Title: Time of Birth, Breast Milk Feeding and Health Outcomes in the Neonatal Intensive Care Unit

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Abstract: Breast milk feeding in the Neonatal Intensive Care Unit (NICU) is associated with a host of improved health outcomes. However, breast milk feeding rates differ by socioeconomic status, race, ethnicity and maternal education indicating that these results are vulnerable to selection bias. Qualitative work by this author and others suggests that women giving birth in the late-night hours are less likely to begin a successful milk expression regimen due to the lack of experienced clinicians working during these shifts. Using the hour of birth as an instrument for breast milk feeding, this study attempts to isolate the effects of breast milk feeding on incidence of deadly conditions in the NICU, as well as the infant's growth patterns and length of stay. This study also uses innovative measures of the indications for delivery type in order to construct a sub-sample whose distribution of delivery times is the most random, thereby increasing the validity of the analysis. The first-stage of the analysis revealed no significant relationship between late-night births and breast milk feeding at discharge, contrary to the claims of clinicians and mothers interviewed in a separate study. C-Section delivery and shorter maternal lengths of stay were significantly predictive of decreased breast milk feeding at discharge, even after controlling for potential confounders. The reduced-form analysis suggests that infants born in the evening (5pm-Midnight) are roughly 2-4% more likely to contract Necrotizing Enterocolitis at some point during their stay in the NICU. The majority of associations between hour of birth and other health outcomes were insignificant. Evidence of heterogeneity in hour of birth effect size by birth weight, gestational age, race/ethnicity and maternal age were also explored.

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Introduction: Breast Milk Feeding in the Neonatal Intensive Care Unit

Premature, low birth weight infants are believed to be at a health and social disadvantage over the life course compared to their full-term, normal weight counterparts (Örtenstrand et al., 2010) (Klassen et al., 2004) (Anderson, Doyle, & and the Victorian Infant Collaborative Study Group, 2003) (Stein, Siegel, & Bauman, July 2006). A large volume of medical research supports the beneficial effects of breast milk feeding in the neonatal intensive care unit (NICU). Breast milk feeding is associated with lower risk of serious gastrointestinal illnesses, such as Necrotizing Enterocolitis (Moore, Hanson, & Anderson-Berry, 2011), (Lucas & Cole, 1990). Necrotizing Enterocolitis, while rare, is one of the most dangerous illnesses in the NICU population (Berseth, Bisquera, & Paje, 2003). Breast milk feeding is also associated with superior developmental outcomes at 18 (Vohr et al., July 2006) and 30 (Vohr et al., October 2007) months of age. Breast milk feeding is associated with shorter lengths of stay in the NICU (Örtenstrand et al., 2010), as well as decreased incidence of sepsis and other infections (Hylander, Strobino, & Dhanireddy, 1998). Some research hypothesizes that breast milk feeding can have significant *programming* effects, implying that maternal feeding decisions in the early years can impact a child's health into adulthood (Lucas 2005)

The above studies are based on observational data. Systematic reviews of the evidence on breast milk feedings and premature infant health suggest that these observational studies suffer from poor study designs, small sample sizes and inconsistent definition of treatment (de Silva, Jones and Spencer 2004). Bauchner, Leventhal and Shapiro (1986) state that "The studies that met important methodological standards and controlled for confounding variables suggest that breast-feeding has at most a minimal protective effect in industrialized countries." Observational studies of breast milk feeding and infant health outcomes in the NICU suffer from the threat of Omitted Variables Bias. The same factors that determine the likelihood of breast milk feeding may determine likelihood of adverse health outcomes. Because of this, past estimates of the effects of breast milk feeding are either over or understated—the direction depends on the correlation between our omitted variables and both breast milk feeding and health outcomes.

More certain evidence about causal effects in medical studies typically comes from randomized controlled trials. Because this is not entirely possible for this type of treatment, researchers have attempted to introduce exogenous variation in other ways. Many times, researchers randomize mothers of NICU infants into treatment and control groups based on an intervention (McInnes & Chambers, 2008). The majority of quasi-experimental studies focus on interventions to increase skin-to-skin care, itself associated with breast milk feeding. Rojas, et al (2003) found that those randomly assigned to interventions to increase skin-to-skin contact experience statistically significant increases in breast milk feeding rates and head circumference growth, as well as decreased episodes of oxygen desaturation. There was no evidence of advantage in other measures. Blaymore-Bier, et al (1996) found that a similar intervention to increase rates of skin-to-skin care also increased rates of breast milk feeding and decreased incidence of oxygen desaturation. In 1989, Alfonso, et al randomly assigned mothers into groups based on the type of skin-to-skin care performed (true skin-to-skin vs. conventional swaddled holding). He found that in the true skin-to-skin group, there were statistically significant differences in breastfeeding rates (higher), length of stay in the NICU (lower), time in the incubator (lower) and weight gain (higher). Another form of intervention common to these types of studies is treatment to increase milk production. Gunn, et al (1996) found in a randomized trial of human growth hormone (hGH) that hGH increased breast milk volume by 31% ($p<.001$) and that infant health outcomes in the treatment group were significantly better than the control group. Limitations of these quasi-experiments include: small sample sizes (usually between 20 and 50), differential definition of the treatment variable, non-random attrition and lack of clarity in the causal pathways. On the latter point, it is difficult to isolate whether the increase in breastfeeding *causes* the increased potential for improved health outcomes or whether the intervention causes the outcomes in a different way. Because of the impossibility of randomly assigning breast milk feeding in the NICU, we must approach the question of causality in a different way.

In this study, I apply an Instrumental Variables approach. This method is superior to standard techniques, as long as the instrument is valid. The IV approach requires finding a set of variables that is highly correlated with the treatment variable (in this case, breast milk feeding), but uncorrelated with omitted variables that determine our outcomes. A history of the Instrumental Variables approach can be found in (Stock & Trebbi, 2003).

A Conceptual Model of Breast Milk Feeding in the NICU

Infant health outcomes in the neonatal intensive care unit are a function of prenatal and postnatal experience. As an infant ages in the NICU, less of the prenatal environment is responsible for the health outcomes (Scott and Duncan, 1999) Breast milk feeding is one part of the postnatal environment that is a function of maternal and institutional constraints. Maternal choice, supply issues and institutional capacity are all determinants of whether an infant will be fed breast milk, formula, or a combination of both.

A mother may optimize the amount of breast milk she expresses for her child by considering the following: time it takes to express milk (pump), travel time to deliver the milk, her perception of the benefits of breast milk, and her physical ability or comfort in the act of expression. Institutions may optimize the amount of breast milk fed to an infant in the NICU based on formal or informal operating procedures. Certain institutions may favor infant formula over breast milk for some clinical presentations, depending on the culture of the organization and the beliefs of the leadership (Lee & Gould, 2009). There is wide variation in hospital’s dedication to increasing breast milk feeding in the NICU. Variations at the individual and institutional level are non-random. Studies have found that hospitals most likely to be designated “baby friendly” are more likely to have NICU populations that breast milk feed upon discharge (Merewood, Philipp, Chawla, & Cimo, 2003) (Merten, Dratva, & Ackermann-Liebrich, 2005). Studies also find that willingness to breast milk feed is positively correlated with socio-economic status, maternal age and maternal education (Lee & Gould, 2009). While some studies find significantly higher rates of breast milk feeding among non-US-born Hispanic women who give birth to premature infants (Merewood, Brooks, Bauchner, MacAuley, & Mehta, October 2006), others find no significant difference in breast milk feeding rates among different racial or ethnic groups (Espy & Senn, 2003).

I developed the following model to illustrate that breast milk feeding is a function of endogenous variables and its relationship to infant health outcomes.

$$\boldsymbol{BMF = b_0 + b_1X + b_2Z + \varepsilon}$$
$$\boldsymbol{Health = a_0 + a_1BMF + a_2X + \mu}$$

BMF indicates whether an infant received breast milk while in the NICU; X is a vector of characteristics that influence both health outcomes and likelihood of being fed breast milk; Z is a vector of variables that influence whether a baby is fed breast milk, but are uncorrelated with $\boldsymbol{\mu}$ and *Health* is an indicator for the health outcomes of the infant.

I hypothesize that the following variables have an impact on both infant health outcomes and likelihood of breast milk feeding. These variables must be adequately confronted in any empirical analysis of breast milk and health outcomes.

- Newborn Diagnoses and Clinical Stability. Infants who are very high risk may be ordered to gain weight more rapidly. Studies show that infant formula is associated with hyper-active growth in the first weeks of life—a detriment to full term babies, but a potential life-saver for premature infants. Depending on the institutional standard procedures, these highest risk babies might be more likely to receive infant formula and more likely to have poor health outcomes. Conversely, infants with severe gastrointestinal illnesses during their hospital stay may be more likely to receive breast milk, given the research evidence supporting the strongest link between GI morbidities and breast milk feeding.
- Maternal distance from hospital. Mothers who live far away from the hospital may be less likely to transport expressed milk, and also less likely to visit. Visitation is also an important determinant of likelihood to engage in skin-to-skin care (STSC). STSC is associated with improved health outcomes, specifically in improved

weight gain and decreased incidence of respiratory distress (STSC).

- Maternal length of stay in the hospital. Mothers who stay longer in recovery may be exposed to more education and more time to express milk under the tutelage of experienced clinicians. However, the maternal length of stay may be connected to a third variable indicating poor health of the mother that could also affect the health of the child in-utero and beyond.

Choosing a Suitable Instrument

The most important consideration in any IV approach is to select instruments that influence likelihood of the treatment but are uncorrelated with μ**.** For this study, I propose that the hour of birth is a valid instrument for breast milk feeding. The inspiration for this approach comes from both reviews of the literature on full-term infants and maternal length of stay (Malkin, Broder, Keeler, 2000) and interviews with clinicians and mothers in the NICU as part of my work with the University of California, San Francisco Department of Pediatrics and Neonatology. Through my work on this project, I noticed trends in the qualitative data suggesting that staff buy-in and education was an important factor in whether a mother who gives birth prematurely would begin to express milk in a timely manner. Research indicates that women should begin to express milk as soon as possible after birth in order to induce an adequate supply (Groh-Wargo & Sapsford, June-

July 2009). Milk expression should be initiated within 4-6 hours of birth. For this to occur, the mothers must be given a hospital-grade breast pump, be taught how to use it, and be taught to pump early and quite often (Nyqvist, 2004). Qualitative work (Lee, et al. 2012) suggests that breast milk feeding is itself a product of the hour of birth; more skilled and experienced staff in the daytime hours may be more likely to initiate and sustain milk expression. Certified Lactation Consultants are often short staffed and spread among many patients (Davanzo, et al., 2009), and much of the primary initiation of milk expression is led by the nursing staff both in Labor and Delivery and Postpartum Recovery (Gooding, et al., 2011). More experienced staff tends to work the day shift, normally between the hours of 8:00-20:00, according to the interviews I collected and previous evidence by health services researchers (Coffey, Skipper, & Jung, 1988). There is ample evidence that night-shift work is correlated with higher job stress and lower job performance among nurses. (Fitzpatrick, While, & Roberts, 1999). Because of this disparity in the experience between day and night shifts, it follows that women who give birth in the late-night and early-morning hours would be less likely to express breast milk than women in the daytime hours, and therefore less likely to establish an adequate supply and continue breast milk feeding for the duration of her infants' stay in the NICU.

Previous research finds a negative relationship between late-night deliveries and risk of mortality for both full-term and pre-term infants

(Stephanson, et al. 2003) (S. K. Lee et al., 2003). Delivery room death attributable to human error, rather than intrapartum causes, is more common for infants born in the late-night hours (Heller, et al. 2000). The potential pathways between hour of birth and mortality are two-fold: 1) Higher-risk births may present themselves in the middle of the night, either for natural or non-natural reasons and 2) less-skilled clinicians, or clinicians on-call suffering fatigue, may be in the delivery room at the time of birth.

The safety of late-night shift work is of interest to policymakers; however, this interest is not equally spread throughout the different clinicians responsible for NICU quality of care. To date, "No state or federal regulations restrict the number of hours a *nurse* may voluntarily work in twenty-four hours or in a seven-day period" (Rogers, 2004). Only California, Maine, New Jersey and Oregon have attempted to restrict working hours by passing bans on mandatory overtime for nurses. However, there are no laws on the books mandating what sorts of hours nurses freely choose to work.

For doctors, and particularly for residents in teaching hospitals, there are policies protecting both staff and patients from the potential hazards of sleeplessness and impaired decision making. In 1989, the highly publicized Bell Regulations in New York regulated that medical residents could not work more than 80 hours per week or more than 24 hours consecutively (Whetsell, 2004). Since then, numerous states and the federal government have enacted similar laws.

There is no published literature to date studying the longer-term health effects of time of birth. For full term births, the influences of the family, the neighborhood and other outside forces may be too complicated to dissect. With premature infants, we are offered a unique situation—one in which every input and output are recorded. In this controlled environment, we are more easily able to isolate potential causes of health outcomes without introducing bias from "the outside". Premature births are also less planned—the timing of the birth is more likely a function of necessity, and less a function of convenience, compared to full term births.

Threats to the Validity of the Instrument

There are two glaring problems with using the hour of birth as an instrument for breast milk feeding. The first potential problem lies in the pathways between hour of birth and health outcomes. In order for the instrument to be valid, the hour of birth can not affect health outcomes in any way above and beyond its effect on breast milk feeding. If more risky pregnancies occur during nighttime hours, then this medical vulnerability can account for both the timing of birth and the eventual outcomes. Further, if birth trauma is a function of clinician fatigue or skill, and those traumas have longer-term effects on health outcomes, then our instrument is invalid. In order to address this issue, I will isolate my analysis to health outcomes not associated in any past literature with delivery room trauma. I will also show a balance of covariates between daytime and PM births in my analysis sample.

Another potential problem with using hour of birth as an instrument for breast milk feeding is the relationship between hour of birth and method of delivery. I hypothesize that even though premature births are usually unexpected, women who have C-Section deliveries are more likely to give birth during the daytime hours. Evidence in previous research tends to support that claim (Mossialos, Allin, Karras, & Davaki, June 2005) (Tollånes, Thompson, Daltveit, & Irgens, 2007) (Grant, 2005), indicating that labor may be slowed in non-emergency situations in order to deliver during more convenient hours. Women who have C-Sections are more likely to have delayed onset of lactogenesis—intial milk production—compared to women who give birth vaginally (Savona, Zanardo, Cadamuro, Cavallin, & Trevisanuto, 2010). Delayed lactogenesis is a significant predictor of shorter average durations of breastfeeding. Conversely, women who have C-Sections also have longer lengths of hospital stays, on average, which may increase their likelihood of breastfeeding compared to women who give birth vaginally. The average length of stay for a C-Section delivery in California in 2004 was 3.3 days, compared to 1.7 days for vaginal deliveries (Evans, Garthwaite, & Wei, 2008). Furthermore, women who give birth vaginally to a preterm infant are more likely to discharge themselves early (Evans et al., 2008). I can address this threat by narrowing my analysis sample to include those C-

Section births that are distributed across the hours of the day in the closest pattern to vaginal births.

Methods

This study has been approved by the Committees on Human Subjects of the University of California, San Francisco and the University of California, Berkeley.

Data

The data for this project is made available through my work with the University of California, San Francisco and the California Perinatal Quality Care Collaborative (CPQCC). The CPQCC member NICU's account for roughly 90% of all NICU admits in the State. This dataset is comprised of three components. The foundation of the data is the long-form Vital Statistics files for all NICU admits during the years 2005-2007. A proportion of the infants in the data also have detailed medical information appended to the vital statistics files. This medical information was recorded by physicians upon admission to the NICU, and upon discharge. Institutional information for each hospital in the dataset comes from the California Office of Statewide Health Planning and Development (OSHPD). The full dataset contains 44,963 observations. The segment of the data that contains detailed medical information is 17,039. This more detailed segment was randomly drawn from the larger dataset.

The information included in this dataset is comprehensive. The long form Vital Statistics data includes information on time and place of birth,

birth weight, prenatal care, maternal self-reported smoking, maternal census tract and zip code, parental occupation and one and five minute Apgar scores. Apgar scores are clinician reported assessments of an infant's vital signs at one and five minutes post-birth. Ranging from 0-10, Apgar scores are generally agreed to be valid, and are based on skin color, respiratory signals and energy levels (Apgar, 1953). The CPQCC medical information includes detailed history of the infant's stay in the NICU, including any surgeries that were performed, diagnoses of morbidity, weight gain, length of stay, and what the infant was fed upon discharge. The OSHPD data is at the institutional level, and includes information on hospital location, the percent of the hospital population on public insurance or uninsured, staff-to-patient ratios, continuing education units among staff, and various other quality metrics. Table 3 provides descriptive statistics for infants in this dataset.

Constructing a Sub-Sample

In this paper, I will not run every estimation procedure on the entire dataset. Because of the assumptions of the conceptual model, we must exclude births that are "less random".

- For this study, I exclude multiple births—twins, triplets, quadruplets and higher. Multiple births are often expected to be premature, and are more likely to occur during normal business hours. Women with high-risk pregnancies, as all multiple pregnancies are deemed, may be more prepared when the birth occurs, as they are likely well aware of the possibility of not carrying to term. The gestational age at which the multiples are born is inversely proportional to the number of infants being carried. Exclusion of this data reduces the sample size to 14,503 singleton births.

- Some observations are missing information on the CPQCC medical portion of the dataset. This is likely due to measurement error, and is unlikely to be correlated with other explanatory variables. Observations with missing outcome data are not included in the analysis sample.
- I also exclude infants who are discharged to another hospital, or are for any other reason not discharged home. This is usually because infants are transferred to larger hospitals that can accommodate their needs, or are transferred to hospitals closer to the parental home.
- Babies with congenital birth defects are also excluded. This brings the full sample to a size of 12,898 NICU admissions.

Sixty-nine percent of all births in this dataset are via C-Section. This presents unique challenges to the study of time of birth and health outcomes. Simply eliminating all C-Sections from our analysis is not useful; while this would greatly diminish the possibility of selection bias, it would also make our results externally invalid. For this study, I combine theoretical assumptions and statistical methods to construct the most appropriate sub-sample for analysis, balancing the threats to internal and external validity.

This unique dataset includes information on labor spontaneity and indications for C-Section. Leveraging these variables allows me to construct a sample for which the time of birth can be considered most natural. Notice I do not use the word “random”, because research shows a non-uniform distribution of time of birth among full-term spontaneous vaginal births (Bernis and Varea, 2011). Since we do not know whether preterm births follow a similar circadian rhythm, the distribution of birth times for spontaneous vaginal deliveries in the full sample will be considered the gold standard in this study. Figure 1 shows the distribution of births across 24 hours for spontaneous vaginal deliveries. Compared to Figure 2, which includes only C-Sections, it is apparent that bunching of C-Section deliveries during normal working hours presents an obstacle to this research. Leveraging the unique indications for C-Section births in this data allows me to isolate the types of C-Sections that are most like the natural distribution of vaginal births. There are three groups of indications for C-Sections: those done as a result of fetal health complications, those as a result of maternal complications (the most common being preeclampsia) and those as a result of obstetrical complications (placenta previa, or unexplained bleeding). Figures 3, 4 and 5 show the time distributions of these three groups. Observation of the distribution supports the claim that those C-Sections performed for the health of the mother are the least likely to exhibit problematic clustering during daytime hours. Adding to this visual analysis, I perform multiple

Kolmogorov-Smirnov tests for equality of distribution functions. While none of the samples is statistically similar to the natural distribution of vaginal births, the raw differences between the distributions is used as further validation that the group of births performed for the health of the mother is the most similar to the vaginal-only group. Therefore, the preferred sub-sample includes only C-Sections in this indication sample. This brings the sample size for the analysis to 7,366 births.

Defining the Treatment Variables

Off-peak hours are defined as the time of day outside normal working hours. Following the work of previous studies, I categorize off-hours deliveries as those occurring between 9pm and 6am. I further narrow this window to 11pm to 4am for “extreme-off-hours” deliveries. I also run analyses using evening hour births between 5pm and Midnight. If the critical time window for beginning milk expression is 4-6 hours, the evening births are potentially the most affected by the lack of lactation support in the nighttime hours.

One of my underlying assumptions is that access to experienced lactation consultants or nurses within the first 4 to 6 hours after birth is critical in establishing a strong milk supply. However, because of the lack of dynamic measurement of breast milk feeding in the dataset, I am unable to fully explore this relationship. The only variable in the data is a categorical variable indicating whether the infant was discharged on full, partial or no breast milk feedings. There is no indication to what proportion the daily feedings were breast milk.

Outcome Variables

The main outcomes of interest are 1) Incidence of Necrotizing Enterocolitis (NEC) or gastrointestinal perforations, 2) Incidence of late-onset sepsis, 3) Length of Stay in the NICU, 4) Incidence of Retinopathy of Prematurity (ROP), 5) Change in weight over the NICU stay, and 6) Change in head circumference over the NICU stay. As a measure of robustness, I also include the incidence of Patent (meaning open) Ductus Arteriosus (PDA) and the proportion of days spent on a ventilator as outcome variables. Past research suggests that these two outcome variables are not associated with breast milk feeding. The former measures a condition present at birth and the latter measures respiratory ailments that are not shown to be associated with feeding method.

Statistical Analysis

All analyses include standard errors clustered at the NICU hospital level. The first stage of the analysis is a multivariable linear regression of Off-Hours birth on the likelihood of receiving any breast milk at discharge. This analysis controls for one and five minute Apgar scores, gestational age in weeks, delivery mode, birth weight, zip code mismatch between the mother's residence and the hospital, as well as maternal length of stay and maternal education. This analysis is repeated using both Extreme Off-Hours birth and Evening birth as the main explanatory variable of interest.

The reduced form—the potential effect of birth hour on health outcomes—analysis controls for the same set of potential confounders and is repeated for Off-Hours, Extreme Off-Hours and Evening births.

In order to check for heterogeneity of the relationships, the first-stage and reduced form analyses are performed for varying subgroups. I explore potential heterogeneity by birth weight, gestational age, race and ethnicity and maternal age.

Results

Descriptive statistics of births occurring in peak and off-hours (9pm-6am) are presented in Table 2. Both the full and analysis sample are shown. For the analysis sample, the majority of covariates are balanced across peak and off hour births. However, the proportion of vaginal births is significantly higher during the nighttime hours when focusing solely on the preferred sub-sample. The decrease in significantly different covariates when the analysis sample is separated from the full sample underscores the necessity of knowing the indication for C-Section delivery. For example, Apgar scores in the full sample are significantly lower during the nighttime hours indicating that high risk births are indeed more likely during late-night shifts. This may explain some of the variance in delivery room deaths found in past research.

Table 3 presents descriptive statistics for both the full and analysis samples by feeding type at discharge. The incidence of being discharged on full breast milk feedings is very rare. Supplementation with formula or other high-calorie fortifiers is common. Therefore, I focus here on infants discharged on any breast milk versus infants discharged on only formula. Demographic characteristics that significantly predict being discharged on only formula include: self-identifying as a non-White race, younger maternal age, lower gestational age, being transferred in post-birth and being born via C-Section. These predictors are significant in the full sample as well. Hispanic ethnicity only predicts discharge on full formula in the full sample.

Table 4 presents the results of the first-stage analysis using off-hours of 9pm-6am. No matter how PM hours are defined (see Tables 5 and 6), there is no significant relationship between the hour of birth and breast milk feeding in either the full or analysis samples. Even when altering the outcome variable to designate *only* breast milk, the significance of the findings remains unchanged. Though these first-stage results make an Instrumental Variables approach unfounded, they do reveal some interesting findings. In the preferred sub-sample, being born vaginally increases an infant's likelihood of being discharged on breast milk by 4.3 percentage points. Furthermore, mismatch between the hospital and maternal residential zip code increases the likelihood of breast milk feedings as does each additional day of the mother's length of stay postpartum. For both samples—full and preferred—birth weight is also a positive predictor of breast milk feeding at discharge. The significance of these findings vary slightly between Tables 4-6, with the extreme off-hours model having less significant coefficients and the evening hours model having more. In particular, the evening hours model indicates a positive association between 5 minute Apgar score and likelihood of breast milk feeding. For each one-unit increase in Apgar assessment score, the percentage point change in likelihood of breast milk feeding is .4%.

The reduced-form analysis is presented in Table 7. Overall, there is little evidence to suggest a longer-term association between hour of birth and health outcomes in the NICU. There are, though, a couple of significant differences in outcomes as a function of birth hour that are worth noting. The results in Model 6 suggest an increased risk of contracting Necrotizing Enterocolitis among babies born between 5pm and Midnight. Babies born in this time period are 2.2% more likely to exhibit this condition at some point in their NICU stay. Model 6 controls for the full set of potential confounders. Infants born in this time window also experience, on average, lengths of stay that are 1.5 days longer than babies born at any other time of day. Conversely, infants bore in the middle of the night (9pm-6am) experience shorter lengths of stay. On average, a baby born during these hours will have a 2.79 day shorter stay than daytime births. The only other significant finding is a decrease in weight gain over the course of the NICU stay for infants born in the 9pm-6am window. The average percentage change in weight for these infants is 7.4 percentage points lower than their daytime counterparts. The average percentage weight change in the preferred sub sample is 110%.

Tables 8-10 explore evidence of heterogeneity in effect size for the first-stage relationship between hour of birth and breast milk feeding. Models are run separately by birth weight category, gestational age, Race/Ethnicity and Maternal Age category. No matter the off-hour definition, there is no evidence to suggest differential effect size by any of these sub-group categories. Much like the first stage results for the full sample, we are unable to isolate any significant relationship.

Tables 11-13 explore heterogeneity in the reduced form analysis. For the 9pm-6am off-hours births (Table 11), women of Non-White race, or those who identify as White and Hispanic, exhibit a larger association between PM births and decreased lengths of stay compared to White mothers. Furthermore, there is a significant positive relationship between PM births and both NEC and GI perforations among White women. Among non-White women, this relationship is negative though not significant. This pattern continues in Table 12, where the coefficient on NEC is larger than in Table 11 indicating an increased risk as the time window for the off-hours grows smaller.

Another distinction of note occurs in Table 12. The magnitude of the length of stay coefficient is much larger for teenage and older mothers than for all other mothers. Among teenage mothers, PM births occurring between 11pm and 4am are associated with a decrease in average stay length of nearly 7 days. For women over the age of 40, this average difference is 4 days less. The magnitude of the coefficient for babies born at less than 32 weeks is also quite large compared to the results in Table 7, Models 3 and 4. The difference among these most medically vulnerable infants is -3 days.

Table 13 alters the definition of PM to include births in the 5pm to Midnight hours. In these models, the most significant change in results comes as a function of race and ethnicity. Among White women only, being born in this time period is associated with an increased risk of not only NEC, but also late-onset sepsis. Percentage changes in weight gain and head growth, however, are greater among PM births to White women. Another significant finding is the relationship between evening births and NEC among the most fragile infants: those under 2500 grams and those born at less than 32 weeks gestational age. Lastly, the increase in infant length of stay associated with an evening birth is very large (16 more days) for mothers over the age of 40.

Discussion

The hour of birth is not a suitable instrument for breast milk feeding at discharge because of the insignificant first-stage relationship between the two variables. However, even though the initial analysis design was not valid, both the full first-stage models and the reduced form models offer interesting results that deserve further exploration.

Contrary to the qualitative evidence previously collected by this author and others, there appears to be no relationship between a late-night delivery and likelihood of being discharged on any breast milk. However, due to the constraints of the data's binary measurement of breast milk feeding, if the relationship between our variables of interest follows a dose-response pattern we are missing any potential relationship between delivery timing and feeding. As part of the CPQCC collaborative, we have collected more detailed information on intensity of breast milk feeding—what proportion of feedings are breast milk—from mothers in three large NICU's in the Bay Area of California. Very preliminary results support the claim that PM births do not predict breast milk feedings, but that PM births do predict a significantly lower proportion of total feedings that are breast milk.

Breast milk feedings are predicted by various explanatory variables, even after controlling for potential confounders. The relationship between birth weight, Apgar scores and breast milk at discharge indicates that either hospital policy disincentives the more medically vulnerable babies from using breast milk as a first feeding or that mothers are responding to the medical vulnerability by decreasing likelihood of breast milk feeding. Anecdotal evidence collected from both mothers and clinicians suggest that the former explanation is more likely. Some medical directors or others in leadership positions are still undecided on the feeding protocol for the most fragile of infants.

The relationship between C-Sections and breast milk feeding success in this sample mirrors findings in full-term populations all over the world (Vieira, et al., 2011). My findings confirm previous research results, but are the first to show that C-Sections may not only delay the onset of milk production, but that this delay in the early perinatal period produces a longer-term disparity in NICU feeding outcomes. A similarly robust finding is the relationship between maternal length of stay and breast milk feeding. Both C-Section births and initial length of stay for the mother are the result of delivery-room policies (via the hospital or insurance companies) that can be manipulated. In future studies, I plan to leverage both maternal distance from the hospital and maternal length of stay as instruments for breast milk feeding.

The reduced-form analysis of the potential effect of hour of birth on various health outcomes produces some surprising findings. In terms of NEC, babies born during the evening hours are more likely to contract this condition than any other delivery time. Why this is, the analysis can not tell us. One hypothesis is that if the breast milk variable were measured more dynamically, this could account for some of the variation in NEC risk. Another explanation is that an intervention in the early hours of life may protect against NEC, and that infants born during the evening hours are less likely to receive this intervention. Previous research suggests that evening hours are a prime time for shift changes, and that critical information about the infant may be overlooked or lost during the handoff. In this data there is no significant relationship between health indicators at birth and later incidence of NEC, suggesting that the innate medical vulnerability of the infant has little to do with eventual outcomes on this measure. Because NEC is one of the most deadly conditions in the NICU, even if it is relatively rare, this result should be further examined in future studies.

Taken together, the results of this study fail to paint a consistent story. While giving birth in the late night hours is associated with a decreased length of stay for the infant, giving birth in the evening is associated with just the opposite. Relationships that were insignificant in the full sample reduced-form analysis become significant when looking at only White women of non-Hispanic ethnicity. Small magnitudes of association are suddenly quite large when partitioning the sample by maternal age. Overall, there is little evidence to suggest that—besides the consistently significant association between hour of birth and NEC—a late night or early morning hour of delivery is indicative of any longer-term health disadvantage in the

NICU population. Despite this lack of association, there are many lessons to be taken from this analysis. Besides exploring the intriguing relationship between hour of birth and NEC, work should be pursued on the policy determinants of breast milk feeding in the NICU, specifically in regards to indications for C-Sections and maternal length of stay.

Tables and Figures

Figure 1: Distribution of Hour of Birth, All Vaginal Births

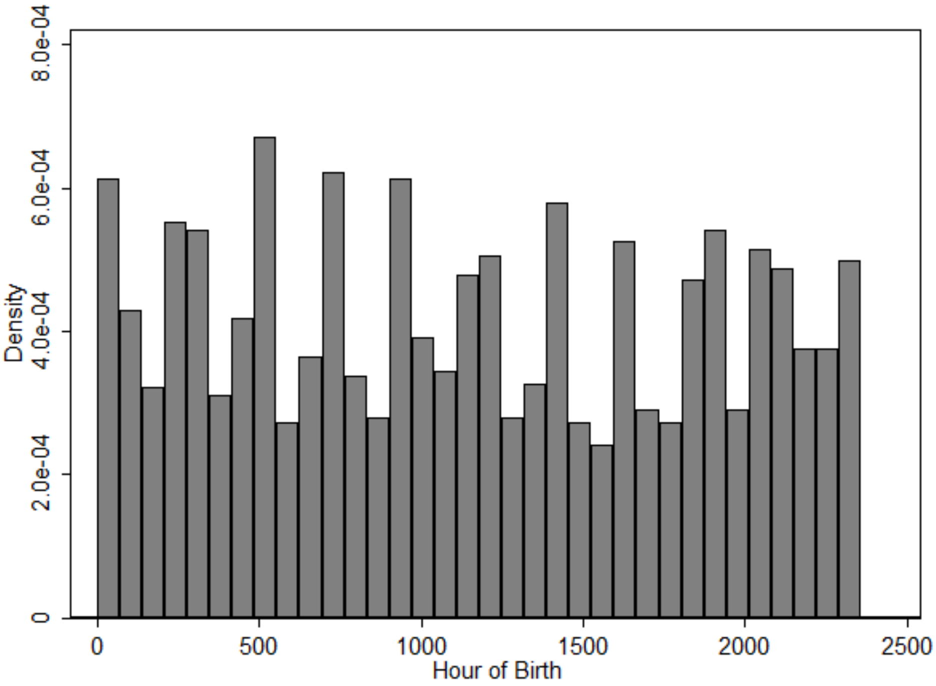

Figure 2: Distribution of Hour of Birth, All C-Section Births

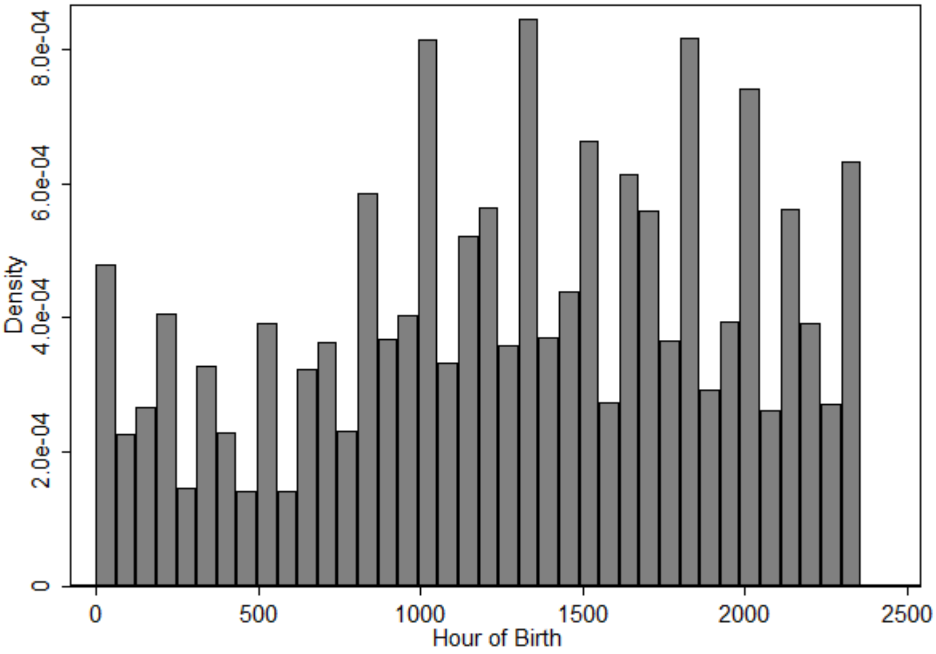

Figure 3: Distribution of Hour of Birth, Spontaneous Labor, No Fetal Indication for C-Section

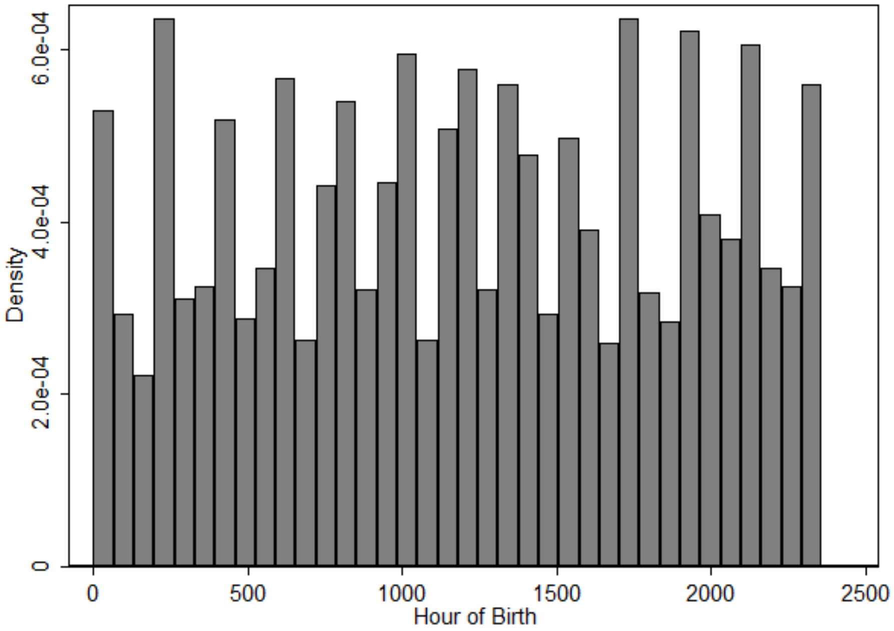

Figure 4: Distribution of Hour of Birth, Spontaneous Labor, No Maternal Indication for C-Section

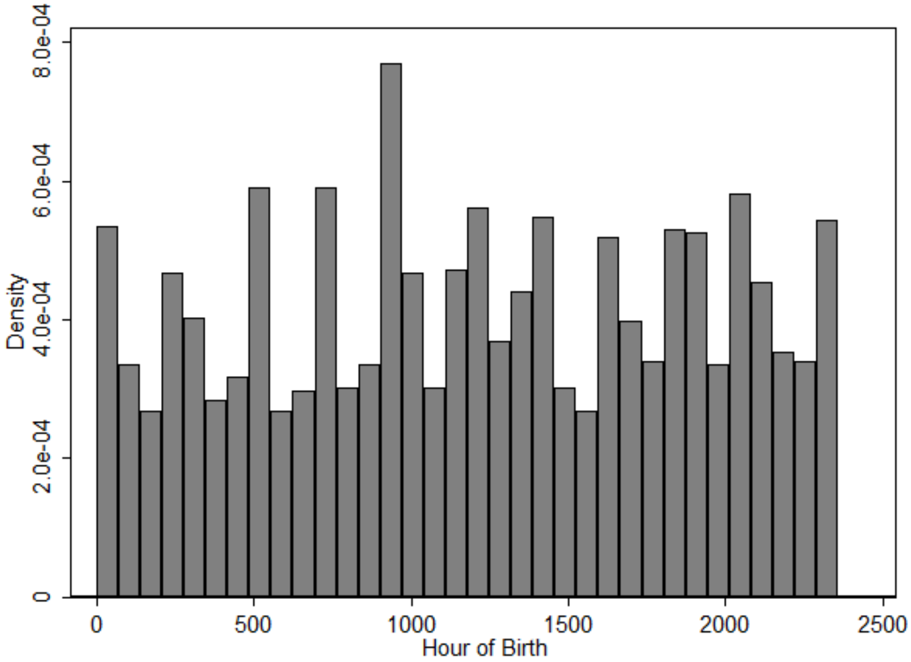

Figure 5: Distribution of Hour of Birth, Spontaneous Labor, No Obstetrical Indication for C-Section

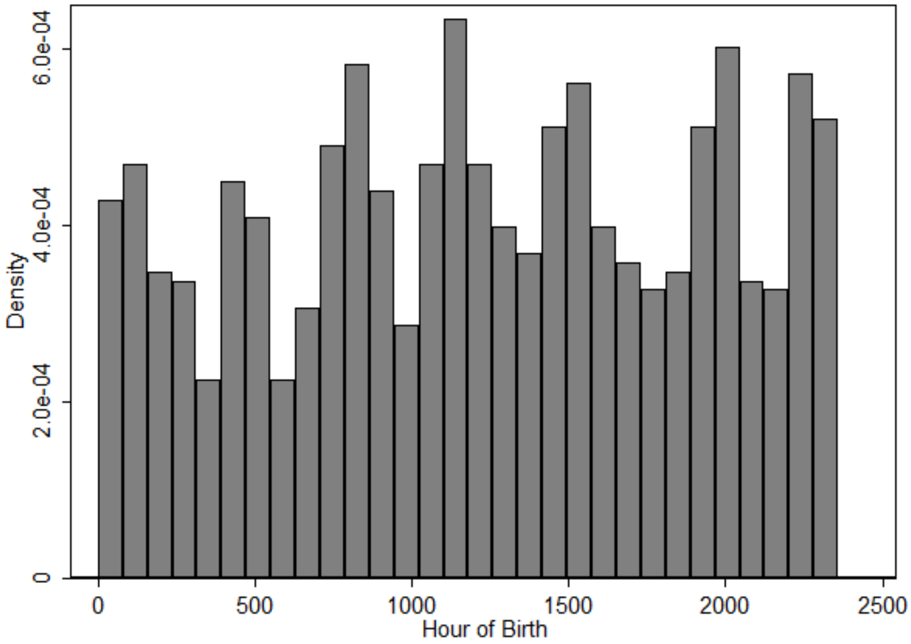

Table 1: K-Smirnov tests of similarity between Vaginal and C-Section Indication Groups

	K-S Difference vs. Vaginal Birth Distribution
Group 1: No Fetal Complications	-.022
Group 2: No Maternal Complications	-.031
Group 3: No Obstetrical Complications	-.052

Table 2: Covariates of Working and Off Hour Groups. Standard Errors in Parentheses

	All Patients N=16812		Preferred Sub-Sample Only N= 7366	
	Working Hours	Off-Hours	Working Hours	Off-Hours
Proportion Non-White	.41 (.01)	.42 (.01)	.44 (.01)	.46 (.01)
Proportion Hispanic (Any Race)	.44 (.01)	.46 (.01)	.51 (.01)	.51 (.01)
Mean Maternal Age	29.83 (.09)	29.49* (.15)	28.03 (.12)	27.87 (.16)
Proportion with any College	.47 (.01)	.46 (.01)	.42 (.01)	.42 (.01)
Mean Gestational Age (Weeks)	28.79 (.03)	28.58** (.06)	27.01 (.05)	26.84 (.07)
Proportion Male Infants	.50 (.01)	.49 (.01)	.54 (.01)	.54 (.01)
Proportion Transferred In	.14 (.004)	.13 (.01)	.19 (.01)	.18 (.01)
Proportion Vaginal Birth	.28 (.004)	.37*** (.01)	.69 (.01)	.73*** (.01)
Mean 1 Minute Apgar Score	6.07 (.06)	5.66*** (.07)	6.64 (.16)	6.52 (.24)
Mean 5 Minute Apgar Score	7.86 (.06)	7.52*** (.07)	8.19 (.17)	8.03 (.24)

*** = (p<.10); ** = (p<.05) * = (p<.01)

Table 3: Covariates by Feeding Type at Discharge. Standard Errors in Parentheses

	All Patients N=16812		Preferred Sub-Sample Only N= 7366	
	Any Breast Milk	Only Formula	Any Breast Milk	Only Formula
Proportion Non-White	.39 (.01)	.45*** (.01)	.42 (.01)	.45* (.01)
Proportion Hispanic (Any Race)	.49 (.01)	.52* (.01)	.54 (.02)	.53 (.02)
Mean Maternal Age	29.89 (.09)	27.77*** (.14)	28.69 (.16)	26.80*** (.23)
Proportion with Any College	.55 (.01)	.38*** (.01)	.49 (.01)	.33*** (.01)
Mean Gestational Age (Weeks)	28.95 (.037)	28.43*** (.058)	28.21 (.06)	27.86** (.11)
Proportion Male Infants	.50 (.01)	.49 (.01)	.52 (.01)	.53 (.01)
Proportion Transferred In	.14 (.004)	.18*** (.01)	.16 (.01)	.23*** (.01)
Proportion Vaginal Birth	.27 (.01)	.27 (.01)	.68 (.01)	.64** (.01)
Mean 1 Minute Apgar Score	6.73 (.10)	6.56 (.15)	7.40 (.24)	7.30 (.34)
Mean 5 Minute Apgar Score	8.45 (.10)	8.27 (.14)	9.04 (.24)	8.89 (.31)

*** = (p<.10); ** = (p<.05) * = (p<.01)

Table 4: Relationship between hour of birth and any breast milk feeding at discharge; Off-Hours Defined as 9pm-6am. Standard Errors in Parentheses

	All Patients N=12898		Preferred Sub-Sample Only N= 4681	
	Model 1	Model 2	Model 3	Model 4
Off-Hours Birth	.007 (.009)	.008 (.012)	.021 (.019)	.009 (.013)
1 Minute Apgar Score	--	-.002 (.002)	--	-.001 (.001)
5 Minute Apgar Score	--	.003* (.002)	--	.002 (.002)
Gestational Age (Weeks)	--	.009*** (.002)	--	.002 (.004)
Vaginal Birth	--	.004 (.011)	--	.043** (.02)
Birth Weight (grams)	--	.0001*** (.00002)	--	.0001*** (.00003)
Mother/Hospital Zip Code Mismatch	--	.062*** (.022)	--	.056* (.03)
Maternal Length of Stay (in Days)	--	.002*** (.0006)	--	.005*** (.001)

*** = (p<.10); ** = (p<.05) * = (p<.01)

Table 5: Relationship between hour of birth and any breast milk feeding at discharge; Extreme Off-Hours of 11pm-4am. Standard Errors in Parentheses

	All Patients N=12898		Preferred Sub-Sample Only N= 4681	
	Model 1	Model 2	Model 3	Model 4
Extreme Off-Hours Birth	.008 (.008)	.009 (.010)	.011 (.017)	.006 (.013)
1 Minute Apgar Score	--	-.0015 (.0017)	--	-.0008 (.002)
5 Minute Apgar Score	--	.004* (0019)	--	.002 (.002)
Gestational Age (Weeks)	--	.010*** (.002)	--	.002 (.004)
Vaginal Birth	--	.0047 (.012)	--	.042 (.016)
Birth Weight (grams)	--	.0001*** (.00002)	--	.0001 (.00003)
Mother/Hospital Zip Code Mismatch	--	.062*** (.022)	--	.057* (.029)
Maternal Length of Stay	--	.0023*** (.0006)	--	.005*** (.001)

*** = (p<.10); ** = (p<.05) * = (p<.01)

Table 6: Relationship between hour of birth and any breast milk feeding at discharge; Evening Hours Defined as 5pm-Midnight

	All Patients N=12898		Preferred Sub-Sample Only N= 4681	
	Model 1	Model 2	Model 3	Model 4
Evening Hours Birth	.011 (.011)	.008 (.013)	.028 (.019)	.014 (.019)
1 Minute Apgar Score	--	-.003 (.002)	--	-.002 (.002)
5 Minute Apgar Score	--	.004** (.002)	--	.004** (.002)
Gestational Age (Weeks)	--	.007** (.003)	--	-.0002 (.004)
Vaginal Birth	--	.010 (.013)	--	.061*** (.018)
Birth Weight (grams)	--	.0001*** (.00002)	--	.0001*** (.00004)
Mother/Hospital Zip Code Mismatch	--	.058** (.026)	--	.069* (.037)
Maternal Length of Stay	--	.003*** (.0008)	--	.007*** (.001)

*** = (p<.10); ** = (p<.05) * = (p<.01)

Table 7: Relationship between Hour of Birth and Health Outcomes. Models (2), (4) and (6) controlling for Apgar Scores at 1 and 5 minutes, Gestational Age, Delivery Mode, Birth Weight, Zip Code Mismatch and Maternal Length of Stay. Preferred Sub-Sample Only. Standard Errors in Parentheses. N=4025

	Off-Hours 9pm-6am		Extreme Off-Hours 11pm-4am		Evening Hours 5pm-Midnight	
Outcome Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Necrotizing Enterocolitis	.004 (.006)	.001 (.007)	.009 (006)	.006 (.007)	.022** (.009)	.022** (.009)
Any GI Perforation	.006 (.005)	.004 (.006)	.006 (.005)	.004 (.005)	-.0004 (.004)	-.003 (.005)
Incidence of Late-Onset Sepsis	.012 (.012)	.011 (.011)	.012 (.011)	.011 (.012)	.012 (.012)	.019 (.013)
Incidence of ROP	.032 (.020)	.031 (.020)	.048** (.019)	.037* (.019)	.023 (.021)	.017 (.019)
Length of Stay (Days)	-2.32* (1.17)	-2.79** (1.29)	-1.40 (1.11)	-1.50 (1.05)	1.25 (.88)	1.50* (.910)
Proportion Weight Gain(a)	-.058 (.041)	-.074* (.043)	-.015 (.038)	-.019 (.032)	.050 (.037)	.056 (.035)
Proportion Head Circumference Gain(a)	-.011* (.006)	-.014 (.007)	-.008 (.005)	-.008 (.005)	.002 (.006)	.003 (.005)
Incidence of PDA	.006 (.017)	.006 (.018)	.009 (.015)	.013 (.017)	.016 (.017)	.014 (.016)
Percentage of Days on Ventilator(a)	.062 (.149)	-.045 (.128)	-.035 (.140)	-.094 (.127)	-.010 (.151)	.011 (.169)

Note: (a) these models were run also controlling for infant length of stay

*** = (p<.10); ** = (p<.05) * = (p<.01)

Table 8: Relationship between Hour of Birth and Any Breast Milk Feeding at Discharge among Sub-Groups. Full Controls. Preferred Sub-Sample Only. Standards Errors in Parentheses. Off Hours Defined as 9pm-6am

	Birth Weight		Gestational Age (Weeks)	Race		Maternal Age	
Outcome Variable	<1500 Grams	<2500 Grams	<32 Weeks	White	Non-White Race or Hispanic. Any Race	<18	>40
Any Breast Feeding	.005 (.014)	.013 (.014)	-.004 (.014)	-.009 (.023)	.039 (.027)	.039 (.069)	.035 (.085)

*** = (p<.10); ** = (p<.05) * = (p<.01)

Table 9: Relationship between Hour of Birth and Any Breast Milk Feeding at Discharge among Sub-Groups. Full Controls. Preferred Sub-Sample Only. Standards Errors in Parentheses. Extreme Off Hours Defined as 11pm-4am

	Birth Weight		Gestational Age (Weeks)	Race		Maternal Age	
Outcome Variable	<1500 Grams	<2500 Grams	<32 Weeks	White	Non-White Race or Hispanic. Any Race	<18	>40
Any Breast Feeding	.002 (.016)	.004 (.014)	-.008 (.016)	-.023 (.022)	.041 (.026)	.016 (.055)	.009 (.084)

*** = (p<.10); ** = (p<.05) * = (p<.01)

Table 10: Relationship between Hour of Birth and Any Breast Milk Feeding at Discharge among Sub-Groups. Full Controls. Preferred Sub-Sample Only. Standards Errors in Parentheses. Evening Hours Defined as 5pm-Midnight

	Birth Weight		Gestational Age (Weeks)	Race		Maternal Age	
Outcome Variable	<1500 Grams	<2500 Grams	<32 Weeks	White	Non-White Race or Hispanic. Any Race	<18	>40
Any Breast Feeding	.016 (.019)	.013 (.019)	.005 (.020)	.0002 (.022)	.036 (.027)	-.004 (.069)	.122 (.079)

*** = (p<.10); ** = (p<.05) * = (p<.01

Table 11: Relationship between Hour of Birth and Health Outcomes among Sub Groups. Full Controls. Preferred Sub-Sample Only. Standard Errors in Parentheses. Off Hours Defined as 9pm-6am

	Birth Weight		Gestational Age (Weeks)	Race		Maternal Age	
Outcome Variable	<1500 Grams	<2500 Grams	<32 Weeks	White Non Hisp	Non-White Race or Hispanic. Any Race	<18	>40
Necrotizing Enterocolitis	.003 (.007)	.006 (.007)	.007 (.008)	.025* (.013)	-.014 (.013)	-.006 (.026)	-.022 (.04)
Any GI Perforation	.0008 (.006)	.004 (.006)	.003 (.006)	.017* (.009)	-.010 (.006)	.024 (.023)	-.009 (.009)
Incidence of Late-Onset Sepsis	.012 (.013)	.011 (.012)	.014 (.013)	.013 (.016)	.008 (.018)	.001 (.039)	-.007 (.057)
Incidence of ROP	.036 (.022)	.031 (.021)	.034* (.018)	.041 (.025)	.016 (.034)	.013 (.063)	.123 (.077)
Length of Stay (Days)	-2.59* (1.36)	-2.78** (1.29)	-2.92** (1.36)	-2.43 (1.88)	-3.53* (1.95)	-6.06 (4.23)	-4.68 (5.23)
Proportion Weight Gain(a)	-.076 (.046)	-.076* (.043)	-.078* (.046)	-.073 (.064)	-.079 (.063)	-.178 (.133)	-.176 (.176)
Proportion Head Circumference Gain(a)	-.014* (.007)	-.015** (.007)	-.015** (.007)	-.012 (.009)	-.016 (.010)	-.028 (.021)	-.029 (.024)
Incidence of PDA	.001 (.017)	.006 (.018)	.003 (.018)	.028 (.023)	-.016 (.027)	-.078 (.061)	.143* (.080)
Proportion of Days on Ventilator(a)	-.041 (.141)	-.043 (.128)	-.041 (.129)	.050 (.20	-.135 (.172)	1.15 (.826)	-.071 (.253)

*** = (p<.10); ** = (p<.05) * = (p<.01)

Table 12: Relationship between Hour of Birth and Health Outcomes among Sub Groups. Full Controls. Preferred Sub-Sample Only. Standard Errors in Parentheses. Extreme Off Hours Defined as 11pm-4am

	Birth Weight		Gestational Age (Weeks)	Race/Ethnicity		Maternal Age	
Outcome Variable	<1500 Grams	<2500 Grams	<32 Weeks	White, Non Hisp.	Non-White Race or Hispanic. Any Race	<18	>40
Necrotizing Enterocolitis	.010 (.008)	.012 (.008)	.014 (.009)	.031** (.012)	-.011 (.014)	-.014 (.025)	.029 (.037)
Any GI Perforation	.002 (.005)	.004 (.005)	.004 (.005)	.015** (.007)	-.008 (.005)	.016 (.020)	-.009 (.009)
Incidence of Late-Onset Sepsis	.011 (.013)	.011 (.012)	.015 (.012)	.021 (.017)	-.003 (.017)	-.018 (.037)	-.025 (.048)
Incidence of ROP	.039* (.020)	.037* (.018)	.039** (.018)	.034 (.024)	.035 (.033)	-.019 (.056)	.109 (.072)
Length of Stay (Days)	-1.41 (1.40)	-1.49 (1.06)	-3.01** (1.33)	-.561 (1.58)	-2.65 (1.68)	-6.89* (3.69)	-4.05** (1.24)
Proportion Weight Gain(a)	-.020 (.034)	-.019 (.032)	-.021 (.036)	.022 (.047)	-.072 (.050)	-.201* (.121)	.060 (.164)
Proportion Head Circumference Gain(a)	-.007 (.005)	-.007 (.006)	-.008 (.005)	-.0013 (.007)	-.016* (.008)	-.029 (.019)	-.013 (.022)
Incidence of PDA	.008 (.018)	.013 (.017)	.012 (.018)	.030 (.022)	-.006 (.024)	-.023 (.046)	.186** (.062)
Proportion of Days on Ventilator(a)	-.099 (.142)	-.092 (.128)	-.091 (.129)	-.065 (.140)	-.111 (.209)	1.38 (.843)	-.262 (.367)

Table 13: Relationship between Hour of Birth and Health Outcomes among Sub Groups. Full Controls. Preferred Sub-Sample Only. Standard Errors in Parentheses. Evening Hours Defined as 5pm-Midnight

	Birth Weight		Gestational Age (Weeks)	Race		Maternal Age	
Outcome Variable	<1500 Grams	<2500 Grams	<32 Weeks	White Non Hisp	Non-White Race or Hispanic. Any Race	<18	>40
Necrotizing Enterocolitis	.020** (.010)	.022** (.009)	.021** (.010)	.019* (.011)	.002 (.001)	-.022 (.030)	.023 (.047)
Any GI Perforation	-.004 (.005)	-.003 (.005)	-.004 (.005)	-.007 (.007)	.001 (.009)	-.023 (.020)	-.011 (.012)
Incidence of Late-Onset Sepsis	.018 (.014)	.018 (.013)	.021 (.014)	.039** (.016)	-.007 (.018)	.047 (.043)	.021 (.056)
Incidence of ROP	.012 (.018)	.017 (.019)	.010 (.019)	.002 (.022)	.030 (.024)	-.081 (.054)	.042 (.078)
Length of Stay (Days)	1.15 (1.00)	1.49 (.94(	-1.43 (1.09)	1.99 (1.31)	.845 (2.02)	1.32 (4.19)	16.10** (5.32)
Proportion Weight Gain$^{(a)}$	.053 (.038)	.057 (.035)	.059 (.036)	.126** (.053)	-.032 (.061)	.023 (.142)	.483* (.252)
Proportion Head Circumference Gain$^{(a)}$	.002 (.006)	.003 (.005)	.004 (.006)	.011* (.006)	-.006 (.011)	.013 (.023)	.071** (.031)
Incidence of PDA	.016 (.017)	.014 (.017)	.016 (.017)	.016 (.020)	.008 (.026)	-.072 (.059)	-.063 (.078)
Proportion of Days on Ventilator$^{(a)}$	.004 (.186)	.010 (.169)	.0008 (.171)	-.102 (.263)	.146 (.320)	-.642 (.415)	-.208 (.183)

*** = (p<.10); ** = (p<.05) * = (p<.01)

References:

Affonso D., Wahlberg V., & Persson B.(1989). Exploration of mother's reactions to the kangaroo method of prematurity care. *Neonatal Network*, 7(6):43-51.

Anderson, P., Doyle, L. W., & and the Victorian Infant Collaborative Study Group. (2003). Neurobehavioral outcomes of school-age children born extremely low birth weight or very preterm in the 1990s. *JAMA: The Journal of the American Medical Association, 289*(24), 3264-3272.

Bauchner, H., Leventhal, J. M., & Shapiro, E. D. (1986). Studies of breast-feeding and infections. *JAMA: The Journal of the American Medical Association, 256*(7), 887-892.

Bernis, C., & Varea, C. (2011). Hour of birth and birth assistance: From a primate to a medicalized pattern? *American Journal of Human Biology*, 24(1), 14-21

Berseth, C. L., Bisquera, J. A., & Paje, V. U. (2003). Prolonging small feeding volumes early in life decreases the incidence of necrotizing enterocolitis in very low birth weight infants. *Pediatrics, 111*(3), 529-534.

Blaymore Bier, J., Ferguson, A.E., Morales, T., LIebling, J.A., Archer, D., Oh, W., & Vohr, B. (1996). Comparison of Skin-to-Skin Contact with Standard Contact in Low-Birth-Weight Infants Who Are Breast-Fed. *Journal of the American Medical Association*, 150(12), 1265-1269

Coffey, L. C., Skipper, J. K., & Jung, F. D. (1988). Nurses and shift work: Effects on job performance and job-related stress. *Journal of Advanced Nursing, 13*(2), 245-254.

Davanszo, R., Ronfani, L., Pierpaolo, B., and Demarini, S. (2009). Breast feeding very-low-birthweight infants at discharge: a multicentre study using WHO definitions. *Paediatric and Perinatal Epidemiology*, 23(6), 590-596

De Silva, A., Jones, P., & Spencer, S. (2004). Does human milk reduce infection rates in preterm infants? A systematic review. *Archives of Disease in Childhood Fetal and Neonatal Edition, 89*(6), F509-13.

Espy, K. A., & Senn, T. E. (2003). Incidence and correlates of breast milk feeding in hospitalized preterm infants. *Social Science & Medicine, 57*(8), 1421-1428.

Evans, W. N., Garthwaite, C., & Wei, H. (2008). The impact of early discharge laws on the health of newborns. *Journal of Health Economics, 27*(4), 843-870.

Fitzpatrick, J. M., While, A. E., & Roberts, J. D. (1999). Shift work and its impact upon nurse performance: Current knowledge and research issues. *Journal of Advanced Nursing, 29*(1), 18-27.

Gooding, J., Cooper, L.G., Blaine, A., Franck, L., Howse, J., & Berns, S. (2003). Family Support and Family-Centered Care in the Neonatal Intensive Care Unit: Origins, Advances, Impact. *Seminars in Perinatology*, 14(2), 218-222

Groh-Wargo, S., & Sapsford, A. (2009). Enteral nutrition support of the preterm infant in the neonatal intensive care unit. *Nutrition in Clinical Practice, 24*(3), 363-376.

Heller G., Misselwitz B., & Schmidt S. (2000). Early neonatal mortality, asphyxia related deaths, and timing of low risk births in Hesse, Germany, 1990-8: observational study. *British Medical Journal*, 321(7256): 274–275.

Hylander, M. A., Strobino, D. M., & Dhanireddy, R. (1998). Human milk feedings and infection among very low birth weight infants. *Pediatrics, 102*(3), e38-e38.

Klassen, A. F., Lee, S. K., Raina, P., Chan, H. W. P., Matthew, D., & Brabyn, D. (2004). Health status and health-related quality of life in a population-based sample of neonatal intensive care unit graduates. *Pediatrics, 113*(3), 594-600.

Lee, H. C., & Gould, J. B. (2009). Factors influencing breast milk versus formula feeding at discharge for very low birth weight infants in California. *The Journal of Pediatrics, 155*(5), 657-662.e2.

Lee, H.C., Martin-Anderson, S., Lydon, A., and Dudley, A. (2012) Clinician Perspectives on Opportunity for Breast Milk Feeding in the Neonatal Intensive Care Unit. *Breastfeeding Medicine.* Forthcoming

Lucas, A., & Cole, T. J. (1990). Breast milk and neonatal necrotising enterocolitis. *The Lancet, 336*(8730-8731), 1519-1523.

Lucas, A. (2005). Long-term programming effects of early nutrition-implications for the preterm infant. *Journal of Perinatology, 25*, 2-6.

Malkin, J. D., Broder, M. S., & Keeler, E. (2000). Do longer postpartum stays reduce newborn readmissions? analysis using instrumental variables. *Health Services Research, 35*(5 Pt 2), 1071-1091.

McCarton C.M., Brooks-Gunn J., Wallace I.F., et al. (1997). Results at age 8 years of early intervention for low-birth-weight premature infants. *Journal of the American Medical Association,* 277 :126– 132

McInnes, R. J., & Chambers, J. (2008). Infants admitted to neonatal units and interventions to improve breastfeeding outcomes: A systematic review 1990-2007. *Maternal & Child Nutrition, 4*(4), 235-263.

Merewood, A., Brooks, D., Bauchner, H., MacAuley, L., & Mehta, S. D. (October 2006). Maternal birthplace and breastfeeding initiation among term and preterm infants: A statewide assessment for Massachusetts. *Pediatrics, 118*(4), e1048-e1054.

Merewood, A., Philipp, B. L., Chawla, N., & Cimo, S. (2003). The baby-friendly hospital initiative increases breastfeeding rates in a US neonatal intensive care unit. *Journal of Human Lactation, 19*(2), 166-171.

Merten, S., Dratva, J., & Ackermann-Liebrich, U. (2005). Do baby-friendly hospitals influence breastfeeding duration on a national level? *Pediatrics, 116*(5), e702-e708.

Moore, T., Hanson, C., & Anderson-Berry, A. (2011) Colonization of the Gastrointestinal Tract in Neonates. *Infant, Child and Adolescent Nutrition*, 3(5), 291-294

Mossialos, E., Allin, S., Karras, K., & Davaki, K. (June 2005). An investigation of caesarean sections in three greek hospitals. *The European Journal of Public Health, 15*(3), 288-295.

Nyqvist, Kirstin H., (1997). Successful breast feeding in spite of early mother-baby separation for neonatal care. *Midwifery*, 13(1), 24-34

Örtenstrand, A., Westrup, B., Broström, E. B., Sarman, I., Åkerström, S., Brune, T., et al. (2010). The stockholm neonatal family centered care study: Effects on length of stay and infant morbidity. *Pediatrics*

Rogers, A.E. (2004). “Work Hour Regulation in Safety-Sensitive Industries,” in Keeping Patients Safe: Transforming the Work Environment of Nurses, ed. A. National Academies Press, 314-358

Rojas M.A., Kaplan M., Quevedo M., Sherwonit E., Foster L.B., Ehrenkranz R.A., & Mayes L. (2003). Somatic growth of preterm infants during skin-to-skin care versus traditional holding: a randomized, controlled trial. *Journal od Developmental and Behavioral Pediatrics*, 24(3), 163-168

Savona, V., Zanardo, V., Cadamuro, C., Cavallin, F., & Trevisanuto, D. (2010). Effects of elective cesarean section on lactogenesis: 438. *Pediatric Research,*

Scott, S., & Duncan, C. J. (1999). Malnutrition, pregnancy, and infant mortality: A biometric model. Journal of Interdisciplinary History, 30(1), pp. 37-60.

Stein, R. E. K., Siegel, M. J., & Bauman, L. J. (July 2006). Are children of moderately low birth weight at increased risk for poor health? A new look at an old question. *Pediatrics, 118*(1), 217-223.

Stephansson O., Dickman P.W., Johansson A.L., Kieler H., & Cnattingius S. (2000). Time of birth and risk of intrapartum and early neonatal death. *Epidemiology*, 14(2), 218-222

Stock, J. H., & Trebbi, F. (2003). Retrospectives: Who invented instrumental variable regression? [Abstract]. *The Journal of Economic Perspectives,* 17(3) 177-194.

Tollånes, M. C., Thompson, J. M. D., Daltveit, A. K., & Irgens, L. M. (2007). Cesarean section and maternal education; secular trends in Norway, 1967–2004. *Acta Obstet Gynecol Scand,* 86(7), 840-848.

Vieira, T., Vieira, G., Giugliani, E., Mendes, C., Martins, C., & Silva, L. (2010). Determinants of breastfeeding initiation within the first hour of life in a Brazilian population: cross-sectional study. *BMC Public Health, 10, 760.*

Vohr, B. R., Poindexter, B. B., Dusick, A. M., McKinley, L. T., Higgins, R. D., Langer, J. C., et al.(October 2007). Persistent beneficial effects of breast milk ingested in the neonatal intensive care unit on outcomes of extremely low birth weight infants at 30 months of age. *Pediatrics, 120*(4), e953

Whetsell, Jennifer F. (2003). Changing the Law, Changing the Culture: Rethinking the Sleepy Resident Problem. *Annals of Health Law*, 12(1), 23-73