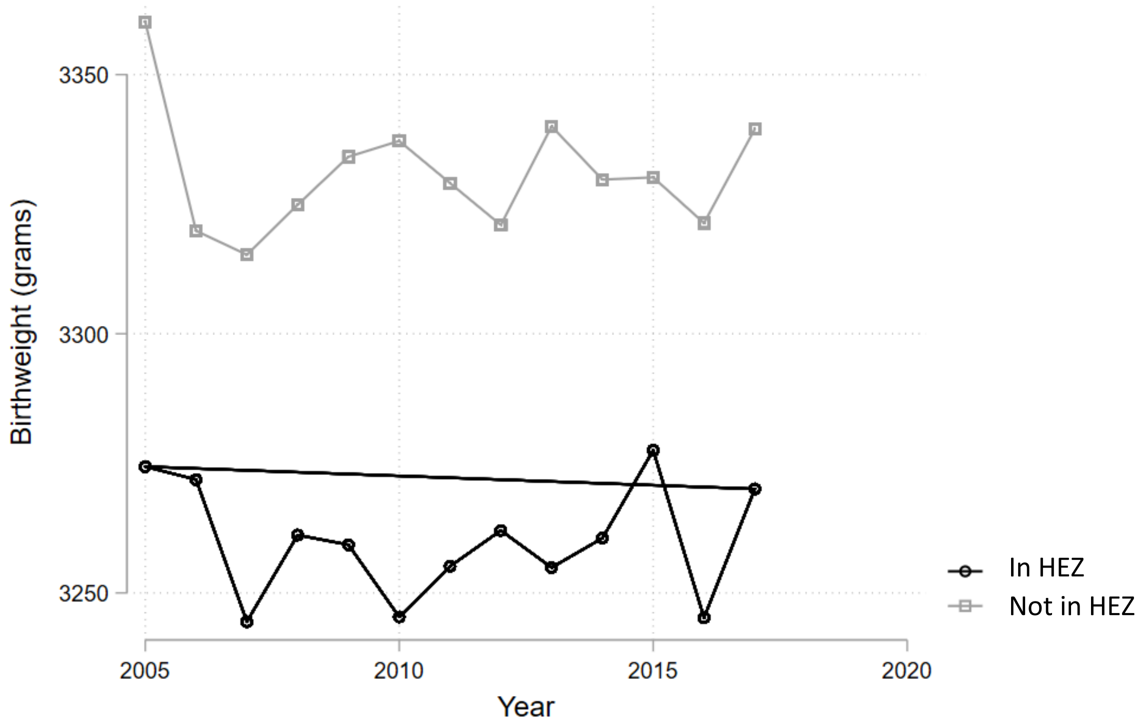
Graphs 1, 2, 3, and 4 depict the trends of outcome variables (birthweight, month prenatal care began, smoking during pregnancy, and gestational age, respectively) from 2005 to 2017. With the exception of gestational age, the HEZ and non-HEZ trendlines appear to track each other closely. Gestational age (*Graph 4*) appears somewhat less correlated between HEZ and non-HEZ, though the absolute amount of variation seems minimal. The dqd estimates of parallel trends, presented in *Table 3*, report that birthweight, smoking, and gestational age all satisfy the parallel trend assumption (H_0: Common pre-dynamics, p=0.4351, p=0.05694, and p=0.4728, respectively). Despite seemingly similar trends when considered graphically, the dqd analysis suggests that the trends for HEZs and non-HEZs for month prenatal care began are not significantly parallel (p= 2.3e-10).

Table 3. dqd Estimates of Parallel Trends

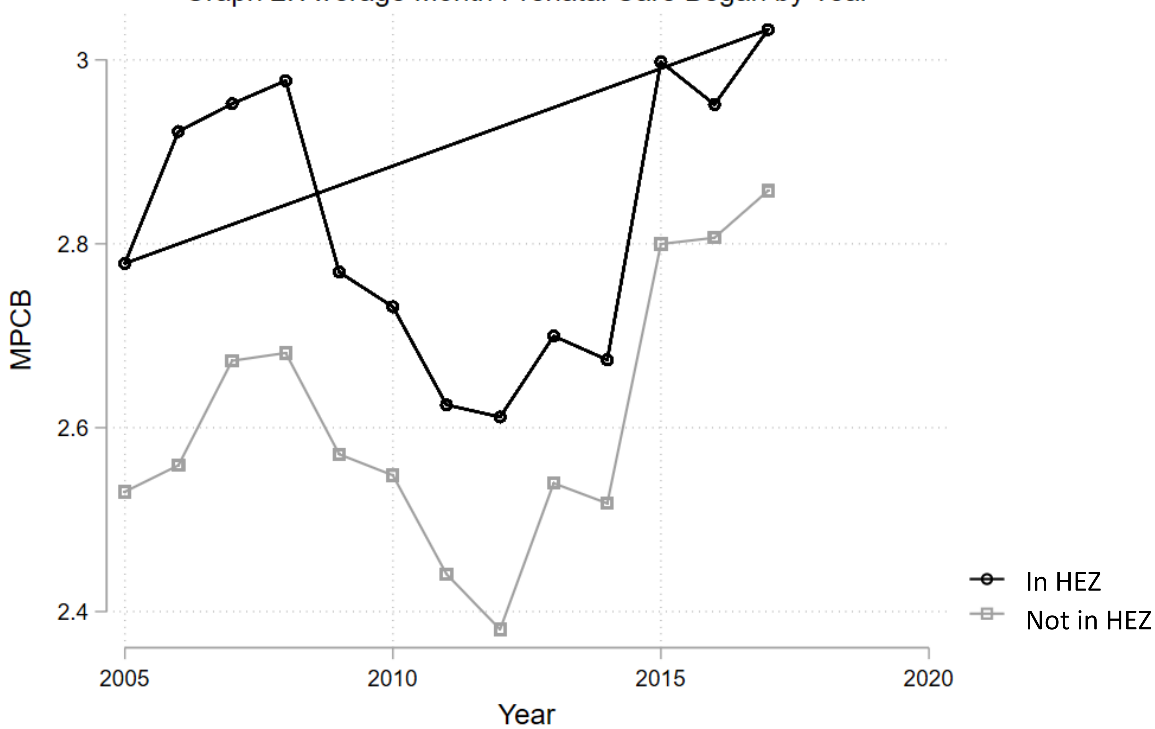
	coefficient	p-value
Birthweight	9.024	0.4351*
Month Prenatal Care Began	63.99	2.3e-10
Smoking	16.51	0.05694*
Gestational Age	8.622	0.4728*

H_0: Common pre-dynamics
*Denotes parallel trends at α=0.05

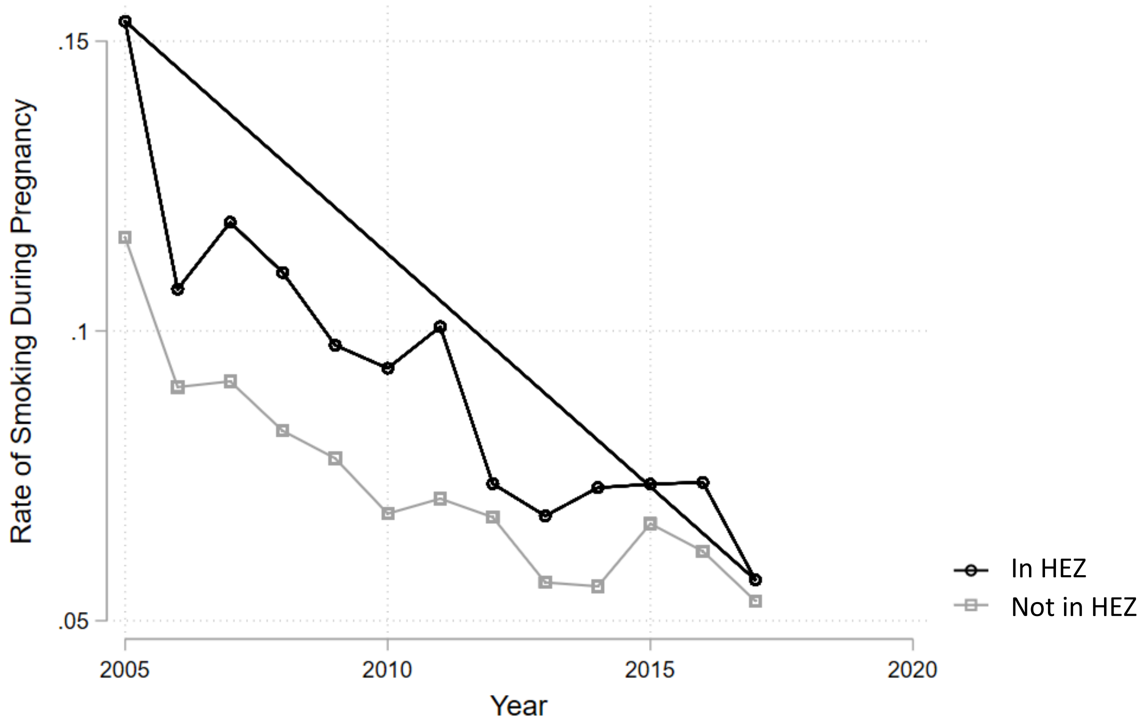
Graph 1. Average Birthweight by Year



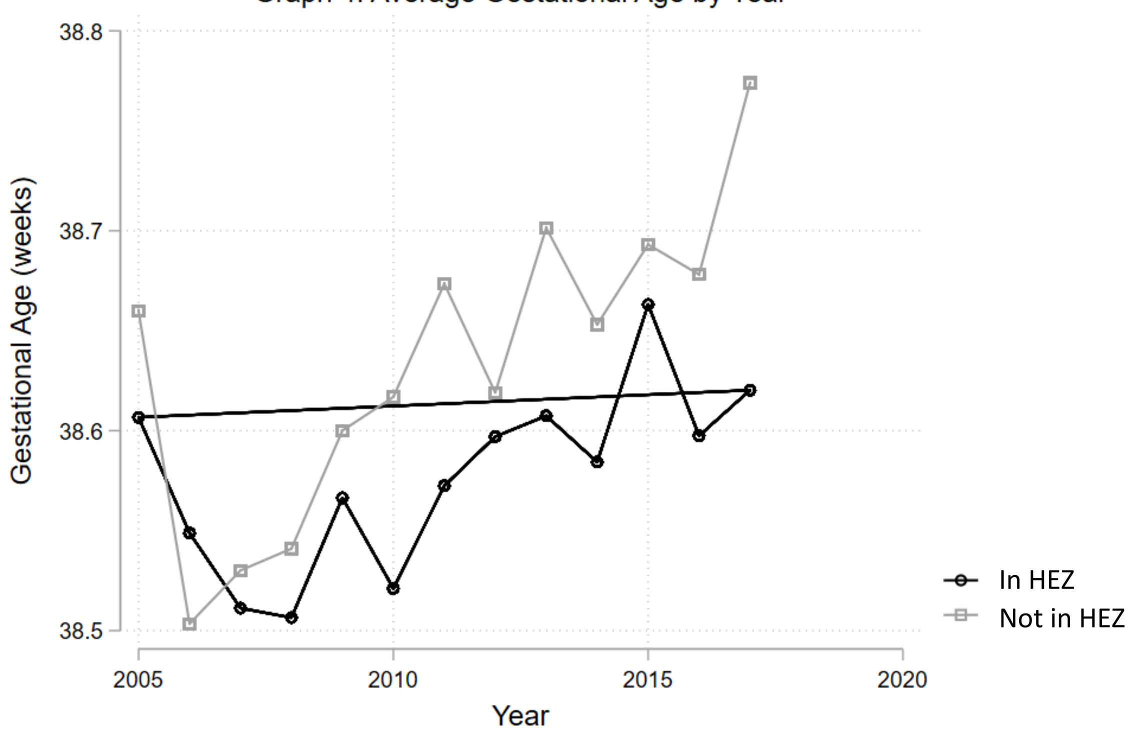
Graph 2. Average Month Prenatal Care Began by Year



Graph 3. Rates of Smoking during Pregnancy by Year



Graph 4. Average Gestational Age by Year



Pooled

In the pooled estimate without controls, living in a HEZ resulted in a decrease in rates of smoking during pregnancy by 1.38 percentage points (p=0.000; *Table 6*) and the month prenatal care began by 0.0621 months, or approximately 1.9 days (p=0.000; *Table 5*). Birthweight (p=0.568; *Table 4*) and gestational age (p=0.156; *Table 7*) were not significantly affected. In the analyses with controls, the only significant change was observed in month prenatal care began (p=0.001), which decreased 0.0520 months, or approximately 1.6 days. Birthweight, smoking during pregnancy, and gestational age did not change significantly (p=0.650, 0.185, and 0.310, respectively).

Table 4. Birthweight: Pooled Regression-Adjusted Estimates

	Coef.	Robust Std. Err.	t	P>|t|	95% Conf. Interval	
Without Controls						
Time	0.110	0.016	6.930	0.000*	0.079	0.141
HEZ	**-0.041**	**0.029**	**-1.420**	**0.156**	**-0.099**	**0.016**
Constant	38.605	0.008	4680.330	0.000	38.589	38.621
With Controls						
American Indian/ Alaskan Native	-49.393	.	.	.	.	.
Asian	-97.587	.	.	.	.	.
Black	-68.567	.	.	.	.	.
Native Hawaiian/ Other Pacific Islander	169.869	.	.	.	.	.
Other Race	-0.648	.	.	.	.	.
Unknown Race	-3.826	.	.	.	.	.
White	68.590	.	.	.	.	.
Hispanic	14.748	4.692	3.140	0.002*	5.552	23.944
Mother's Age	2.056	0.317	6.490	0.000*	1.435	2.676
Public Insurance	-13.087	4.083	-3.210	0.001*	-21.090	-5.084
Smoking	-202.901	6.562	-30.920	0.000*	-215.763	-190.039
Time	-0.469	4.769	-0.100	0.922	-9.815	8.878
HEZ	**3.860**	**8.493**	**0.450**	**0.650**	**-12.786**	**20.505**
Constant	3232.887	.	.	.	.	.

*Significant at α=0.05

Table 5. Month Prenatal Care Began: Pooled Regression-Adjusted Estimates

	Coef.	Robust Std. Err.	t	P>|t|	95% Conf. Interval	
Without Controls						
Time	0.274	0.008	33.200	0.000*	0.258	0.290
HEZ	**-0.062**	**0.016**	**-3.820**	**0.000***	**-0.094**	**-0.030**
Constant	2.547	0.004	633.070	0.000*	2.539	2.555
With Controls						
American Indian/ Alaskan Native	0 (Omitted because of collinearity)					
Asian	0.140	0.042	3.300	0.001*	0.057	0.223
Black	0.147	0.042	3.540	0.000*	0.066	0.229
Native Hawaiian/ Other Pacific Islander	-0.058	0.150	-0.390	0.697	-0.351	0.235
Other Race	-0.126	0.041	-3.060	0.002*	-0.207	-0.045
Unknown Race	0.033	0.056	0.590	0.552	-0.076	0.143
White	-0.090	0.040	-2.250	0.024*	-0.169	-0.012
Hispanic	-0.104	0.009	-11.470	0.000*	-0.122	-0.086
Mother's Age	-0.012	0.001	-19.300	0.000*	-0.013	-0.011
Public Insurance	0.195	0.008	25.030	0.000*	0.179	0.210
Smoking	0.204	0.015	14.090	0.000*	0.176	0.233
Time	0.288	0.008	35.220	0.000*	0.272	0.304
HEZ	**-0.052**	**0.016**	**-3.240**	**0.001***	**-0.084**	**-0.021**
Constant	2.955	0.045	65.510	0.000	2.866	3.043

*Significant at α=0.05

Table 6. Smoking During Pregnancy: Pooled Regression-Adjusted Estimates

	Coef.	Robust Std. Err.	t	P>|t|	95% Conf. Interval	
Without Controls						
Time	-0.015	0.002	-7.480	0.000*	-0.019	-0.011
HEZ	**-0.014**	**0.004**	**-3.620**	**0.000***	**-0.021**	**-0.006**
Constant	0.076	0.001	70.580	0.000*	0.074	0.078
With Controls						
American Indian/ Alaskan Native	0 (Omitted because of collinearity)					
Asian	-0.120	0.013	-9.570	0.000*	-0.145	-0.095
Black	-0.113	0.013	-8.980	0.000*	-0.138	-0.088
Native Hawaiian/ Other Pacific Islander	-0.089	0.041	-2.170	0.030*	-0.169	-0.009
Other Race	-0.130	0.012	-10.410	0.000*	-0.154	-0.105
Unknown Race	-0.090	0.014	-6.460	0.000*	-0.117	-0.063
White	-0.041	0.012	-3.310	0.001*	-0.065	-0.017
Hispanic	0.058	0.002	25.990	0.000*	0.054	0.063
Mother's Age	-0.002	0.000	-10.590	0.000*	-0.002	-0.001
Public Insurance	0.123	0.002	58.360	0.000*	0.119	0.127
Time	-0.015	0.002	-7.680	0.000*	-0.019	-0.011
HEZ	**-0.005**	**0.004**	**-1.330**	**0.185**	**-0.012**	**0.002**
Constant	0.087	0.013	6.580	0.000	0.061	0.113

*Significant at $\alpha=0.05$

Table 7. Gestational Age: Pooled Regression-Adjusted Estimates

	Coef.	Robust Std. Err.	t	P>|t|	95% Conf. Interval	
Without Controls						
Time	0.110	0.016	6.930	0.000*	0.079	0.141
HEZ	**-0.041**	**0.029**	**-1.420**	**0.156**	**-0.099**	**0.016**
Constant	38.605	0.008	4680.330	0.000	38.589	38.621
With Controls						
American Indian/ Alaskan Native	0 (Omitted because of collinearity)					
Asian	0.144	0.076	1.900	0.057	-0.004	0.293
Black	0.056	0.075	0.750	0.453	-0.091	0.203
Native Hawaiian/ Other Pacific Islander	0.501	0.299	1.680	0.094	-0.085	1.087
Other Race	0.197	0.074	2.670	0.008*	0.052	0.341
Unknown Race	0.046	0.107	0.430	0.670	-0.164	0.255
White	0.270	0.072	3.760	0.000*	0.129	0.411
Hispanic	0.071	0.016	4.320	0.000*	0.039	0.103
Mother's Age	-0.018	0.001	-15.970	0.000*	-0.020	-0.016
Public Insurance	-0.023	0.014	-1.590	0.112	-0.051	0.005
Smoking	-0.256	0.024	-10.540	0.000*	-0.304	-0.208
Time	0.121	0.016	7.590	0.000*	0.089	0.152
HEZ	**-0.030**	**0.029**	**-1.010**	**0.310**	**-0.087**	**-0.028**
Constant	38.864	0.081	478.450	0.000*	38.705	39.023

*Significant at $\alpha=0.05$

Separated

In the separated analysis without controls, birthweight changed significantly only in Newport, where it increased 232.45 grams, or 0.511 pounds (p=0.000; *Table 8A*). When controls were added, Newport remained the only changed HEZ, increasing birthweight by 249.79 grams, or 0.550 pounds (p=0.000; *Table 8B*). *Graph 5* depicts the trend of birthweight in Newport compared to the trends of non-HEZ and pooled HEZ residents.

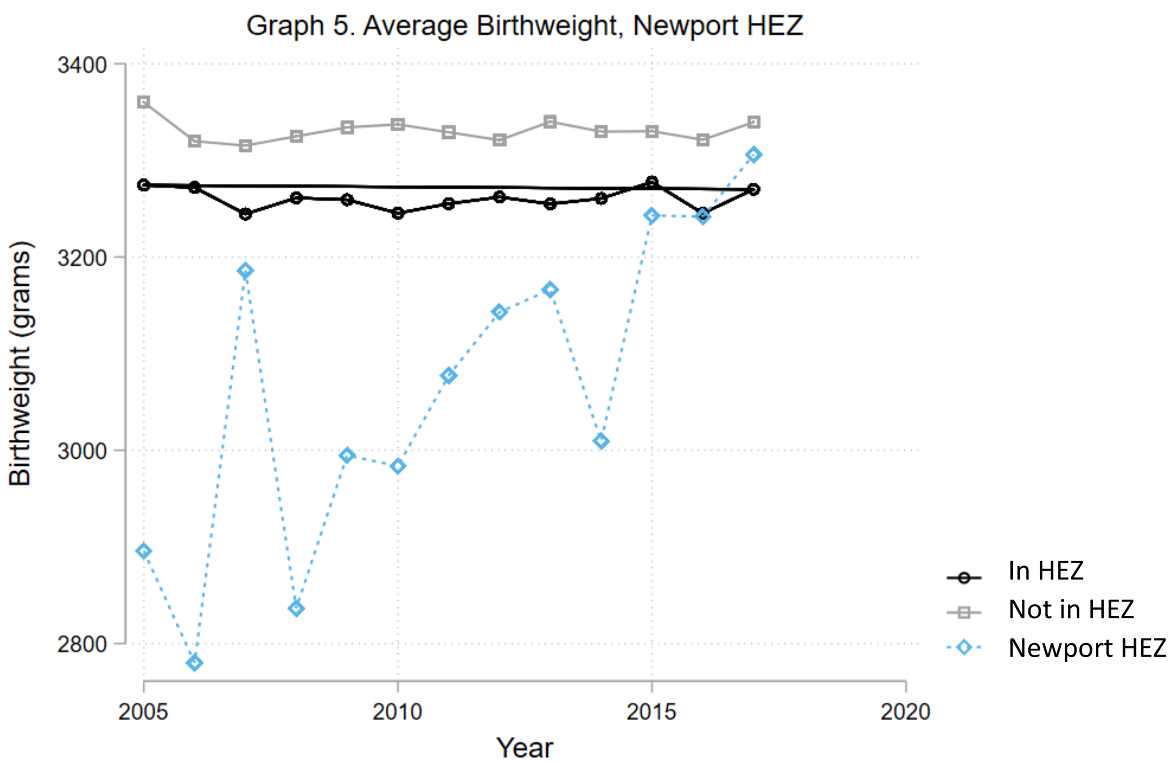


Table 8A. Birthweight: Separated Regression-Adjusted Estimates, No Controls

	Coef.	Robust Std. Err.	t	P>|t|	95% Conf. Interval	
Time	2.303	4.424	0.52	0.603	-6.368	10.973
Providence	-17.170	18.232	-0.94	0.346	-52.904	18.564
Pawtucket/ Central Falls	-34.838	23.448	-1.49	0.137	-80.796	11.121
Newport	**232.449**	**51.981**	**4.47**	**0.000***	**130.567**	**334.331**
Washington	21.021	59.370	0.35	0.723	-95.344	137.386
West Warwick	32.316	20.763	1.56	0.120	-8.380	73.011
Woonsocket	13.538	19.536	0.69	0.488	-24.753	51.829
Bristol	12.338	33.938	0.36	0.716	-54.180	78.857
Constant	3314.224	2.184	1517.35	0.000	3309.943	3318.505

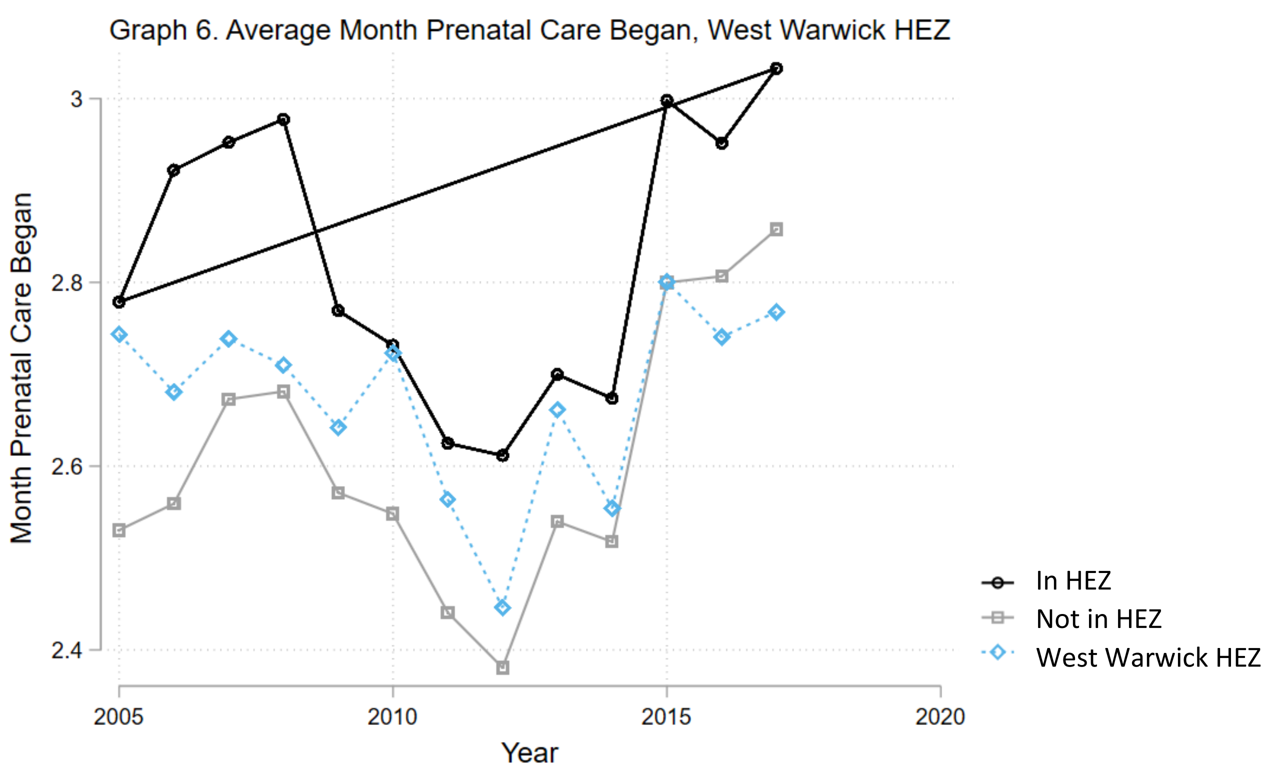
*Significant at α=0.05

Table 8B. Birthweight: Separated Regression-Adjusted Estimates, With Controls

	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf. Interval]	
American Indian/ Alaskan Native	-52.236	.	.	.	.	.
Asian	-101.681	.	.	.	.	.
Black	-73.336	.	.	.	.	.
Native Hawaiian/ Other Pacific Islander	171.877	.	.	.	.	.
Other Race	-6.128	.	.	.	.	.
Unknown Race	-3.311	.	.	.	.	.
White	67.616	.	.	.	.	.
Hispanic	21.264	4.651	4.570	0.000*	12.149	30.379
Mother's Age	2.243	0.316	7.090	0.000*	1.623	2.863
Public Insurance	-17.138	4.052	-4.230	0.000*	-25.080	-9.196
Smoking	-202.452	6.581	-30.760	0.000*	-215.350	-189.554
Time	0.468	4.423	0.110	0.916	-8.201	9.137
Providence	-13.758	18.023	-0.760	0.445	-49.083	21.566
Pawtucket/ Central Falls	-30.139	23.364	-1.290	0.197	-75.933	15.654
Newport	**249.792**	**51.588**	**4.840**	**0.000***	**148.681**	**350.903**
Washington	8.903	59.826	0.150	0.882	-108.355	126.162
West Warwick	28.951	20.446	1.420	0.157	-11.123	69.025
Woonsocket	15.236	19.405	0.790	0.432	-22.797	53.269
Bristol	10.354	33.717	0.310	0.759	-55.731	76.438
Constant	3220.265	.	.	.	.	.

*Significant at α=0.05

Without controls, the month prenatal care began changed significantly in West Warwick and Woonsocket: in West Warwick it decreased 0.130 months, or approximately 4.0 days (p=0.001), and in Woonsocket it increased 0.168 months, or approximately 5.2 days (p=0.000) (*Table 9A*). These two remained the only significantly affected HEZs for the month prenatal care began upon the addition of controls: West Warwick decreased the month prenatal care began by 0.127 months or approximately 3.9 days (p=0.001) and Woonsocket increased the month prenatal care began by 0.159 months or approximately 4.9 days (p=0.000) (*Table 9B*). *Graph 6* depicts the trend of month prenatal care began in the West Warwick HEZ compared to the trends of non-HEZ and pooled HEZ residents. *Graph 7* does the same for the Woonsocket HEZ.



Graph 7. Average Month Prenatal Care Began, Woonsocket HEZ

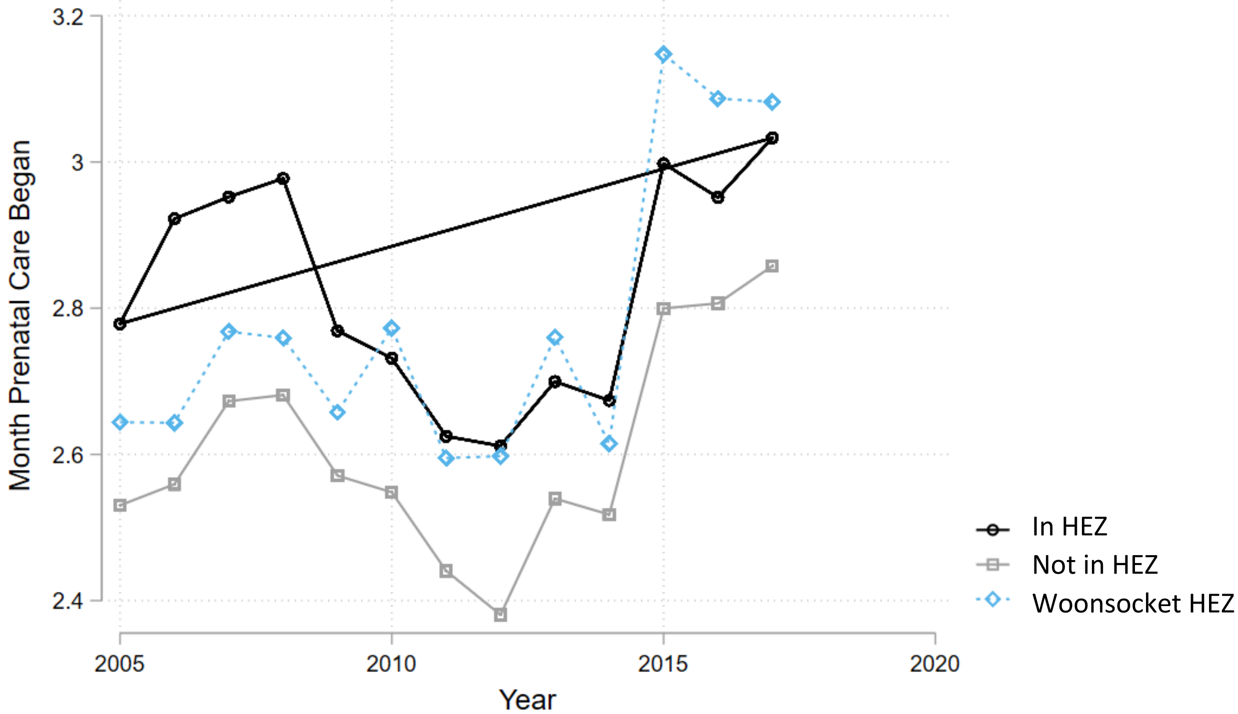


Table 9A. Month Prenatal Care Began: Separated Regression-Adjusted Estimates, No Controls

	Coef.	Robust Std. Err.	t	P>|t|	95% Conf. Interval	
Time	0.254	0.008	32.340	0.000*	0.238	0.269
Providence	-0.029	0.037	-0.770	0.444	-0.102	0.045
Pawtucket/ Central Falls	-0.016	0.048	-0.330	0.742	-0.109	0.078
Newport	0.045	0.071	0.640	0.523	-0.094	0.184
Washington	-0.048	0.100	-0.480	0.631	-0.243	0.147
West Warwick	**-0.130**	**0.039**	**-3.310**	**0.001***	**-0.207**	**-0.053**
Woonsocket	**0.168**	**0.038**	**4.470**	**0.000***	**0.094**	**0.241**
Bristol	0.053	0.054	0.980	0.329	-0.053	0.159
Constant	2.604	0.004	666.770	0.000	2.596	2.612

*Significant at α=0.05

Table 9B. Month Prenatal Care Began: Separated Regression-Adjusted Estimates, With Controls

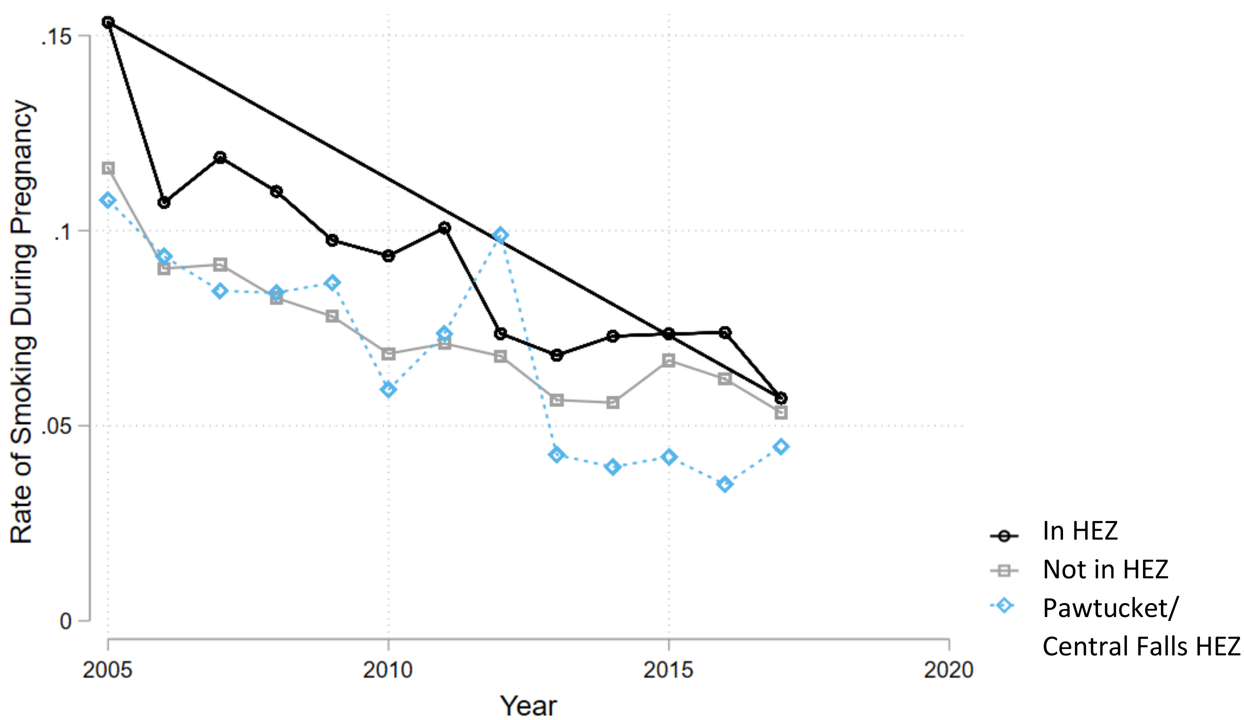
	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf. Interval]	
American Indian/ Alaskan Native	0 (Omitted because of collinearity)					
Asian	0.144	0.042	3.400	0.001*	0.061	0.227
Black	0.150	0.042	3.610	0.000*	0.069	0.232
Native Hawaiian/ Other Pacific Islander	-0.072	0.150	-0.480	0.632	-0.366	0.222
Other Race	-0.123	0.041	-2.990	0.003*	-0.204	-0.043
Unknown Race	0.029	0.056	0.510	0.607	-0.081	0.138
White	-0.095	0.040	-2.380	0.017*	-0.174	-0.017
Hispanic	-0.119	0.009	-13.110	0.000*	-0.136	-0.101
Mother's Age	-0.012	0.001	-20.070	0.000*	-0.014	-0.011
Public Insurance	0.207	0.008	26.780	0.000*	0.192	0.223
Smoking	0.208	0.015	14.310	0.000*	0.179	0.236
Time	0.272	0.008	35.030	0.000*	0.257	0.287
Providence	-0.039	0.037	-1.060	0.291	-0.112	0.033
Pawtucket/ Central Falls	-0.007	0.048	-0.140	0.889	-0.100	0.087
Newport	-0.050	0.070	-0.710	0.478	-0.187	0.088
Washington	-0.021	0.098	-0.210	0.834	-0.213	0.172
West Warwick	**-0.127**	**0.039**	**-3.260**	**0.001***	**-0.203**	**-0.051**
Woonsocket	**0.159**	**0.037**	**4.260**	**0.000***	**0.086**	**0.231**
Bristol	0.032	0.054	0.590	0.558	-0.074	0.137
Constant	3.003	0.045	66.760	0.000	2.915	3.091

*Significant at α=0.05

Only Pawtucket/Central Falls demonstrated decreased rates of smoking during pregnancy when analyzed without controls. Pawtucket/Central Falls decreased the rate by 1.84 percentage points (p=0.034; *Table 10A*). However, when controls were added, the effect was much smaller (0.338 percentage point decrease) and became statistically insignificant (p=0.695) (*Table 10B*). The opposite trend is true of Bristol. When considered without controls, Bristol's effect on the rate of smoking during pregnancy was insignificant (decrease of 1.69 percentage points, p=0.175; *Table 10A*). Upon adding controls, the magnitude of the decrease in the rate of smoking during pregnancy rose to 2.80 percentage points and became statistically significant (p=0.024; *Table*

10B). *Graph 8* depicts the trend of rates of smoking during pregnancy in the Pawtucket/Central Falls HEZ compared to the trends of non-HEZ and pooled HEZ residents. *Graph 9* does the same for the Bristol HEZ.

Graph 8. Rates of Smoking During Pregnancy, Pawtucket/Central Falls HEZ



Graph 9. Rates of Smoking During Pregnancy, Bristol HEZ

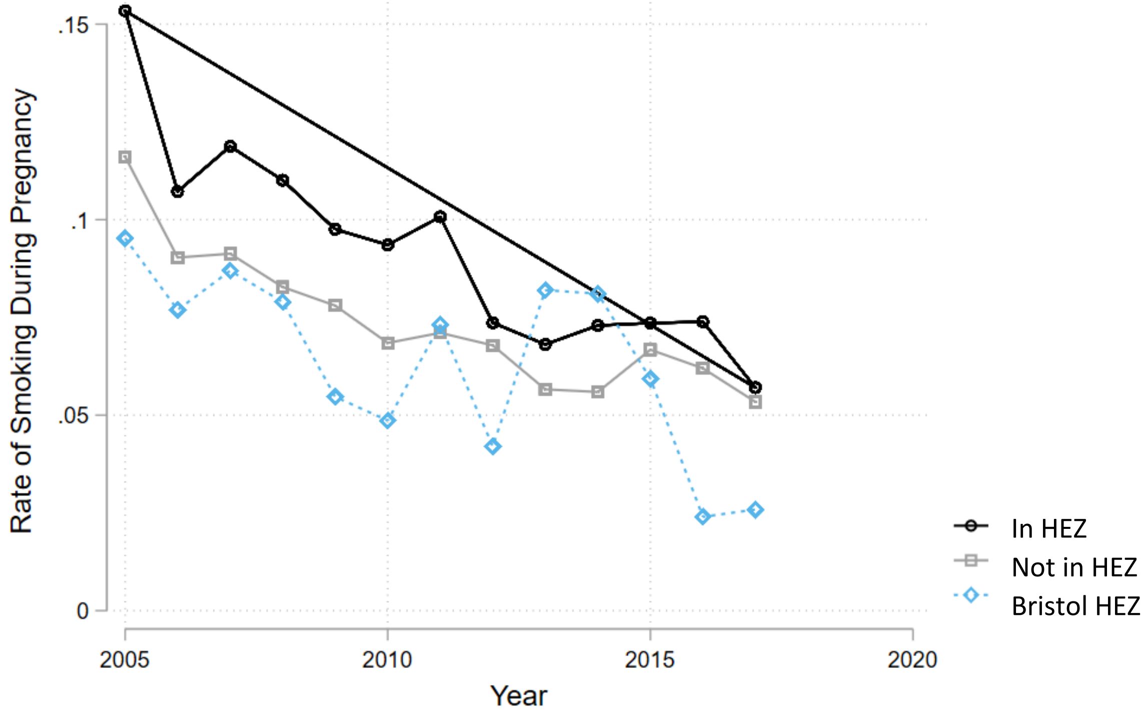


Table 10A. Rates of Smoking During Pregnancy: Separated Regression-Adjusted Estimates, No Controls

	Coef.	Robust Std. Err.	t	P>|t|	95% Conf. Interval	
Time	-0.017	0.002	-9.190	0.000*	-0.021	-0.013
Providence	0.006	0.007	0.750	0.455	-0.009	0.020
Pawtucket/ Central Falls	**-0.018**	**0.009**	**-2.110**	**0.035***	**-0.035**	**-0.001**
Newport	0.029	0.017	1.680	0.093	-0.005	0.063
Washington	-0.029	0.024	-1.210	0.225	-0.075	0.018
West Warwick	-0.007	0.013	-0.530	0.600	-0.033	0.019
Woonsocket	-0.022	0.012	-1.880	0.060	-0.044	0.001
Bristol	-0.017	0.012	-1.360	0.175	-0.041	0.008
Constant	0.074	0.001	75.910	0.000	0.072	0.076

*Significant at α=0.05

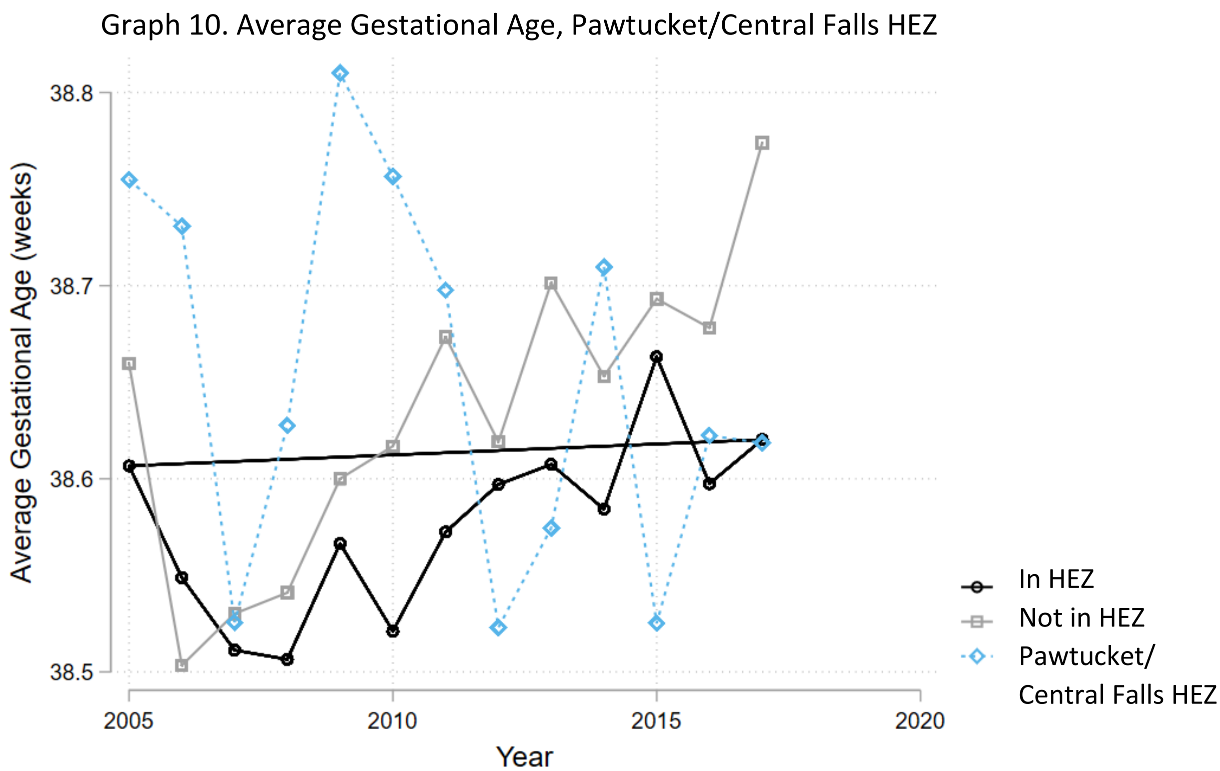
Table 10B. Rates of Smoking During Pregnancy: Separated Regression-Adjusted Estimates, With Controls

	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
American Indian/ Alaskan Native	0 (Omitted because of collinearity)					
Asian	-0.127	0.013	-10.100	0.000*	-0.151	-0.102
Black	-0.114	0.013	-9.060	0.000*	-0.139	-0.089
Native Hawaiian/ Other Pacific Islander	-0.096	0.040	-2.440	0.015*	-0.174	-0.019
Other Race	-0.131	0.012	-10.510	0.000*	-0.155	-0.106
Unknown Race	-0.097	0.014	-7.020	0.000*	-0.125	-0.070
White	-0.048	0.012	-3.860	0.000*	-0.072	-0.024
Hispanic	0.054	0.002	24.720	0.000*	0.050	0.059
Mother's Age	-0.001	0.000	-9.300	0.000*	-0.002	-0.001
Public Insurance	0.122	0.002	58.690	0.000*	0.118	0.126
Time	-0.015	0.002	-8.190	0.000*	-0.018	-0.011
Providence	0.007	0.007	0.970	0.332	-0.007	0.021
Pawtucket/ Central Falls	-0.003	0.009	-0.390	0.695	-0.020	0.014
Newport	0.011	0.016	0.670	0.503	-0.021	0.043
Washington	-0.030	0.023	-1.280	0.201	-0.076	0.016
West Warwick	-0.015	0.013	-1.180	0.238	-0.040	0.010
Woonsocket	-0.019	0.011	-1.750	0.080	-0.041	0.002
Bristol	**-0.028**	**0.012**	**-2.250**	**0.024***	**-0.052**	**-0.004**
Constant	0.088	0.013	6.720	0.000	0.063	0.114

*Significant at α=0.05

Both the Pawtucket/Central Falls and Newport HEZs significantly affected gestational age when considered without controls. Pawtucket/Central Falls decreased gestational age by 0.168 weeks or 1.17 days (p=0.034), and Newport increased gestational age by 1.10 weeks or 7.72 days (p=0.000) (*Table 11A*). When controls were added, Newport remained significant, effecting an increase in gestational age of 1.07 weeks or 7.48 days (p=0.000). However, the effect of Pawtucket/Central Falls on gestational age became insignificant (decrease of 0.144 weeks or 1.00 days, p=0.068) (*Table 11B*). *Graph 10* depicts the trend of gestational age in the Pawtucket/Central

Falls HEZ compared to the trends of non-HEZ and pooled HEZ residents. *Graph 11* does the same for the Newport HEZ.



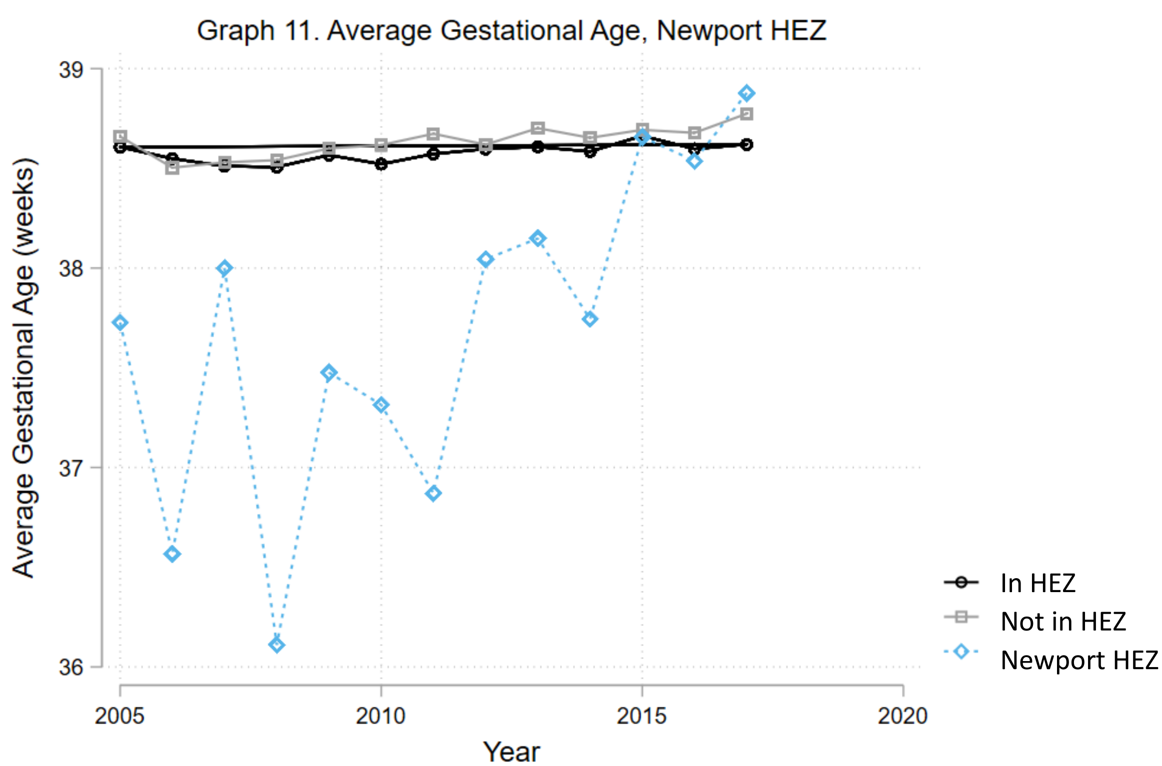


Table 11A. Gestational Age: Separated Regression-Adjusted Estimates, No Controls

	Coef.	Robust Std. Err.	t	P>|t|	95% Conf. Interval	
Time	0.095	0.015	6.430	0.000*	0.066	0.124
Providence	-0.016	0.064	-0.250	0.801	-0.142	0.110
Pawtucket/ Central Falls	**-0.168**	**0.079**	**-2.120**	**0.034***	**-0.323**	**-0.013**
Newport	**1.104**	**0.209**	**5.290**	**0.000***	**0.695**	**1.513**
Washington	0.178	0.180	0.990	0.324	-0.175	0.531
West Warwick	0.028	0.065	0.430	0.669	-0.100	0.155
Woonsocket	0.039	0.069	0.570	0.570	-0.096	0.174
Bristol	-0.021	0.110	-0.190	0.848	-0.237	0.195
Constant	38.596	0.008	5070.230	0.000	38.582	38.611

*Significant at α=0.05

Table 11B. Gestational Age: Separated Regression-Adjusted Estimates, With Controls

	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf. Interval]	
American Indian/ Alaskan Native	0 (Omitted because of collinearity)					
Asian	0.143	0.076	1.890	0.059	-0.005	0.291
Black	0.051	0.075	0.680	0.498	-0.096	0.197
Native Hawaiian/ Other Pacific Islander	0.501	0.300	1.670	0.095	-0.088	1.089
Other Race	0.189	0.074	2.570	0.010*	0.045	0.334
Unknown Race	0.051	0.107	0.480	0.634	-0.159	0.261
White	0.270	0.072	3.760	0.000*	0.129	0.411
Hispanic	0.081	0.016	4.990	0.000*	0.049	0.113
Mother's Age	-0.018	0.001	-15.750	0.000*	-0.020	-0.016
Public Insurance	-0.027	0.014	-1.910	0.056	-0.055	0.001
Smoking	-0.252	0.024	-10.330	0.000*	-0.299	-0.204
Time	0.108	0.015	7.280	0.000*	0.079	0.137
Providence	-0.008	0.064	-0.120	0.905	-0.134	0.118
Pawtucket/ Central Falls	-0.144	0.079	-1.830	0.068	-0.299	0.010
Newport	**1.069**	**0.208**	**5.130**	**0.000***	**0.661**	**1.477**
Washington	0.149	0.180	0.820	0.410	-0.205	0.502
West Warwick	0.019	0.065	0.300	0.765	-0.108	0.146
Woonsocket	0.050	0.069	0.730	0.468	-0.085	0.185
Bristol	-0.036	0.110	-0.330	0.744	-0.251	0.179
Constant	38.849	0.081	481.430	0.000	38.691	39.007

*Significant at α=0.05

Discussion

Methodological Decisions

In performing this analysis, I chose to drop observations that were not linked to hospital discharge data. The hospital discharge data include variables for various birth defects and complications; given their low prevalence and the size of my sample, analyses of these variables lacked adequate power to be included in my primary analyses and can be found instead in the appendix (see *Appendix: Hospital Discharge Data*). Despite not using hospital discharge variables in my primary analyses, I chose to drop unlinked data because of the primary reasons for missing hospital discharge data. The most common situations resulting in observations not being linked to hospital discharge data include births of Rhode Island residents that occur outside of Rhode Island and children being put up for adoption. I wanted to exclude any instances of the former situation; if a birth occurs out-of-state, it may be the case that the mother resides and/or spends a majority of her time out-of-state and has not officially changed her place of residence, in which case the mother would be unlikely to receive the full potential benefits of a HEZ. Because I could not separate these potentially out-of-state mothers from other mothers missing hospital discharge data, and because doing so would still leave me with an ample sample size for analysis, I dropped all unlinked observations.

Some zip codes are only partially contained in a HEZ; i.e. only a fraction of the area delineated by a particular zip code is contained in a HEZ. In such instances I assign the entire zip code to the HEZ, so that all observations in that zip code are considered as belonging to the respective HEZ. I was provided only the zip code of residence for each observation, so it is not possible for me to sort observations into HEZ or non-HEZ on a more granular geographic level. Additionally, including the entire zip code in the HEZ helps contain spillover effects, i.e. the fact that individuals living immediately outside a HEZ may still derive benefit from many of the HEZ initiatives, given their proximity and the indiscriminate nature of many of the initiatives, which are not strictly limited to HEZ residents. For example, a person living immediately outside a HEZ may still frequent community centers within the HEZ, utilize walking and biking trails within the HEZ, attend farmers' markets within the HEZ, etc.

Data

Inherent to certain variables is a degree of uncertainty resulting from measurement methodology. The variable "month prenatal care began" takes a discrete value from zero to nine (inclusive); it does not indicate how early or late in the month the care began. Therefore, there is no way to differentiate an individual who began receiving care on the first day of a particular month of pregnancy from one who began receiving care on the last day of the same month of pregnancy. Almost an entire month of care, which represents approximately 11% of a full pregnancy term, separates the two, but the data do not reflect this distinction. Results that rely on the "month prenatal care began" variable necessarily reflect the imprecision inherent in the measurement. The variable "gestational age" also exhibits a degree of uncertainty. Gestational age (the number of weeks between conception and birth) is based on a physician's estimate of the time of conception. Typically, gestational age is measured beginning from the date of a woman's most recent menstrual period, even though conception is most likely to occur mid-cycle, or an average of two weeks after the menstrual period. In some instances a physician or mother may be able determine a more accurate estimate, in which case he or she will use this more specific date as the beginning of the gestational period. Therefore, the accuracy of "gestational age" depends on the ability to estimate the date of conception, which itself depends on several factors including how early in the gestational period a woman realizes she is pregnant, how soon after conception a woman visits her physician, the physician's experience, etc. The variation in the accuracy of values for gestational age results in less precise results from regression analyses using this variable.

Spillover effects may dilute the measured efficacy of the HEZs. Spillover effects refer to the benefits non-HEZ residents derive from living close to a HEZ. Many HEZ projects and initiatives are not strictly exclusive to HEZ residents; although they are centered and instituted within a HEZ, non-HEZ residents can, in many cases, still take advantage or derive benefit. For example, a non-HEZ resident living just outside the Providence HEZ may still attend the free fitness classes organized by the HEZ or frequent the newly-established farmer's markets that provide subsidies for fruits and vegetables to individuals using Supplemental Nutrition Assistance Program (SNAP) or Special Supplemental Nutrition Program for Woman, Infants and Children (WIC) benefits. In such cases, benefits from the HEZ "spillover" into the non-HEZ population, thereby diluting the measured effect of HEZs in regression analyses. Spillover effects are especially potent in cases where individuals live outside a HEZ but spend most of their time in the HEZ, e.g. to attend work or school. In instances where only a section of a zip code region is contained within a HEZ, I include the entire zip code region in the HEZ in my analyses; doing so helps mitigate spillover effects, but likely only to a minor degree. Because many HEZs do not keep detailed records of event attendees, and because of the non-exclusive nature of many of the projects and initiatives implemented by HEZs, it is difficult to estimate the magnitude and significance of spillover effects. Nonetheless, it is important to acknowledge their potential effects on this analysis, which is to decrease the reported effect of HEZs.

The sizes and populations of the HEZs vary greatly (see *Appendix: Health Equity Zone Details and Descriptions*); one HEZ represents an entire county (Washington HEZ), another represents a small neighborhood (Olneyville HEZ). In performing the “separated” analysis, the power of the analysis decreases considerably as a result of the decreased sample size of each treatment group. For example, the number of annual births in Washington HEZ ranges from 28 in 2005 to 56 in 2010 for a total of 539 observations over the study period 2005 to 2017 (*Table 1A)*. Therefore, the separated analyses are less robust than the pooled analyses.

Birthweight

The pooled analysis did not detect any significant effects of HEZs on birthweight. However, the separated analysis found that Newport effected a significant increase in birthweight by 249.79 grams, or 0.55 pounds. Given that the average birthweight for the entire sample (HEZ and non-HEZ) is 3,306.88 grams, or 7.28 pounds, Newport’s effect on birthweight represents an increase of almost 8% of the average and meets the standard of clinical significance. However, *Graph 5* depicts a great deal of noise in Newport’s birthweight trend; it does not appear to follow the trends of either non-HEZ or pooled HEZs, and there seems to be significant variation in averages of birthweight year-to-year. Therefore, it is difficult to separate the effect of the HEZ from noise in the data. Newport is one of the HEZs with the lowest number of observations (883 over the entire study period), which may account for the high variation. Although we cannot be certain of the exact magnitude of the effect of the Newport HEZ on birthweight, the fact that analysis detected such a significant effect is promising; even if the effect is smaller than reported, the trend is moving in a positive direction.

Month Prenatal Care Began

Although the pooled effect of HEZs on the month prenatal care began is statistically significant (p=0.000 without controls, p=0.001 with controls; *Table 5*), HEZs and non-HEZs fail to meet the assumption of pre-treatment parallel trends, according to dqd analysis (*Table 3)*. In performing a visual analysis of HEZ and non-HEZ trends (*Graph 2*), it appears that the month prenatal care began did not follow any predictable or steady trend in the pre-treatment period. Therefore, we cannot reach certain conclusions about the effects of HEZs on the month prenatal care began. This is true of both the pooled analysis, which detect that HEZs significantly decrease the month prenatal care began, and for the separated analyses, which detect that West Warwick decreased the month prenatal care began and Woonsocket increased it by approximately the same magnitude. Additionally, even if we consider the effect of greatest magnitude for this outcome variable, i.e. Woonsocket's increase of 0.168 months (measured without controls), this increase represents a change of approximately five days. Such a difference, while statistically significant, is clinically insignificant; a five-day difference in the start date of prenatal care matters only in extreme cases of significant health issues of the mother and/or fetus. This lack of clinical significance, in combination with the failure to satisfy the pre-treatment parallel trend assumption and previously discussed measurement error for the month prenatal care began variable, render results for the HEZs effects on the month prenatal care began inconclusive.

Rates of Smoking During Pregnancy

Without controls, the pooled analysis suggests that HEZs significantly decreased rates of smoking during pregnancy by 1.2%; however, when controls are added, the effect becomes insignificant (*Table 6*). The same is true of Pawtucket/Central Falls in the separated analysis:

without controls the HEZ seems to decrease smoking by 1.8%, but the effect becomes insignificant upon adding controls. Bristol experiences the opposite phenomenon: without controls its effect on smoking is insignificant, but when measured with controls Bristol decreases rates of smoking during pregnancy by 2.8% (*Tables 10A* and *10B*). *Graphs 8* and *9* depict a generally downward trend in smoking rates during entire study period (2005-2017), but with a sudden increase in smoking sometime between 2010 and 2015 in both Pawtucket/Central Falls and Bristol; in Pawtucket/Central Falls the rates increase appreciably in 2011 and 2012 before dropping back down in 2013, and in Bristol rates increase appreciably two times, in 2011 and again in 2013. These sudden increases represent anomalies in smoking rates' generally-downward trend, but due to their temporal proximity to HEZ implementation in 2015, they may bias the results of my analysis. Because the increases in smoking rates occurred just before HEZ implementation, the decrease in smoking rates detected in my analysis may represent, in part, reversion to an already-downward trend.

Gestational Age

The pooled analysis detects no significant effect of HEZs on gestational age (*Table 7*). The separated analysis identifies effects for both Pawtucket/Central Falls and Newport. In the case of Pawtucket/Central Falls, the effect is only detected in the analysis with no controls; upon adding controls the effect becomes insignificant (*Tables 11A* and *11B*). Neither robustness analysis (see *Appendix: Robustness Checks*) finds a significant effect of Pawtucket/Central Falls on gestational age. Additionally, the magnitude of the Pawtucket/Central Falls' effect on gestational age in the regression without controls is a decrease of 0.168 weeks, or 1.17 days, which is not clinically meaningful. Therefore, the actual effect of Pawtucket/Central Falls on gestational age is likely trivial. Newport's effect on gestational age is more compelling; it is significant in analyses with and without controls, representing an increase of 1.10 and 1.07 weeks respectively (*Tables 11A* and *11B*). This translates to an increase in gestational age of 7.6 days, an increase of almost 3% of a full-term gestation (38-40 weeks). Even a week of additional gestation can significantly increase a neonate's chances of survival, especially for those born prematurely (i.e. before reaching full-term gestation). For babies born between 22 and 26 weeks gestation, each additional week of gestation increases the probability of survival by an odds ratio of 3.3 (Stensvold et al. 2017). Therefore, Newport's effect on gestational age is both statistically and clinically significant.

Newport

The Newport HEZ effected statistically and clinically significant improvements in both birthweight and gestational age. It is the only HEZ to have effected improvements in two outcome metrics, and therefore deserves further examination. In considering projects that may have contributed to Newport's success, three stand out: community baby showers, Fresh Zones, and Get Well/Stay Well programs (*Appendix: Health Equity Zone Details and Descriptions*). Community baby showers are festival-like events that provide pregnant women the opportunity to participate in raffles and giveaways for necessary childcare products. Professionals at these baby showers connect women with relevant resources and present demonstrations and information on child and maternal wellbeing. Fresh Zones increase access to fruits and vegetables, and Get Well/Stay Well programs include free exercise classes, disease prevention and management classes, and community groups. These three projects seem likely to have contributed the largest amount to Newport's success because they target metrics that have been shown to directly impact maternal and neonatal health. However, a lack of participation data (how many individuals participated in each project, demographics of these individuals, etc.) limits the potential of regression analysis in determining the effects of specific projects.

Another likely contributor to Newport's success is the HEZ's notable level of organization and administrative support. This may be a result of Newport's demographic composition- the area exhibits a high degree of income disparity, with very wealthy individuals on the coast and much poorer areas located more centrally (*Appendix: Map of Rhode Island Health Equity Zones*). As such, Newport is able to leverage the support and resources of its wealthy sections to the benefit of its poorer sections. This high degree of organization and administrative support is demonstrated in Newport's comprehensive and robust community needs assessment, performed early in HEZ planning, which allowed Newport to institute projects that precisely targeted community needs. Newport's informational/public relations materials and consistent social media presence also reflect the HEZ's organizational sophistication. These avenues of information dissemination serve to encourage community engagement and likely increase resident involvement in HEZ projects, which further contributes to the HEZ's success.

Conclusion

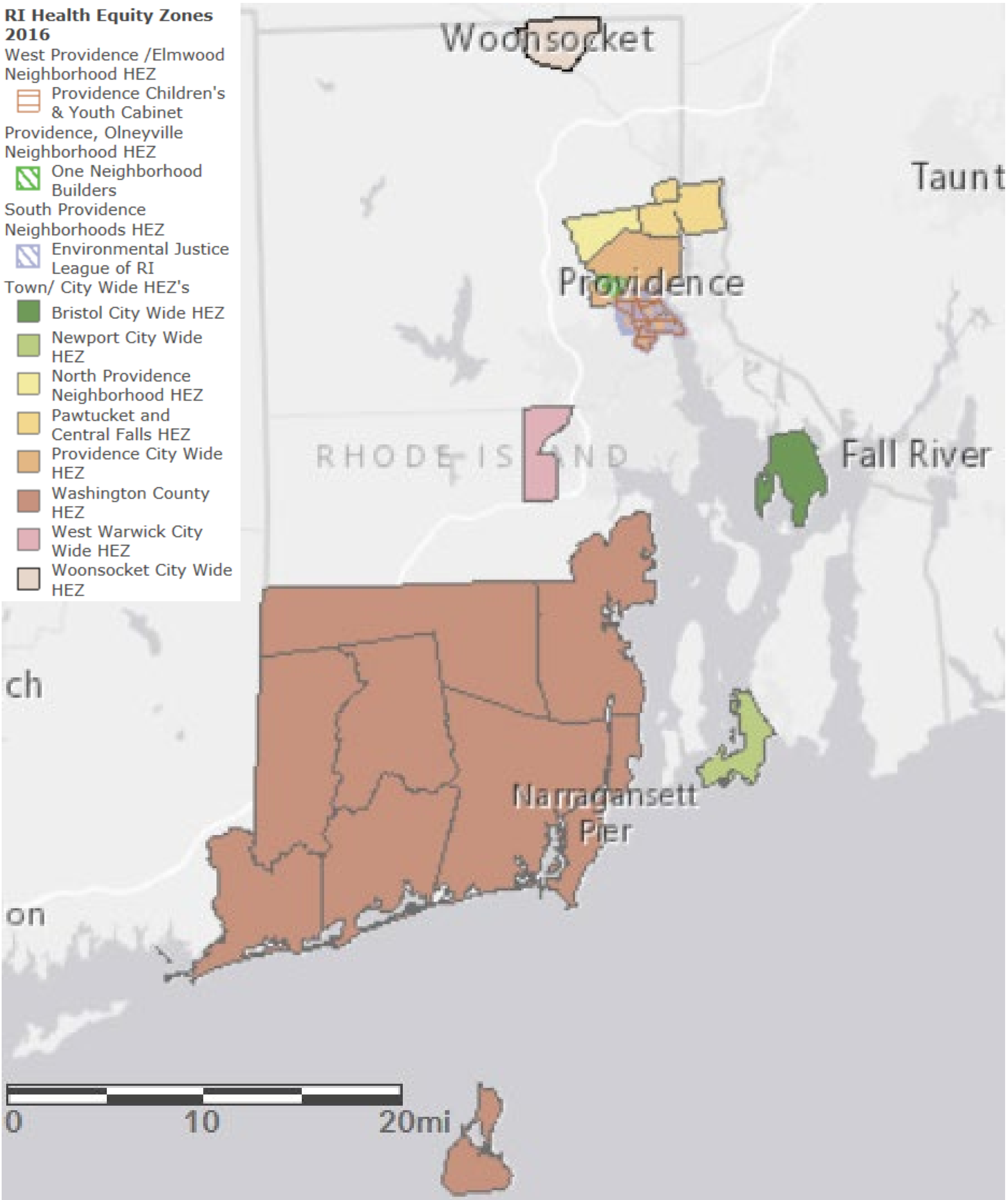
Although difference-in-differences regression analysis detected several statistically significant effects of HEZs, confounding factors make it difficult to decisively conclude that HEZs positively and significantly impact maternal and neonatal health. In the separated analysis, the relatively small sample size of each HEZ contributes to a higher degree of variation when compared to non-HEZs, making it difficult to determine whether the parallel-trends assumption is satisfied. Many of the HEZs also demonstrate a generally-improving pre-treatment trend with respect to each health outcome. This is particularly evident in the pooled analysis, whose lower variance makes it easier to identify trends, but it seems roughly true for the separated analyses as well. In the case of separated analyses, the high degree of variation makes it difficult to isolate HEZ-specific effects from natural variance in the data. For both pooled and separated analyses, it is difficult to separate HEZ-effects from already-improving trends.

I believe that due to the nature of HEZs and method of implementation, these results are consistent with what one would expect from such an initiative at this still-early stage. Abrupt impacts are often the result of highly-targeted initiatives aimed at a specific health metric. In contrast, HEZs tend to target very general health improvement goals, and they do so by employing many small-scale, community-based projects. These projects and policies are diffuse and geared more towards "community building" and systemic change than directed and targeted impacts toward specific health metrics. Additionally, although RIDOH implemented HEZs in 2015, rollout rates for HEZ projects varied significantly and were largely dependent on the HEZs' pre-existing infrastructure and capacity. HEZs with experience in community initiatives, such as Providence, were able to immediately introduce many of their proposed projects. Such HEZs sometimes had community-health programs that predated HEZ implementation, further increasing the difficulty of isolating HEZ-specific effects from already-established initiatives. Other HEZs required more time to plan and build the necessary infrastructure and personnel capacity to support their projects; these HEZs rolled out projects more slowly, introducing only a few in 2015 and more each successive year. It will take time for all HEZs to mature and completely implement their full slate of projects, and further time for those projects to effect positive changes in health metrics, given that meaningful changes in general health and wellbeing (the goal of HEZs) typically require sustained lifestyle changes. For difference-in-differences analysis to conclusively detect the effect of HEZs will require more years of data and further maturation of HEZs.

Although it is difficult to identify the magnitude of the effects of HEZs, the trends in health outcomes within HEZs generally move in a direction of improvement (i.e. increased birthweight, decreased month prenatal care began, decreased rates of smoking during pregnancy, increased gestational age). This suggests a net positive effect resulting from the HEZs, even if the effect is small (given the recency of HEZ implementation) and difficult to isolate. Both the nascency and nature of the HEZ initiative contribute to the difficulty in isolating specific effects; nonetheless, analysis suggests that the HEZs have had net-positive effects on maternal and neonatal health. The initiative warrants further analysis as it continues to progress and mature, and as more data are collected. As more years of data become available, analysis ought to expand to examine the effects of HEZs on health outcomes beyond those specific to maternal and neonatal health. The HEZs should also consider recording participation data, i.e., information on the individuals who participate in specific projects, to enable analysis on the efficacy of these specific projects in an effort to increase HEZ efficiency.

Appendix

Map of Rhode Island Health Equity Zones



(Rhode Island Department of Health 2016)

Health Equity Zone Details and Descriptions

The following pages contain descriptions of each HEZ including population, size (in square miles), contained zip codes, mission, description, and initiatives/projects. Mission, description, and initiatives/projects are taken directly from HEZ publications, websites, public relations and advertising materials, including, in some instances, social media accounts. The sources of the information for each HEZ are listed below.

With two exceptions, all population estimates are the most recent population estimates from the US Census Bureau ("U.S. Census Bureau QuickFacts" n.d.). Olneyville's population estimate comes from Olneyville: Action for a Healthier Community, a report published by Olneyville Housing Corporation and RIDOH (Olneyville Housing Corporation and Rhode Island Department of Health 2011). Southside, Elmwood, West End's population estimate comes from Providence Tomorrow's Neighborhood Plan (Department of Planning and Development 2009).

Citations:

Providence: (Healthy Communities Office, City of Providence 2018; Bertoldi and Cynar 2017)

Pawtucket/Central Falls: (Rhode Island LISC 2016, 2017)

Newport: (Newport Health Equity 2015; Newport Health Equity Zone Transportation Working Group 2017; "Newport Health Equity" 2019)

Olneyville: (Olneyville Housing Corporation and Rhode Island Department of Health 2011; Olneyville Health Equity Zone n.d.; "Olneyville Health Equity Zone" n.d.)

Southside, Elmwood, West End: (Department of Planning and Development 2009; Providence Children & Youth Cabinet n.d.; Rhode Island Department of Health n.d.)

Washington: (Ausura and George 2017; Rhode Island Department of Health n.d.; Healthy Bodies, Healthy Minds 2016)

West Warwick: (West Warwick Health Equity Zone 2016; Arias 2017; Rhode Island Department of Health n.d.)

Woonsocket: (Agudelo, n.d.; Rhode Island Department of Health n.d.)

Bristol: (Rhode Island Department of Health n.d.; "Bristol Health Equity Zone" n.d.; Bristol Health Equity Zone n.d.)

Providence HEZ

Population: 180,393	**Size (sq. mi.):** 18.9	**Zip codes:** 02908, 02918, 02906, 02909, 02903, 02907, 02905, 02904
Mission: To improve nutrition, enhance healthy food policies, increase safety in parks and recreation centers and improve environmental health citywide.		
Description: Focuses on improving community health around the city's recreation centers, improving nutrition, developing community gardens, offering Providence Summer Food Service program, developing healthy food policies for public facilities, increasing access to physical fitness programs for adults and youth in public places, conducting activities to increase health and safety in parks and recreation centers, offering diabetes prevention and self-management programs, and improving environmental health by implementing green infrastructure projects.		
Initiatives/Projects*: -Engagement of a Resident Farmer to engage neighbors in growing and learning about healthy foods at City parks -Bicycle education and safety programs delivered by Recycle-A-Bike at City schools and recreation centers -Peer-led health education provided by Youth in Action at City recreation centers -Youth employment and green infrastructure improvements through the Groundwork Providence Green Team -Outreach and promotion of farmers' markets and of incentives for low-income shoppers, conducted by Farm Fresh Rhode Island -Staff training, certification and delivery of the Diabetes Prevention Program at Lifespan Community Health Institute -Training community members in nonviolence strategies, conducted by the Institute for the Study and Practice of Nonviolence -The Partnership for Providence Parks' implementation of PlayCorps (free play program for children in seven parks throughout the city) in seven City parks -Development of designs for healthier school and park play spaces -Increasing capacity of Parks and Recreation staff through trainings in CPR, Playground Safety, First Aid and other topics -Providing free adult fitness classes in diverse locations -Providing Providence residents with Community Health Worker trainings through Community Health Innovations of Rhode Island -Developing a Healthy Eating Policy for the City's Recreation Centers		

*NOTE: Providence has a "Healthy Communities Office" (HCO) that partners with other agencies to implement public health initiatives, much like those of the HEZs. Providence Citywide HEZ was overseen by HCO; the following list includes only those projects done in explicitly through the HEZ initiative

Pawtucket/Central Falls HEZ

Population: 91,360	**Size (sq. mi.):** 10.2	**Zip codes:** 02863, 02860, 02861

Mission:
Focus on adolescent and behavioral health while supporting culturally competent health services.

Description:
Focuses on resident engagement around increased access to healthy affordable food, diabetes prevention and other self-management programs, adoption of nutrition guidelines where food is sold, healthy housing and empowering tenants, increasing landlord accountability, community kitchen development, improving transportation efficiency, creating linkages to job training, supporting small and micro businesses, establishing youth coalitions, and facilitating positive relationships across diverse neighborhood populations. LISC also focuses on adolescent and behavioral health while supporting culturally competent health services.

Initiatives/Projects:

-Project RENEW to conduct street outreach to commercial sex workers.
-Addressing race as a social determinant of health and its impact on girls of color
-Membership subsidies for youth to participate in club activities
-Empowering tenants through the translation of lead poisoning prevention materials into Portuguese, Cape Verdean and Creole. Conduct workshops and outreach.
-School Based Health Center, medicine and marketing materials
-Focused on grassroots Latina women's health. Acquisition of a laptop and incentives to support outreach and events dedicated to this topic.
-Provide Mental Health First Aid (MHFA) Training and Certification for parents, family members, caregivers, teachers, school staff and health and human service workers.
-Formation of a stipended group of Central Falls high school students to launch an initiative to rehabilitate Higginson Field.
-Implement a Healthy Aging Initiative through teaching senior citizens computer skills.
-Provide financial support for community gardens
-Diabetes Prevention and Self-management Program
-Create a resident-lead Urban Growers Network of Central Falls and Pawtucket stakeholders to serve as a clearing house of communication, resource sharing and training, and a platform for collective impact.
-Expand existing mobile produce markets and farmers that provide subsidies and incentives designed to increase access to fresh, healthy and affordable food. Ensure that residents from immigrant and historically underrepresented communities are involved in processes to identify WHERE and WHEN markets should be held, and WHAT food is desirable in those communities.
-Outreach to increase SNAP and WIC participation
- All Comers Voucher Program: Serve low-income families who may not be eligible for federal benefit incentive programs that will reduce stigma and encourage residents to shop at places that sell fresh, often local produce and value-added food products.
-Create Food Map: Identifies venues in the HEZ that sell affordable, fresh fruit and vegetables and highlights services and programs available, seasonal variations, tips and recipes, coupons and other promotions to incentivize purchasing of fruits and vegetables.
-Safety Field Day to promote police relationships with the community
-Intergenerational yoga and stress management.

Pawtucket/Central Falls HEZ, cont.

Initiatives/Projects (cont.):
-Recover excess or imperfect fresh fruit and vegetables to direct to Central Falls and Pawtucket schools, markets and food pantries
-Create SAFE places for runaways and homeless teens
-Conduct lead mitigation programs for homeowners.
-Provide financial fitness coaching to residents
-Expand HIV, STD and family planning education and screening services for adolescents in public schools
-Develop comprehensive list of bilingual health, behavioral health and other support services available in the HEZ in more than one language.
-HIV and HCV screenings: Promote opportunities for screenings in clinical settings, develop routine screening programs, bundle HCV screening with mental health service provision
-Design home repair grant and lending programs for low moderate-income homeowners.
-Update and distribute Landlord/Tenant Handbook in English, Spanish, Portuguese and Cape Verde Creole.
-Tenant rights and housing safety workshops in multiple languages
-Job training and English language classes
-Micro loans to small businesses
-Construct community/commercial kitchen with food safety classes and onsite childcare
-Walking paths throughout the HEZ with art exhibits (ex. solar sculptures) or historical facts along the path to entice walking. Walking paths will be available to residents on-line and/or apps that would provide residents with the opportunity to select which path they want to walk based on distance and time.
-Walking groups
-Youth-led snow removal program to provide service to the elderly population

Newport HEZ

Population: 24,942	**Size (sq. mi.):** 8.3	**Zip codes:** 02840

Mission:
To mobilize residents and resources of the Broadway and North End neighborhoods to make Newport a place where everyone can thrive.

Description:
Focuses on mobilizing residents and resources of the Broadway and North End neighborhoods, improving transportation, increasing healthy food access, creating economic opportunity, securing open space, parks and, trails; embracing arts and culture, and developing physical and emotional health through two new neighborhood Wellness Hubs that will house evidence-based programs, offering diabetes prevention and other self-management programs, and LAUNCH.

Initiatives/Projects:
-Breastfeeding support group for women of color
-Community baby showers
-Fresh Zones: Sell fruits and veggies in local corner stores, increase awareness of farmers' markets
-Established new farmers' market
-Get Well/Stay Well: Classes and programs offered to residents; exercise classes, disease prevention & management classes; community groups
-Diabetes prevention program
-Diabetes self-management program
-Chronic disease self-management program
-Grandma community connection
-Male unity group S.T.R.O.N.G
-Yoga & Meditation classes
-Aquidneck Island Double-dutch (kids jump rope league)
-Step it Up (walking & weight training class)
-Active Transportation Plan: Increase frequency of walking & biking commuting by increasing safety, improving connectivity, broadening participation and use, and encouraging responsiveness and investment
-Certified Community Health Worker training
-Prioritize and install signals, mirrors, streetlights, and other street-crossing safety equipment
-Walking school bus
-Adopt ordinance requiring bike parking quota for all new developments and the retrofitting of older developments
-Establish interdepartmental team to cooperatively implement the city's Bicycle and Pedestrian Master Plan
-Install sidewalks and repair damaged areas
-Expand Police Department programs to include educational curricula for children and adults related to walking and biking
-Develop pedestrian and bicycle linkages between neighborhoods and major natural areas, recreation facilities, and education centers.
-Install way-finding and route signs and provide maps and internet-based information to guide users through the City's pedestrian and bicycle systems.
-Online resources: Pre-diabetes screening test, Healthy recipes
-Racial equity training
- Public art (sidewalk parades, tree-path project)

Olneyville HEZ

Population: 6,495	**Size (sq. mi.):** 0.56	**Zip codes:** 02909
Mission: To reach deeply into all sectors of the community to activate public passion and pride, and to elevate the quality of life for a community in transition.		
Description: Focuses on increasing and promoting physical activity, access to healthy affordable foods, farmers markets and community gardening, redevelopment of distressed and vacant properties, addressing public safety issues, improving public transportation, offering diabetes prevention and other self-management programs, opportunities for resident financial stability, and community engagement through community pride events and initiatives in efforts to build a more collective and cohesive community.		
Initiatives/Projects: -Free fitness classes -Walking school bus -Bike share program -Free youth sports camp -Health & resource fairs -Healthy cooking classes -Veggie van: delivering healthy foods to residents -Diabetes prevention classes		

Southside, Elmwood, West End HEZ

Population: 22,242	**Size (sq. mi.):** 5.9	**Zip codes:** 02907, 02903, 02905, 02909
Mission: To activate public passion and pride, and to elevate the quality of life for a community in transition.		
Description: Focuses on increasing enrollment and implementation of the Incredible Years Parent Program (promoting young children's social, emotional, and academic lives), creating solutions for greater resident engagement, community organization, and neighborhood ecosystem support, reducing violence, and improving distressed and vacant properties.		
Initiatives/Projects: -Incredible Years Parent Program: promoting young children's social, emotional and academic lives -Maternal/child home visiting -Building Trauma-Sensitive Schools initiative: A therapeutic program designed to reduce symptoms of post-traumatic stress disorder in adolescents -Familias Unidas: A culturally specific program designed for first generation Latino immigrant parents of adolescents -Positive Action: A school-based program that promotes a positive school culture and encourages elementary and middle school children to make positive behavioral choices		

Washington HEZ

Population: 126,150	**Size (sq. mi.):** 350.9	**Zip codes:** 02822, 02852, 02873, 02832, 02898, 02892, 02874, 02881, 02833, 02894, 02804, 02808, 02891, 02813, 02879, 02882, 02807, 02812, 02875, 02836
Mission: To impact childhood obesity and mental health, as well as promoting healthy eating through programs with local farmers.		
Description: Focuses on and promotes programs related to childhood obesity and mental health. Programs include: 5-2-1-0, an evidence-based program, encouraging families to keep a healthy weight, Reach Out and Read, promoting reading aloud to children daily, and Youth Mental Health First Aid, for those interacting with adolescents, and LAUNCH, serving families with children birth to 8 years of age. The HEZ also focuses on connecting residents to local farmers markets accepting SNAP and WIC benefits for access to healthy food		
Initiatives/Projects: -Expand farmer's markets that accept SNAP & WIC benefits -5-2-1-0: Program to decrease the rates of childhood obesity and to encourage youth to live a healthy lifestyle. -Reach out and Read: Encourages parents to read to their child every day -Youth mental health first aid -Project LAUNCH: Targets children ages 0-8 with concrete programs and services, including home visits; developmental assessments in childcare, school, and pediatric care settings; integration of behavioral health into primary care settings; mental health consultation; family strengthening and parent skills training -Guided walks		

West Warwick HEZ

Population: 28,626	**Size (sq. mi.):** 8.2	**Zip codes:** 02893

Mission:
Utilize collective impact and leverage community resources to address health and wellness disparities in West Warwick by focusing on the social determinants of health.

Description:
Focuses on improving walkability and transportation, access to recreation, increased access to healthy affordable fresh food, weekly farmers markets, community garden and orchard, summer meal and school meal programs, addressing high rates of substance use and overdose through rescue, treatment, and recovery strategies, naloxone training, Police Department behavioral health pilot, medication assisted treatment, peer recovery supports, adolescent healthcare with school and community support links, trauma and toxic stress mitigation, diabetes prevention and other self-management programs. Works with 10 engaged neighborhood leaders acting as HEZ citizen ambassadors.

Initiatives/Projects:
-Summer pop-up and seasonal farmer's markets
-Subsidize SNAP & WIC farmer's market purchases
-Peer recovery supports for drug addiction
-Free community pop-up drug recovery center
-Diabetes prevention program
-Community orchard
-Naloxone training
-Medication-assisted treatment for drug addiction
-Free summer meal program
-Behavioral health training for police

Woonsocket HEZ

Population: 28,626	**Size (sq. mi.):** 8.2	**Zip codes:** 02893

Mission:
Utilize collective impact and leverage community resources to address health and wellness disparities in West Warwick by focusing on the social determinants of health.

Description:
Focuses on access to healthy affordable fresh food, year-round farmers markets, addressing high rates of substance use and overdose through rescue, treatment, and recovery strategies, opened The Serenity Center (free community drop-in center for adults in recovery), naloxone training, medication assisted treatment, peer recovery supports, teen health, adolescent medical homes, trauma awareness, physical activity, pedestrian walking plan "Woonsocket Walks - A City on the Move", and offering diabetes prevention and other self-management programs. Works with 10 engaged neighborhood leaders acting as HEZ citizen ambassadors.

Initiatives/Projects:
-Year-round weekly farmer's markets
-The Serenity Center: A drug-addiction recovery community center
-Trauma-informed care and toxic stress training
-Diabetes prevention program
-Naloxone training workshops

Bristol HEZ

Population: 22,290	**Size (sq. mi.):** 10.0	**Zip codes:** 02809

Mission:
To help people of all ages and abilities gain access to emotional, physical, and environmental resources they need to live life well.

Description:
Focuses on improving nutritional standards and access to healthy food, promoting physical activity throughout the community for a range of demographics, facilitating community public health events (including opioid forums, suicide prevention efforts, and an annual Recovery Rally), educating the community to facilitate adoption of a Green and Complete Streets policy, offering diabetes prevention programming, expanding collaboration of faith-based leaders, increasing awareness of substance use disorders in the areas of prevention, recovery, and rescue, including supporting the opening of the East Bay Recovery Center in March 2018, and implementing a suicide prevention program.

Initiatives/Projects:
-Diabetes prevention program
-Senior transportation services
-Healthy recipe guide and cooking demonstrations
-Farmer's market vouchers
-Coggeshall Farm ‘Moo, Cluck, Yum’ School Program: Farm field trips for 5th grade students
-Community gardens
-Walk with Ease: 6-week walking program
-Recreational activities at community center
-East Bay Fitness Challenge for Families and Seniors: Free 10-week fitness program
-Drug-addiction recovery center
-Distribution of drug-recovery toolkits
-Too Good for Drugs: 5th grade curriculum that builds the framework for drug-fee living
-Project ALERT: Classroom-based substance abuse prevention program for 7th and 8th graders
-Parents as Teachers: Program provides biweekly or monthly home visits to families in Bristol and Warren with children between the ages of birth and three.
-Boy's Town Common Sense Parenting Program: Seven-week parenting program designed to teach parents or professionals working with youth easy-to-learn techniques to address issues of communication, discipline, decision making, relationships, self-control and school success.
-Mental health first aid training
-Breastfeeding support group

Robustness Checks

To substantiate my results and check for robustness, I perform two additional analyses similar to my primary analysis. The methodology remains the same as that described in the body of the paper. In the first supplemental analysis, the year of implementation is changed from 2015 to 2016, where 2015 data are included and represent the last pre-implementation year. The second supplemental analysis also changes the year of implementation from 2015 to 2016, but drops all data from 2015, such that 2014 represents the last pre-implementation year. Since HEZ implementation occurred in 2015, and full-term gestation is approximately nine months, only babies born in the last several months of 2015 had mothers who could have potentially derived benefit from HEZ programs from the start of their pregnancies. The former analysis groups those few mothers who could benefit from HEZ programs for the entire duration of their pregnancies with those who benefited for only a part of their pregnancies, and places this group in the "pre-implementation" category. This has the effect of diluting the measured effects of HEZs, since some mothers who derived benefit are included in the pre-treatment group, which is meant to represent those who do not benefit from the treatment and against which the treatment group is measured to determine the effects of treatment. The latter analysis, which drops 2015 data and assigns 2016 as the year of implementation, completely removes the 2015 mixed-treatment group from the analysis. Any benefit or detriment affecting mothers giving birth in 2015 therefore goes unmeasured, but dropping 2015 observations allows a distinct delineation between non-treated and treated individuals. *Table A1* reports the coefficients and p-values for all three pooled analyses (2015 as year of implementation; 2016 as year of implantation; and 2016 with year of implementation, dropping 2015 data) for all outcomes for which any analysis detected a significant effect. *Table A2* presents the same information for all three separated analyses for all HEZs for which any analysis detected a significant effect.

Table A1. Robustness tests, Pooled: Comparison of Significant Results

	Month Prenatal Care Began	*Rates of Smoking during Pregnancy*	*Gestational Age*
2015 Implementation	**No Controls: -0.0620803 (p=0.000)*** **Controls: -0.0520392 (p=0.001)***	**No Controls: -0.013814 (p=0.000)*** Controls: -0.0049051 (p=0.185)	No Controls: 4.880733 (p=0.568) Controls: 3.859513 (p=0.650)
2016 Implementation	**No Controls: -0.0696821 (p=0.000)*** **Controls: -0.05805 (p=0.002)***	**No Controls: -0.0122272 (p=0.004)*** Controls: -0.0035701 (p=0.391)	**No Controls: -0.0700504 (p=0.035)*** Controls: -0.058539 (p=0.078)
Drop 2015	**No Controls: -0.0744884 (p=0.000)*** **Controls: -0.0618373 (p=0.001)***	**No Controls: -0.0134049 (p=0.002)*** Controls: -0.0040874 (p=0.332)	**No Controls: -0.0691468 (p=0.039)*** Controls: -0.0564659 (p=0.092)

*Significant at α=0.05
†No significant effects on birthweight detected in any analysis

Table A2. Robustness Tests, Separated: Comparison of Significant Results

	Birthweight	Month Prenatal Care Began			Rates of Smoking during Pregnancy		Gestational Age	
	Newport	*West Warwick*	*Woonsocket*	*Newport*	*Pawtucket/ Central Falls*	*Bristol*	*Pawtucket/ Central Falls*	*Newport*
2015 Implementation	**No Controls: 232.4487 (p=0.000)*** **Controls: 249.7921 (p=0.000)***	**No Controls: -0.1297424 (p=0.001)*** **Controls: -0.1266329 (p=0.001)***	**No Controls: 0.1676263 (p=0.000)*** **Controls: 0.1585385 (p=0.000)***	No Controls: 0.0453041 (p=0.523) Controls: -0.049724 (p= 0.478)	**No Controls: -0.0183716 (p=0.035)*** Controls: -0.0033771 (p=0.695)	No Controls: -0.016941 (p=0.175) **Controls: -0.0280329 (p=0.024)***	**No Controls: -0.1676469 (p=0.034)*** Controls: -0.1441714 (p=0.068)	**No Controls: 1.103814 (p=0.000)*** **Controls: 1.068598 (p=0.000)***
2016 Implementation	**No Controls: 175.6889 (p=0.000)*** **Controls: 183.8493 (p=0.000)***	**No Controls: -0.1462773 (p=0.001)*** **Controls: -0.1391521 (p=0.002)***	**No Controls: 0.122613 (p=0.005)*** **Controls: 0.1141549 (p=0.009)***	No Controls: -0.1288661 (p=0.072) **Controls: -0.1959308 (p=0.005)***	No Controls: -0.0143553 (p=0.136) Controls: -0.0019526 (p=0.838)	**No Controls: -0.0252502 (p=0.042)*** **Controls: -0.0307992 (p=0.014)***	No Controls: -0.1245814 (p=0.149) Controls: -0.0999817 (p=0.245)	**No Controls: 0.7533926 (p=0.000)*** **Controls: 0.7222325 (p=0.000)***
Drop 2015	**No Controls: 241.5838 (p=0.000)*** **Controls: 257.4326 (p=0.000)***	**No Controls: -0.1549308 (p=0.001)*** **Controls: -0.147731 (p=0.001)***	**No Controls: 0.1363792 (p=0.002)*** **Controls: 0.1141549 (p=0.009)***	No Controls: -0.0127797 (p=0.865) Controls: -0.1098394 (p=0.140)	No Controls: -0.0159838 (p=0.102) Controls: -0.0021346 (p=0.825)	**No Controls: -0.0252393 (p=0.046)*** **Controls: -0.0325204 (p=0.011)***	No Controls: -0.1434518 (p=0.098) Controls: -0.1173955 (p=0.175)	**No Controls: 1.109884 (p=0.000)*** **Controls: 1.070242 (p=0.000)***

*Significant at α=0.05

Hospital Discharge Data

Hospital discharge data includes information on birth defects and complications; the health outcomes in which I am interested (described below) have low incidences, and my sample size is insufficient to conclusively capture changes in these metrics. Analyses on these data involved the same methodology described in the body of the paper, with pooled and separated analyses, each with and without controls.

Diagnoses are coded and reported according to the International Classification of Diseases (ICD). Diagnoses were coded according to ICD-9th revision (ICD-9) until October 1, 2015, when the National Center for Health Statistics (NCHS) mandated coding according to the updated ICD-10th revision (ICD-10) ("ICD - ICD-10-CM - International Classification of Diseases, Tenth Revision, Clinical Modification" 2018). Therefore, diagnoses for children born before Oct. 1, 2015 are identified by ICD-9 codes, while diagnoses for children born after this date are identified by ICD-10 codes. The following variables, accompanied in parentheses by their respective ICD-9 and ICD-10 codes, are obtained from the hospital discharge dataset: Congenital heart defects (745-746; Q20-Q24), fetal alcohol syndrome (760.71; Q86.0), neonatal abstinence syndrome (779.5; P96.1), meconium aspiration (770.11, 770.12; P24.0), persistent pulmonary hypertension of the newborn (747.83; P29.30), intrauterine growth retardation (764.9; P05.9), preeclampsia (642.40, 642.50; O14.00, O14.10, O14.90), and neonatal hypoglycemia (775.6; P70.4) ("ICD - ICD-9-CM - International Classification of Diseases, Ninth Revision, Clinical Modification" n.d.; "ICD - ICD-10-CM - International Classification of Diseases, Tenth Revision, Clinical Modification" 2018).

The revision of ICD-9 to ICD-10 included updating the definitions and classifications of certain diagnoses; therefore, the diagnoses coded according to ICD-9 may not represent exactly the same conditions as those coded according to ICD-10. For example, the ICD-9 code for neonatal abstinence syndrome includes neonate withdrawal symptoms for both drug addiction and prescription use, whereas the ICD-10 code includes only the illicit drug use pertaining to withdrawal. However, the ICD-9 and ICD-10 codes used to identify diagnoses for this analysis were chosen in an effort to minimize these inconsistencies, and the cross-walk from ICD-9 to ICD-10 does not seriously affect the legitimacy of this analysis. The results are reported in *Table A3* on the following page; I report all results from the pooled analysis, and only significant results from the separated analysis.

Table A3. Difference-in-Differences Regression Results, Hospital Discharge Data

	Congenital Heart Defect	*Fetal Alcohol Syndrome*	*Neonatal Abstinence Syndrome*	*Meconium Aspiration*	*Intrauterine Growth Retardation*	*Neonatal Hypoglycemia*
Total Observations	1391	18	763	452	107	2927
Pooled						
No Controls	0.004* *-0.021*	0.000 *0.280*	0.001 *0.617*	0.000 *0.689*	0.000 *0.739*	-0.003 *0.284*
Controls	0.004* *0.029*	0.000 *0.503*	0.002 *0.140*	-0.001 *0.356*	0.000 *0.689*	-0.002 *0.392*
Separated (With controls, only significant results reported)						
Newport	-0.029* *0.011*					-0.038* *0.001*
Providence			0.007* *0.043*			
Washington			-0.008* *0.018*		-0.003* *0.000*	
Bristol					-0.003* *0.000*	
Woonsocket						0.017* *0.018*

*Significant at α=0.05

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