EFFECTS OF BIRTH INTERVALS VARY WITH LEVEL OF DEVELOPMENT: EVIDENCE FROM THE UTAH POPULATION DATABASE, 1870-2016

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ABSTRACT. A large body of research has examined whether birth intervals influence perinatal outcomes and child health. Most of the existing literature shows that very short birth intervals, and in some cases also very long intervals, increase the risk of infant mortality, low birth weight, and preterm birth. However, recent research in high-income countries has shown that after adjusting for unobserved maternal frailty by comparing siblings within the same family, birth intervals do not seem to matter for the risk of poor perinatal outcomes. In this study we use data from the Utah Population Database to examine the effects of birth intervals on infant mortality over the period 1870-2016, and low birth weight and preterm birth over the period 1947-2016. We find that the negative effects of very short birth intervals decreases as the level of development increases, and this is particularly clear for infant mortality. Our study shows that public health conditions and the developmental context are important moderators for the effects of birth intervals on child health outcomes.

INTRODUCTION

The potential consequences of fertility timing for child health is a research topic that has received a great deal of attention from researchers, development agencies, as well as national and international health organizations, such as the Centers for Disease Control (CDC) in the United States, and the World Health Organization. Indeed, the World Health Organization has universal recommendations for delaying further pregnancies until at least 24 months after the birth of the previous child in order to reduce the risk of poor perinatal outcomes and infant mortality (WHO, 2005). The WHO's recommendation is based upon a large body of research that has shown that short birth intervals increase the risk of infant mortality, low birth weight (LBW), preterm birth, being small for gestational age (SGA), as well as other poor outcomes, and these risks have been documented in high-income countries as well as low-income countries (Fortney and Higgins, 1984; Casterline, 1989; Huttly et al., 1992; Smith et al., 2003; Stephansson

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et al., 2003; Rutstein, 2005; Conde-Agudelo et al., 2005; Hussaini et al., 2013; McKinney et al., 2017). A meta-analysis of 67 studies published up to 2006 showed that there is a J-shaped curve in the relationship between the length of birth intervals and peri-natal and child health outcomes, with interpregnancy intervals shorter than 18 months, and longer than 59 months significantly associated with poor perinatal outcomes (Conde-Agudelo et al., 2006). The potential negative long-term consequences of LBW and preterm birth are well-documented, with those who experienced these poor perinatal outcomes found to have suffer long-term consequences in terms of both socioeconomic attainment (Conley and Bennett, 2000; Black et al., 2007), and health (Leon et al., 1998; Moster et al., 2008; Swamy et al., 2008). This has been supported by other research that has shown that that short birth spacing is associated with poor long-term development, as evidenced by lower grades in high school, and a lower probability of pursuing tertiary education (e.g. Powell and Steelman, 1990, 1993; Buckles and Munnich, 2012).

The conclusion that particularly short or long birth intervals were associated with worse short- and long-term outcomes was largely considered settled until a study published by Ball et al. in 2014. Using data from Australia, Ball et al. (2014) found that when comparing siblings born to the same mother, the association between short birth spacing and the risk of preterm birth, low birth weight, and SGA was either completely removed, or substantially reduced. A further study, using data from Canada, corroborated these findings (Hanley et al., 2017). The results from these two studies suggested that the length of birth intervals may not actually have a causal effect on the risk of poor peri-natal outcomes, and that the long documented association might result from omitted variable bias. Birth intervals are not randomly distribution across families, and it might be the case that children born after short birth intervals are more likely to be born to mothers with worse health, for example. This perspective that neither particularly short or long birth intervals are causally responsible for poor child outcomes was given further support by a pair of recent studies using a sibling fixed effects design that found that birth intervals did not matter for long-term educational or socioeconomic attainment, or health (Barclay and Kolk, 2017, 2018). However, another pair of recent studies that also used a sibling-comparison design found that the association between short intervals and an increased risk of preterm birth and low birth weight persisted (Shachar et al., 2016; Koullali et al., 2016). Partly in response to these new findings, a 2015 report from the Centers for Disease Control and Prevention (CDC) in the United States suggested that more research is needed to understand the impact of birth spacing on maternal and child health (Copen et al., 2015).

More recently, a pair of studies have suggested that it may not simply be a question of whether birth intervals matter or not for child health outcomes, but instead under which conditions birth intervals matter for child health. Using historical data from Stockholm county in Sweden from the period 1878 to 1926, Molitoris (2017) used sibling fixed effects models and showed that the beneficial effect of avoiding extremely short birth intervals diminished substantially, falling almost to zero by 1926, over a period characterized by major changes in public health conditions and economic development in Stockholm. A second recent study, using Demographic and Health Survey (DHS) data, found that very short birth intervals are strongly associated with the risk of infant mortality in low-income contexts, even after adjusting for unobserved heterogeneity across sibling groups (Molitoris et al., 2018). However, Molitoris et al. (2018) also found that the beneficial effects of avoiding extremely short birth intervals diminished as public health conditions improved and levels of development increased. These studies suggest a way to unite the existing literature on the negative effects of birth intervals, by showing that they matter very much for child health and survival in low development contexts, but that the negative effects of short intervals diminishes as the socio-epidemiological environment improves.

In this study we use data from the Utah Population Database (UPDB), an extraordinary resource that allows us to examine whether the effects of birth intervals on infant health and survival have been changing over time. We use the UTPD to examine the changing effect of birth interval length on infant mortality over the period 1870-2016, and the changing effects of birth interval length on the probability of low birth weight and preterm birth over the period 1947-2016. We do so using a within-family sibling comparison design that allows us to minimise residual confounding and to isolate the net effect of birth interval length on infant health. In doing so we build on the recent literature that has attempted to isolate the effect of birth intervals on child outcomes net of confounding factors, and to add to the growing literature that demonstrates how changing contextual conditions over time moderate the relationship between birth interval length and infant health.

Data, and Methods

Data. In this study we use the Utah Population Database to examine the relationship between birth intervals and infant mortality, low birth weight, and preterm birth. The Utah Population Database (UPDB) at Huntsman Cancer Institute at the University of Utah is a remarkable source of in-depth information that supports research on genetics, epidemiology, demography, and public health. The central component of the UPDB is an extensive set of Utah family histories, in which family members are linked to demographic and medical information. Family linkages prior to the 1940s are based upon genealogical data, while linkages since the 1940s are based on vital registration. The UPDB includes diagnostic records about cancer, cause of death, and medical details associated with births. In this study we use data from 1870 to 2016 to study how birth intervals are associated with the probability of infant mortality, and data from 1947 to 2016 to study how birth intervals are associated with the probability of preterm birth and low birth weight. The measure for the birth interval that we use in this study is the length of the

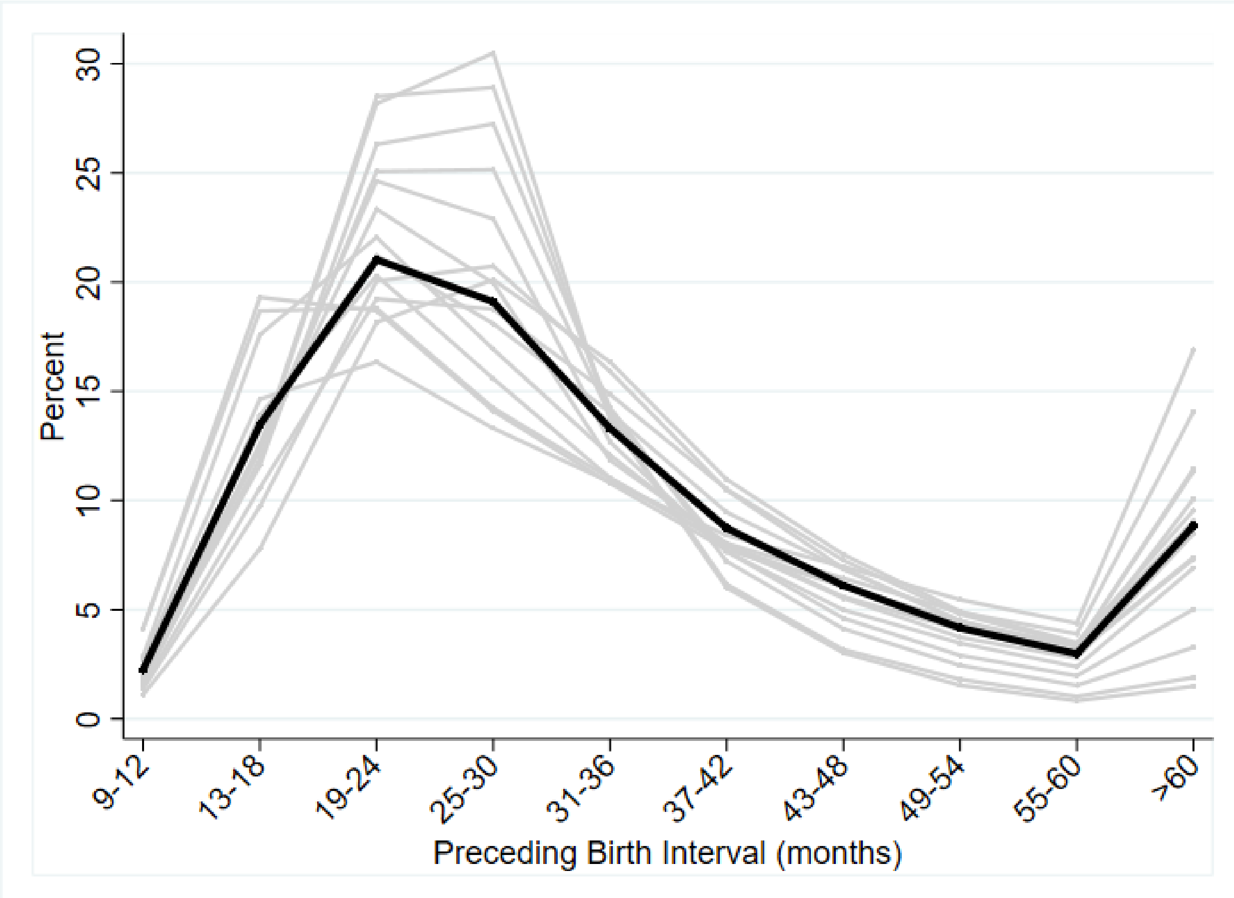

FIGURE 1. Distribution of the length of preceding birth intervals in months by birth cohort in Utah, 1870-2016. Mean shown by black line.

birth-to-birth interval, meaning the period of time in months from one live birth to another. We categorise the length of the birth interval into 16 different categories, which are 6 month periods from a minimum of 9 months to 96 months or longer. In our analyses we choose a reference category for the preceding and subsequent birth interval of 25-30 months. The distribution of birth intervals in Utah between 1870 and 2016 is shown in Figure 1.

Our analysis is based upon the population of sibling groups with at least three children. The reason that we focus upon sibling groups with at least three children is that the sibling fixed effects models that we employ, described in greater detail below, exploit variance within the sibling group in order to generate the estimates. Thus, we need to observe at least two birth intervals within a sibling group in order to be able to estimate the relationship between birth interval length and the outcomes that we examine. To have information on the length of the preceding birth interval we also need to observe at least two sets of sibling-pairs with adjacent birth orders in each sibling group. This is worth mentioning as the genealogical proportion of the UTPD has some missing information due to its historical nature. By two sets of sibling-pairs with adjacent birth orders, we mean that we should have at least two children where are are able to observe the timing of birth for both the index child as well as the older sibling, in order to be able to calculate the length of the preceding birth interval. For example, three children with birth orders 1,2,3 would provide us with that information, as we could calculate the length of the preceding interval for the children with birth orders 2 and 3. Alternatively, if we observed four children in a sibling group with birth orders 2,3 and 4,5, this would also provide us with the necessary information on the length of two birth intervals. While complete information is available for many of the sibling groups included in our analysis, there is no methodological need to discard information from incomplete sibling groups. In total our examination of the relationship between birth intervals and infant mortality is based upon 1,351,235 unique observations, while our analyses of LBW and preterm birth are based upon 914,543 and 880,590 unique observations, respectively.

Outcome Variables.

Infant Mortality. Infant mortality is defined as mortality within the first 12 months of life.

Low Birth Weight. Infants with birth weight less than 2500g are classified as being born with low birth weight.

Preterm Birth. Following standard practice, we categorize preterm births as those births that occur before 37 weeks of gestation.

Covariates. In addition to our main explanatory variable, the length of birth intervals, we include several covariates in our models that are likely to be associated with both birth spacing as well as long-term health. Factors such as birth order, parental age at the time of birth, and birth year may be associated with birth interval length, and are also associated with peri-natal health outcomes. We include controls for birth order as both the confluence hypothesis and the resource dilution hypothesis predict independent effects of birth order and birth spacing, and previous research has indicated that birth order is related to the probability of low birth weight and preterm birth (Kramer, 1987; Shah, 2010). Birth interval length is also likely to be associated with maternal age, and maternal age is associated with perinatal outcomes and infant mortality (Andersen et al., 2000; Finlay et al., 2011). We adjust for maternal age using one-year categories. It is well known that there are secular trends in infant mortality rates and the incidence of low birth weight and preterm birth, so we also adjust our analyses for birth year. In our results section we present information on the temporal trends for the three outcome variables that we examine in this study.

Statistical Analyses. For each outcome variable we estimate two different models: one within-family comparison examining the relationship between the preceding birth interval and the outcome variable using the pooled data across the period 1870-2016, and one within-family comparison examining the interaction between birth intervals and birth cohort group. We divide birth cohort into 10-year categories where possible. Our sibling fixed effects model is specified as follows:

$$y_{ij} = \beta_1 PBI_{ij} + \beta_2 BirthOrder_{ij} + \beta_3 MatAge_{ij} + \beta_4 BirthYear_{ij} + \alpha_j + \varepsilon_{ij} \quad (1)$$

where y_{ij} is the outcome for individual i in sibling group j on infant mortality, low birth weight, and preterm birth. PBI_i is entered into the model as a series of 10 dummy variables based on categories for the length of the preceding birth interval, corresponding to the categories shown in Figure 1. Our analysis population is second and later-born children in sibling groups with at least three children, meaning that we exclude first-borns as they have no value for the length of the preceding interval. The sibling fixed effect is denoted by α_j.

RESULTS

Infant Mortality. We first present results examining the relationship between the length of the preceding birth interval and the probability of infant mortality. Figure 2 shows the trend in infant mortality rates (IMR) amongst births in Utah over the period 1870-2016. As can be seen, the IMR was high in the late 19th century, with around 80 or 90 deaths in the first 12 months of life for every 1,000 births. Over the period 1900 to 1970, but further large relative declines in the rate have continued up until 2010s.

Figure 3 shows the relationship between the length of the preceding birth interval and the probability of infant mortality in the pooled data. That is, we pool all births over the period 1870-2016, while adjusting for birth order and maternal age. Although this model is somewhat naive given the enormous contextual changes over this period of almost 150 years, we nevertheless present the pooled results as a starting point for interpreting the relationship between the length of the preceding birth interval and the probability of infant mortality in Utah. The reference category in Figure 3 is a preceding birth interval of 25-30 months. The most striking pattern shown in Figure 3 is that very short birth intervals of 9-12 months are associated with a much higher probability of infant mortality. Indeed, given the average baseline probability of 0.04, a relative increase of 0.014 reflects a 35% increase in the relative probability of infant mortality. We can also see that the predicted probability of mortality declines with longer birth intervals, particularly those longer than 54 months. The lower probability of mortality

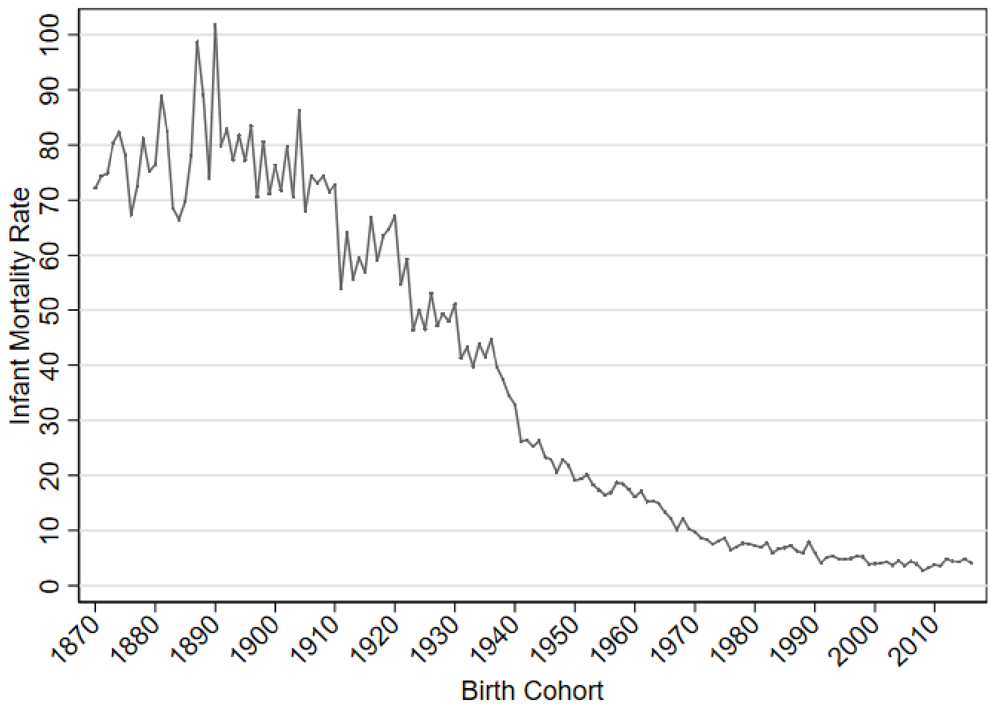

FIGURE 2. Infant mortality rates in Utah, 1870-2016.

associated with a preceding birth interval of 9-12 months is puzzling and defies an immediate explanation.

Figure 4 shows the results from models examining the interaction between the length of the preceding birth interval and birth cohort. The results shown in Figure 4 are all based upon one statistical model, but we split the results into different panels given the large number of parameters. The reference category for the results shown in Figure 4 is birth intervals of 25-30 months in the 1990-1999 birth cohort. Note that the results presented in Figure 4 are not based upon a factorial interaction, but an interaction where each combination of birth interval length and cohort group. Every other point estimate in Figure 4 should be evaluated relative to that reference point.

The results shown in Figure 4 reveal a number of interesting patterns. A further estimation of the factorial interaction between birth interval length and infant mortality shows that this interaction is generally not statistically significant (estimates not shown here); increases and decreases in the patterns observed are driven by the main effects of birth cohort and birth interval length rather than a change in the relative importance of birth intervals for infant mortality over time. However, there are two exceptions, which are the effects of very short birth intervals (9-12 months), and very long birth intervals (>60 months) on infant mortality, for which there

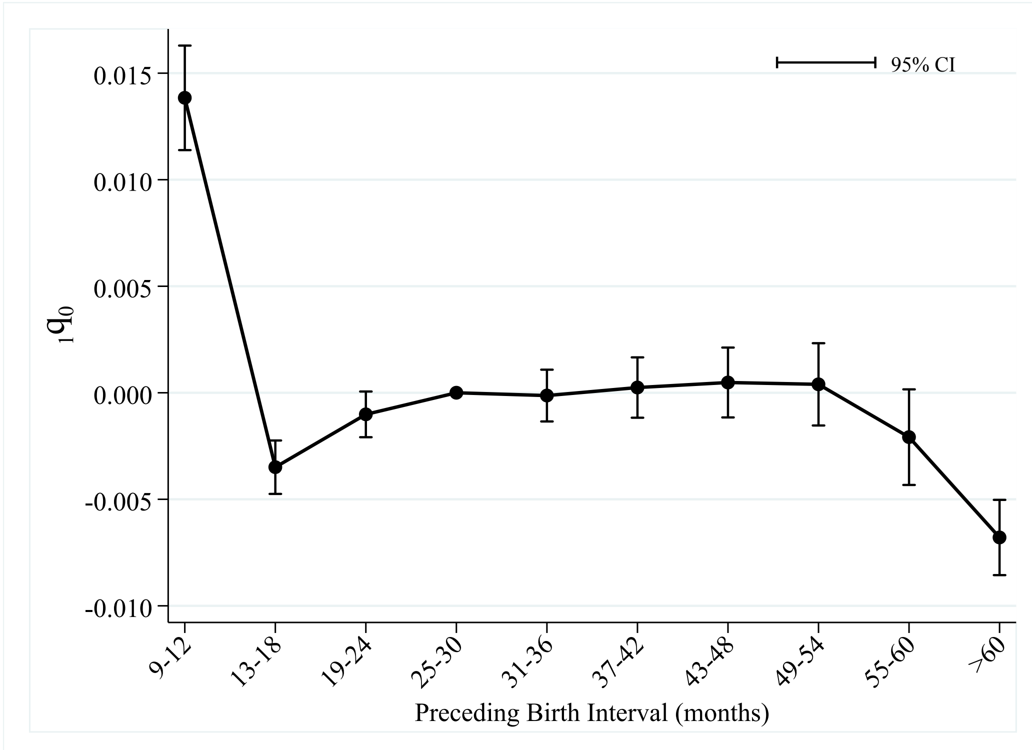

FIGURE 3. The relationship between the length of the preceding birth interval and probability of infant mortality, sibling groups with at least 3 children born in Utah, 1870-2016. Results from linear probability models applying sibling fixed effects.

are statistically significant interactions with birth cohort. The results from our interaction analyses show that, net of the main effect of birth cohort on mortality, the negative effects of birth intervals of 9-12 months was greater from the 1870s to the 1960s. However, from the 1970s to the 2010s, even very short birth intervals did not increase the probability of dying in the first year of life. Our interaction analyses reveal a similar pattern for the effects of long birth intervals. The results from our interaction analyses show that, net of the main effect of birth cohort on mortality, the negative effects of birth intervals of 55 months or longer was greater from the 1870s to the 1940s.

Low Birth Weight. We now present results for the two peri-natal outcomes that we examine in this study. The results shown in Figure 5 are estimates from a linear probability model examining the relationship between birth interval length and the probability of low birth weight in the pooled sample of infants born between 1947 and 2016.

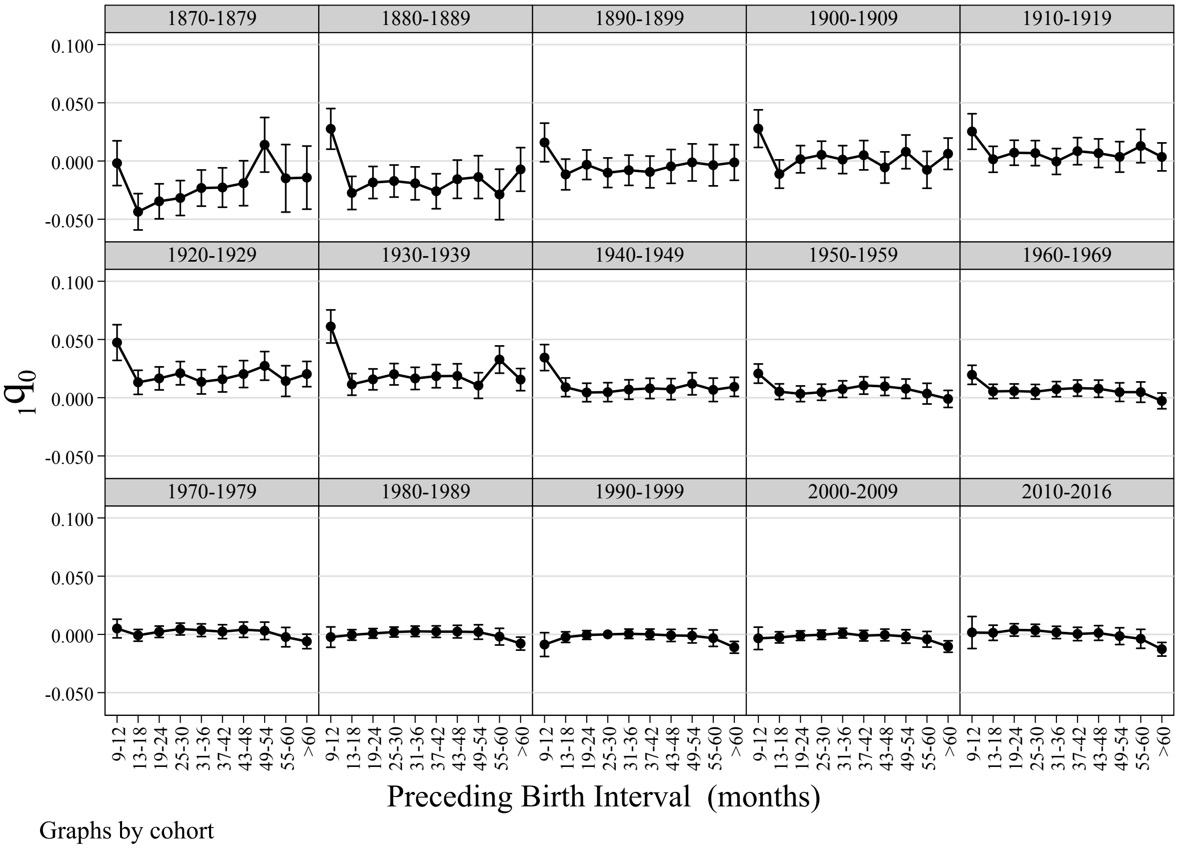

FIGURE 4. The relationship between the length of the preceding birth interval and probability of infant mortality, sibling groups with at least 3 children born in Utah 1870-2016, by birth cohort group. Results from linear probability models applying sibling fixed effects.

As Figure 5 shows, the probability of LBW is significantly and substantially elevated for infants born after a birth interval of less than 18 months. Indeed, given the baseline probability of LBW of 0.04, the relative probability of LBW is elevated by 128% for those born after an interval of 9-12 months relative to the reference category of 25-30 months. Longer intervals also have a mildly protective effect against the probability of LBW. However, as with the pooled analysis for infant mortality, these results potentially mask substantial heterogeneity in the relationship between birth intervals and the probability of LBW over time.

Figure 6 shows the results of a model examining the interaction between birth intervals and LBW for different cohort groups. As with the results for the cohort interaction presented above for infant mortality, the results shown in Figure 6 are all based upon one statistical model, but we split the results into different panels given the large number of parameters. The reference category for the results shown in Figure 6 is birth intervals of 25-30 months in the 1990-1999 birth cohort. Note that the results presented in Figure 4 are not based upon a factorial interaction, but an interaction where each combination of birth interval length and cohort group. Every other point estimate in Figure 6 should be evaluated relative to that reference point.

The point estimates shown in Figure 6 indicate that the negative effects of very short birth intervals may have been decreasing over time. However, a further estimation of the factorial interaction between birth interval length and LBW shows that this interaction is generally not statistically significant (estimates not shown here); increases and decreases in the patterns observed are driven by the main effects of birth cohort and birth interval length rather than a change in the relative importance of birth intervals for infant mortality over time. The only exception is that we find that the negative effects of very short intervals (9-18 months) for the probability of LBW, net of the main effects, were significantly elevated in the 1950s, 1960s, and 1980s.

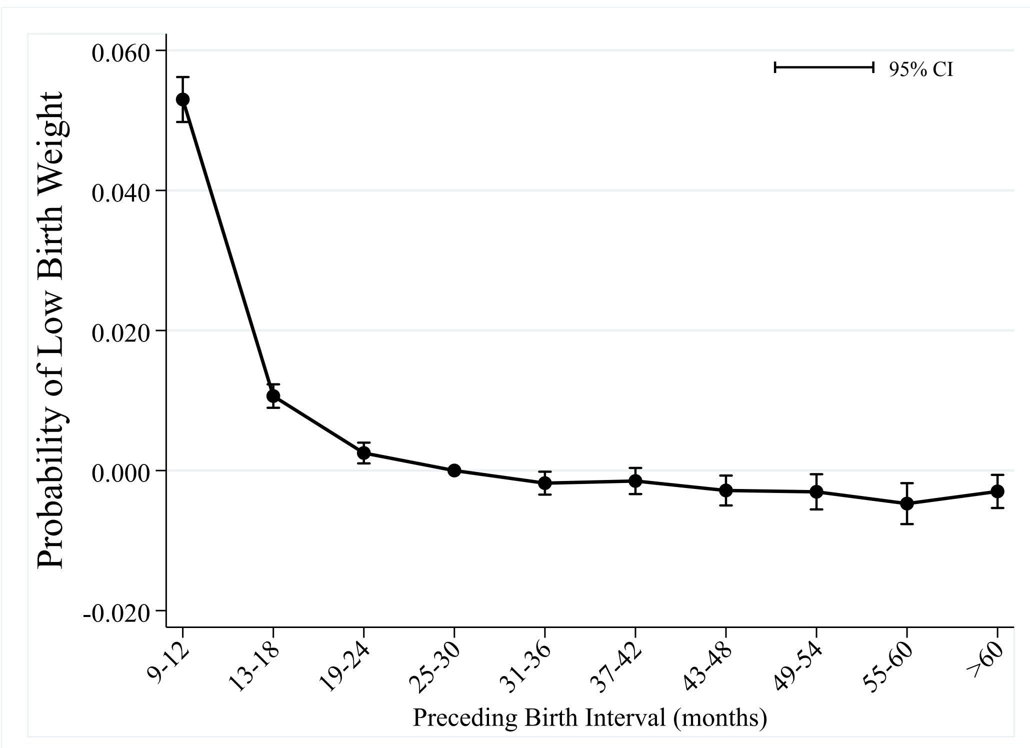

FIGURE 5. The relationship between the length of the preceding birth interval and probability of low birth weight, sibling groups with at least 3 children born in Utah, 1947-2016. Results from linear probability models applying sibling fixed effects.

Preterm Birth. We now turn to our analyses of preterm birth. Figure 7 shows the incidence of preterm birth in Utah over the period 1947 to 2016. As can be clearly seen, there has been a dramatic increase in the incidence of preterm birth since the early 1980s.

Figure 8 shows the results from our pooled analysis of the relationship between birth interval length and the probability of preterm birth over the period 1947-2016. As can be seen, short intervals of 9-12 months are associated with a very large increase in the risk of preterm delivery. However, it should be noted that this is likely to be at least partially a function of the fact that we use a measure of birth-to-birth intervals for our analysis. That is to say, the increase in the risk is an artifact of the measure that we currently use for birth intervals. For example children born after a birth-to-birth interval of 9 months will be preterm almost by definition unless the mother conceived directly after the previous pregnancy. In the coming months we intend to supplement

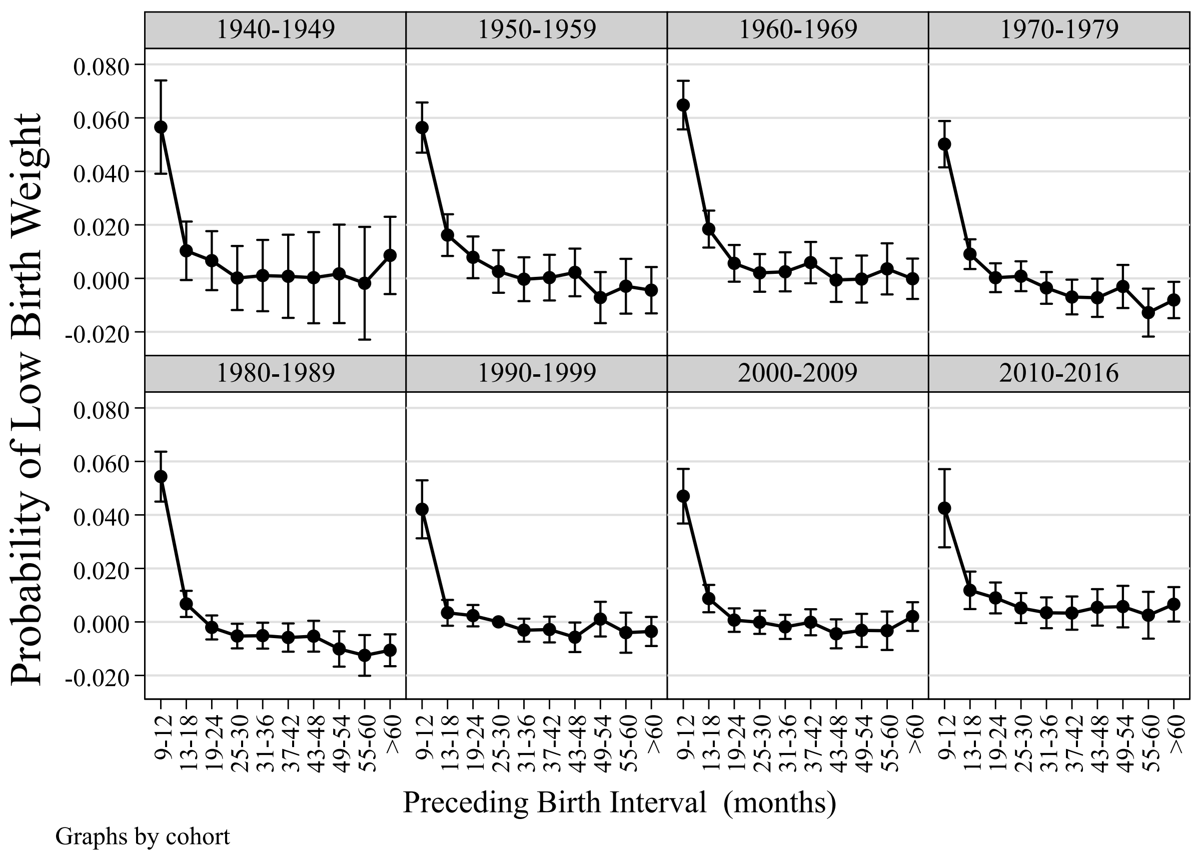

FIGURE 6. The relationship between the length of the preceding birth interval and probability of low birth weight, sibling groups with at least 3 children born in Utah 1947-2016, by birth cohort group. Results from linear probability models applying sibling fixed effects.

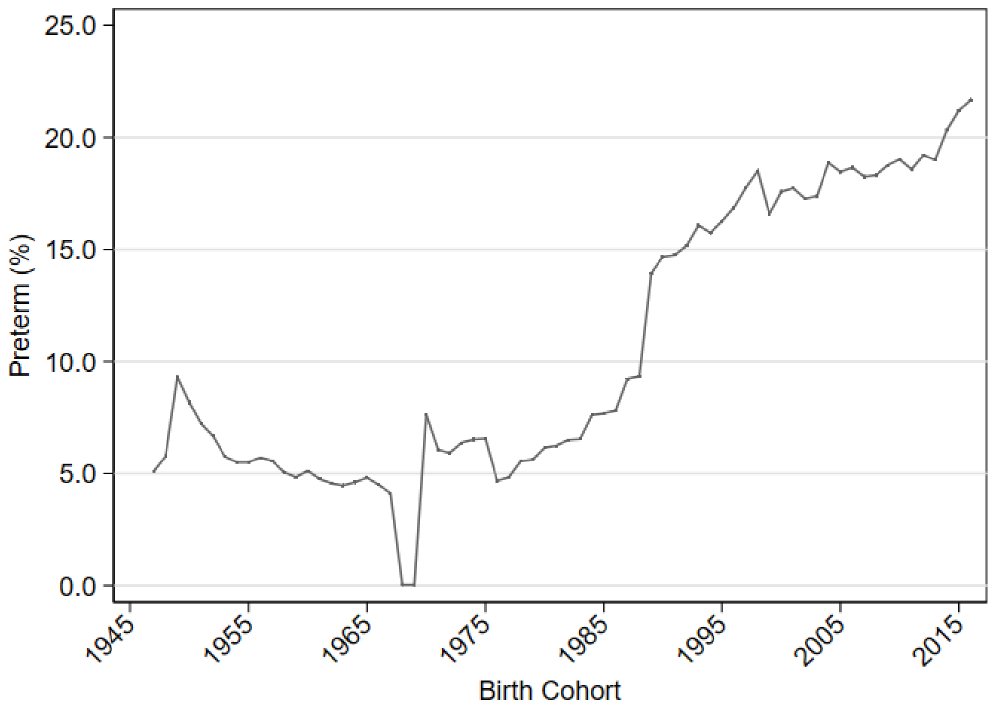

FIGURE 7. Incidence of preterm delivery in Utah, 1947-2016.

these analyses by using a measure of the interpregnancy interval instead of the birth-to-birth interval, which will circumvent this problem.

Figure 9 shows the results of a model examining the interaction between birth intervals and LBW for different cohort groups. As with the results for the cohort interaction presented above for infant mortality, the results shown in Figure 9 are all based upon one statistical model, but we split the results into different panels given the large number of parameters. The reference category for the results shown in Figure 9 is birth intervals of 25-30 months in the 1990-1999 birth cohort. Note that the results presented in Figure 9 are not based upon a factorial interaction, but an interaction where each combination of birth interval length and cohort group. Every other point estimate in Figure 9 should be evaluated relative to that reference point.

The point estimates shown in Figure 9 indicate that the negative effects of very short birth intervals may have been *increasing* over time. A further estimation of the factorial interaction between birth interval length and preterm confirms this. However, as mentioned above, we are aware that this pattern is at least partially an artifact of our measure of birth-to-birth intervals, and we will re-examine this relationship using a measure of the interpregnancy interval in advance of the 2019 PAA meeting.

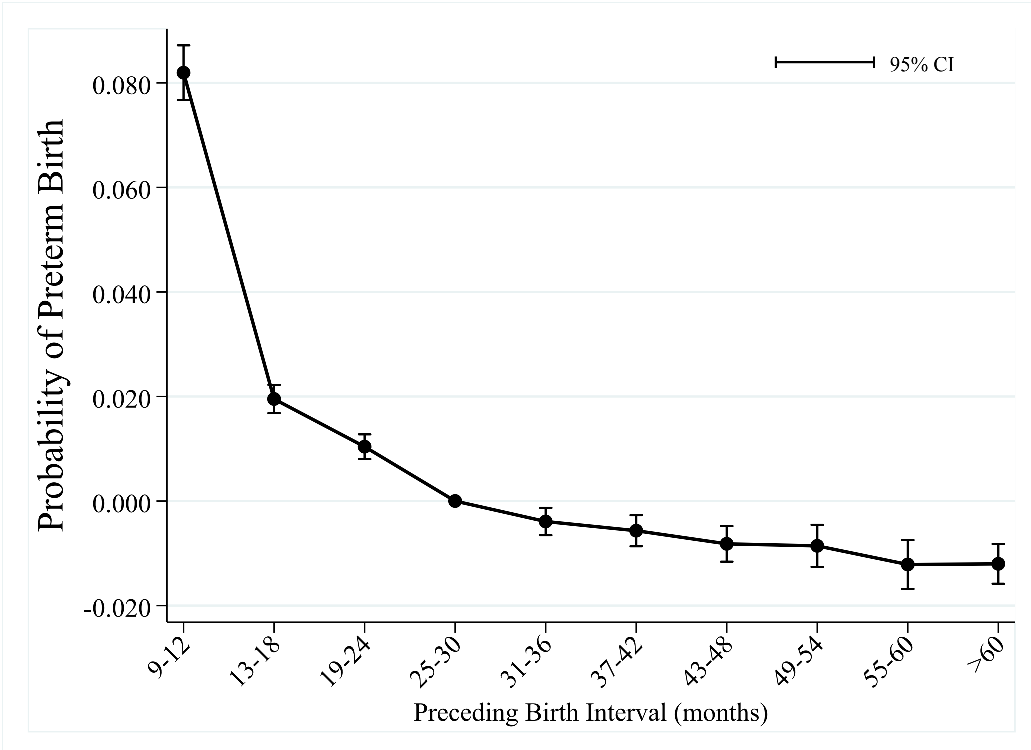

FIGURE 8. The relationship between the length of the preceding birth interval and probability of preterm birth, sibling groups with at least 3 children born in Utah, 1947-2016. Results from linear probability models applying sibling fixed effects.

PRELIMINARY DISCUSSION

This study uses an extraordinary dataset with information on birth interval length and child health outcomes over almost 150 years for infant mortality, and almost 70 years for low birth weight and preterm birth. Our study contributes to the existing literature by demonstrating that the relationship between the length of birth-to-birth intervals and child health outcomes is moderated to an important extent by the historical developmental context. This connects the current existing literature showing that birth intervals are very important for child health outcomes in low-income contexts, but much less so in high development contexts; however, few previous studies have been able show how this relationship changes over time and with increasing development, and none over such an extended time period. We find that for infant mortality and the risk of low birth weight, very short birth intervals, and in some cases also very long birth intervals, were more detrimental in the past. However, with increasing development and improvements to public health conditions, very short intervals are no longer important the risk of infant mortality, and are less important for the probability of low birth weight.

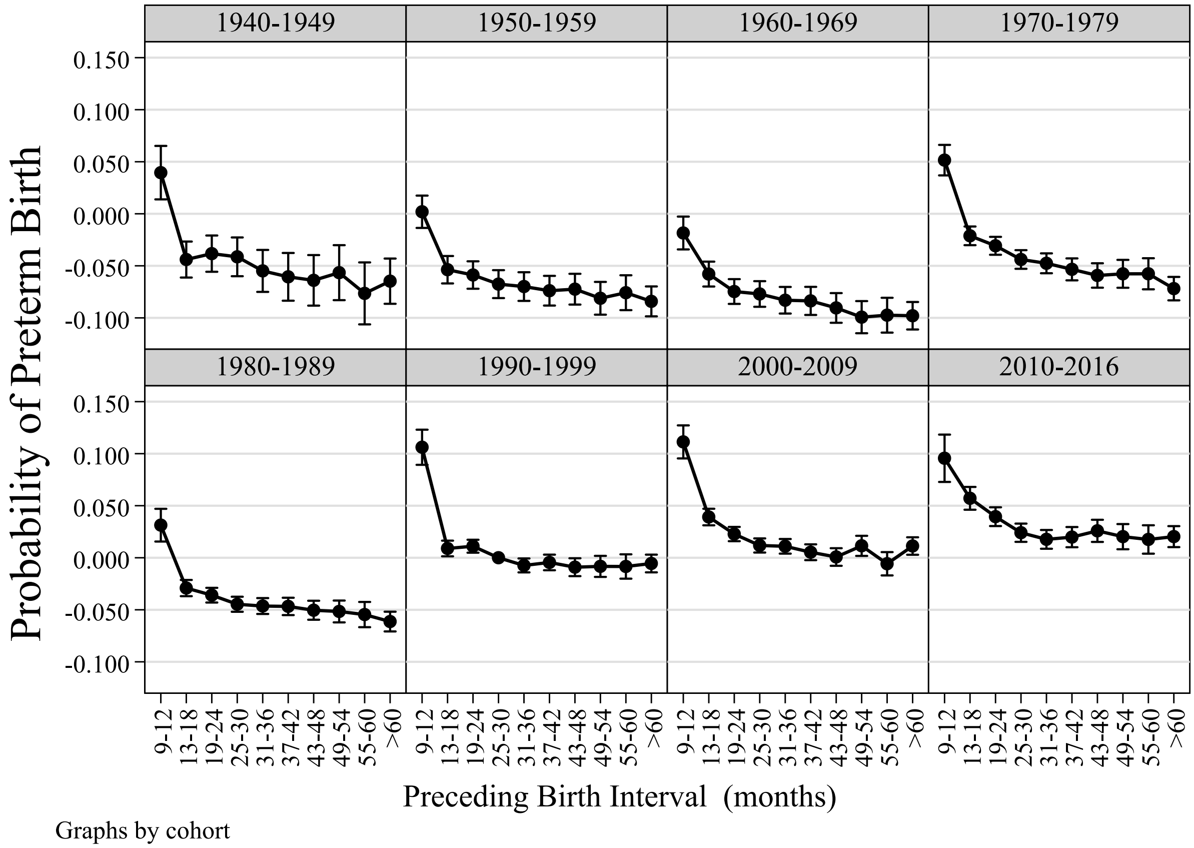

FIGURE 9. The relationship between the length of the preceding birth interval and probability of preterm birth, sibling groups with at least 3 children born in Utah 1947-2016, by birth cohort group. Results from linear probability models applying sibling fixed effects.

In future work in advance of the 2019 PAA meeting, we intend to re-examine the results for LBW and preterm birth using a measure of the interpregnancy interval (i.e. the time from birth to the following conception) instead of a measure of the birth-to-birth interval. We also intend to extend the existing literature by examining other important interactions between birth intervals and the probability of child health outcomes. For example, we will examine how the relationship between interval length and child health outcomes interacts not only with birth cohort, but also with the socioeconomic status, educational level, and other salient characteristics of the parents. In doing so, we will be able to examine whether the decreasing importance of birth interval length for child health in Utah has been changing at a similar rate for different social groups or not.

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