The Implications of Breastfeeding for Maternal Time Use, Sleep, and Economic Value

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Abstract

Breastfeeding is widely endorsed by the medical community and societal norms as a critical practice for infant health and development, and broadly adopted worldwide. Although breastfeeding is a long-standing practice, it is often conducted in private in modern societies, and little is known about its implications for the individual producing the milk, hereafter referred to as the "mother". Time-intensive caregiving activities, such as milk production, are believed to influence maternal well-being and productivity, yet systematic, data-driven evidence on these impacts remains scarce. We address this gap by collecting high-frequency smartphone data from millions of milk production events, such as breastfeeding and pumping. Using this data, we metricize the time mothers spend on milk production during the first year after childbirth. We show a wide variation in the time spent on milk production across child days, with an interquartile range spanning 90 to 186 minutes. Milk production meaningfully impacts mothers' access to uninterrupted focus time and sleep, with possible implications for maternal well-being and productivity. We estimate that the economic value of the time spent on milk production in the first year after childbirth falls within the interquartile range of $4938 to $9398. We estimate that switching from to bottle feeding and outsourcing part of the activity can lead to time savings of 32% for mothers. By systematically measuring this "invisible labor," our study offers a more comprehensive understanding of the implications of breastfeeding, which inform policy interventions, workplace accommodations, and household decision-making to promote maternal well-being and economic opportunities.

1 Introduction

Breastfeeding is as old as humankind (Austin et al., 2013; Joannes-Boyau et al., 2019) and continues to be widely adopted and encouraged, whether directly at the breast or via expression). International bodies like the World Health Organization (WHO, 2024) and national associations like the American Academy of Pediatrics (AAP, 2022) recommend exclusive breastfeeding for the first six months of an infant's life, after which complementary foods can be introduced. The AAP further advises breastfeeding for the first two years of a child's life or longer (AAP, 2022). It is estimated that the rate of exclusive breastfeeding in the first six months of life reached 48% globally in 2023. Further, there is heterogeneity in these rates, with countries like Norway and Sweden at 2% and 13%, measured in 2019 and 2017, and the U.S. at 25%, measured in 2022.

While extensive research has focused on the biological consequences of breastfeeding for infants, its impact on birthing parents, hereafter referred to as "mothers," has received far less attention (USDA, 2019). Little is known about how this practice shapes mothers' time use—that is, the overall time required for milk production, disruptions to sleep, availability of focus time, and the economic value of this time. Some work has relied on approximations or small-scale surveys (Graham & Pearson, 2022; Rosenberg, 2022) to shed light on this form of "invisible labor", which unilaterally affects mothers.

Understanding how breastfeeding shapes mothers' time use–specifically, the availability of time–is important because time is a finite resource influencing maternal well-being, economic opportunities, and family dynamics. This is particularly relevant for efforts to reduce the risk of postpartum depression, improve female labor market integration, and address the motherhood wage penalty. Failing to account for the time required for breastfeeding may prevent the development of policies and workplace accommodations, such as extended parental leave and flexible work arrangements, and hinder mothers and families from establishing effective routines and schedules. By systematically quantifying the temporal demands of breastfeeding, researchers, policymakers, organizations, and families can gain a more comprehensive understanding of breastfeeding's implications and implement data-driven strategies to better support mothers.

In this article, we use large-scale smartphone data on millions of milk production events to shed light on the implications of breastfeeding and breast-pumping for maternal time use. In the first

90 days, the average mother in our data spends 149 minutes per day on milk production (median 130 minutes), has one (1) uninterrupted three-hour period per day (no four-hour or longer period), and two nighttime disruptions. We trace the evolution of these patterns over the first year after childbirth. The economic value of time (VOT) in the first year, using a VOT estimate of $15.93/hr, is $7736 on average (median $6850), and goes up to $23,895 (for mothers who spend 1,500 hours). We find that by switching to bottle-feeding and dividing the task with their partner, using a 71-29 split, the mother can save 35% of their original time.

Studying the time use implications of the decision to feed infants with breastmilk contributes to this existing literature on gender gaps. In particular, it contributes to the growing set of studies on disparities in labor market outcomes (Goldin and Katz, 2002; Rippeyoung and Noonan, 2012) and mental health (Escribà-Agüir & Artazcoz, 2010; McCardel et al., 2022) following childbirth. More broadly, this study expands efforts to use high-frequency to shed light on "hidden labor" and its role in shaping inequality (Babcock et al., 2017; Gewin, 2022). We also build on work in economics, which emphasizes the importance of opportunity costs and the value of time (Goldszmidt et al., 2020), viewing time as both an investment and a consumption good.

2 Quantifying the Hidden Labor of Breastfeeding Using Smartphone Data

By utilizing large-scale, high-frequency smartphone data, we overcome the limitations of survey methods, which typically involve smaller samples and are susceptible to response biases. Our data comes from BabyConnect, an app that allows parents to track the time spent on feeding-related activities. It spans 203660177 feedings from 247222 anonymized infants between 2012 and 2022. Our analyses focus on the time spent nursing (i.e., feeding from the breast), expressing (often referred to as "pumping" breastmilk), and bottle feeding (including both expressed breastmilk and formula). We define "milk production" activities as either nursing or expressing, and "feeding" activities as nursing, expressing, or bottle-feeding. We further define the child-day level as daily observations recorded for each child based on their age in days.

Our study concentrates on the first year of life, excluding the initial two weeks after birth for data quality reasons. We exclude entries with implausible durations, defined as either being less

than 1 minute or longer than 12 hours, as these suggest input errors. Furthermore, when users log an activity without recording the duration—most commonly for bottle-feeding—we impute the duration based on the activity and child's age. Since our analysis is primarily conducted at the child-day level, there is a potential concern that activity recording is incomplete for some users on some days. To ensure that we consider a sample for which recording is plausibly thorough, we only include child-days where users reported at least one daytime feeding and where the milk production activities recorded are at or above the 20th percentile for that age. For full details on sample restrictions and missing data imputation, see the appendix.

3 Milk Production Duration, Frequency, and Implications for Focus Time and Sleep

Figure 1(a) shows distribution of time spent on milk production activities in a day (defined as a 24-hour period) during the first 90 days. Averaging over each child-day in our sample, we find mothers spend an average of 149 minutes per child-day on milk production activities. Notably, % of child-days involve mothers spending more than 3 hours in a day, which is equivalent to over half of a standard workday when aggregated to a seven-day week.

Timing of production events matters, notably maintaining frequent and consistent milk production is necessary to sustain milk supply and prevent physical issues, including unwanted leakage and pain caused by breast engorgement, plugged ducts, or mastitis. For nursing mothers, infants' demand for milk further limits flexibility. To characterize the daily frequency of disruptions associated with milk production activities, we analyze the number of unique milk production events. Note that here and below, we ignore bottle feeding activities, meaning that these are lower bound estimates. On average, mothers engage in 8 distinct milk production events per day (Figure 1(b)).

Next, we examine the number of continuous time periods throughout the day (6am to 10pm) that are not interrupted by milk production activities. This is important as tasks unrelated to milk production can vary substantially in duration. For example, tasks like responding to emails or washing dishes may take only half an hour, while more complex tasks critical for many jobs, such as writing, reviewing documents, or conducting analyses, require longer uninterrupted periods. We find that, on average, mothers have 11 uninterrupted time periods of at least one hour, and 0

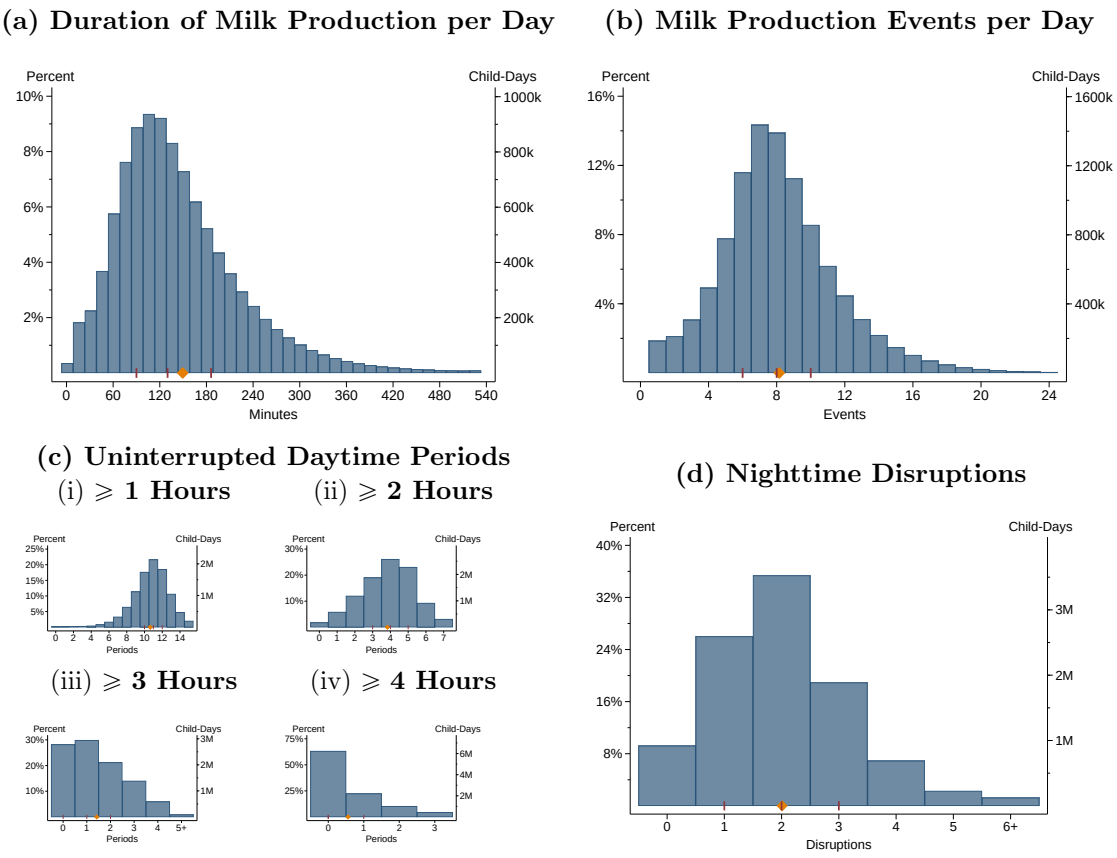


Figure 1: Milk Production

Notes. ◆ denotes the mean, and | denotes the 25th, 50th, and 75th percentiles. Day is defined as a 24-hour day. Daytime is defined as being from 6am to 10pm. Nighttime is defined as being from 10pm to 6am. The age range of this sample is between 15 days and 84 days (12 weeks). "k" in panels (a) and (b) refers to thousand (e.g., 700k means 700,000). "M" in panels (c) and (d) refers to million (e.g., 3M means 3,000,000).

periods of at least four uninterrupted hours a day (Figure 1(c)).

Finally, we examine the number of nighttime (10pm to 6am) interruptions that are linked to milk production activities (Figure 1(d)). Interruptions during that time matter as they likely affect sleep, which is shown to be important for human well-being and performance. We find that on average, mothers face 2 interruptions at night, with the 95th percentile experiencing 4 or more interruptions.

4 Variation Across the First Year

The duration of daily milk production may vary over time, as solid foods get introduced (generally recommended no earlier than 4 months of age), as mother and infant become more efficient, and as some mothers re-enter the labor force. Figure 2 examines trends in milk production across three age cohorts: 15-90 days (as shown in the prior section), 91-180 days, and 181-360 days.

We observe a slight decline in the duration of milk production activities as a child ages. The total time spent in a day drops from an average of 149 minutes in the 15-90 age cohort to 83 minutes in the 181-360 day cohort (Figure 2(a)).

Further, there are significant differences in the number of daily events. Figure 2(b) shows that the median total number of milk production events falls by nearly 50 percent, from 8.2 events for children in the 15-90-day age cohort to 5.3 events for those in the 181-360-day age cohort.

We observe a substantial increase in the number of longer uninterrupted time periods during the day (Figure 2(c)). For example, as children age from 15-90 days to 181-360 days, the number of uninterrupted periods lasting at least three hours doubles (from one to two). A similar increase occurs for the number of uninterrupted periods lasting at least four hours.[1]

A similar trend occurs at night (Figure 2(d)). The number of nighttime disruptions due to milk production activities falls by half, from two interruptions for mothers of children aged 15-90 days to just one for those with children aged 181-360 days.

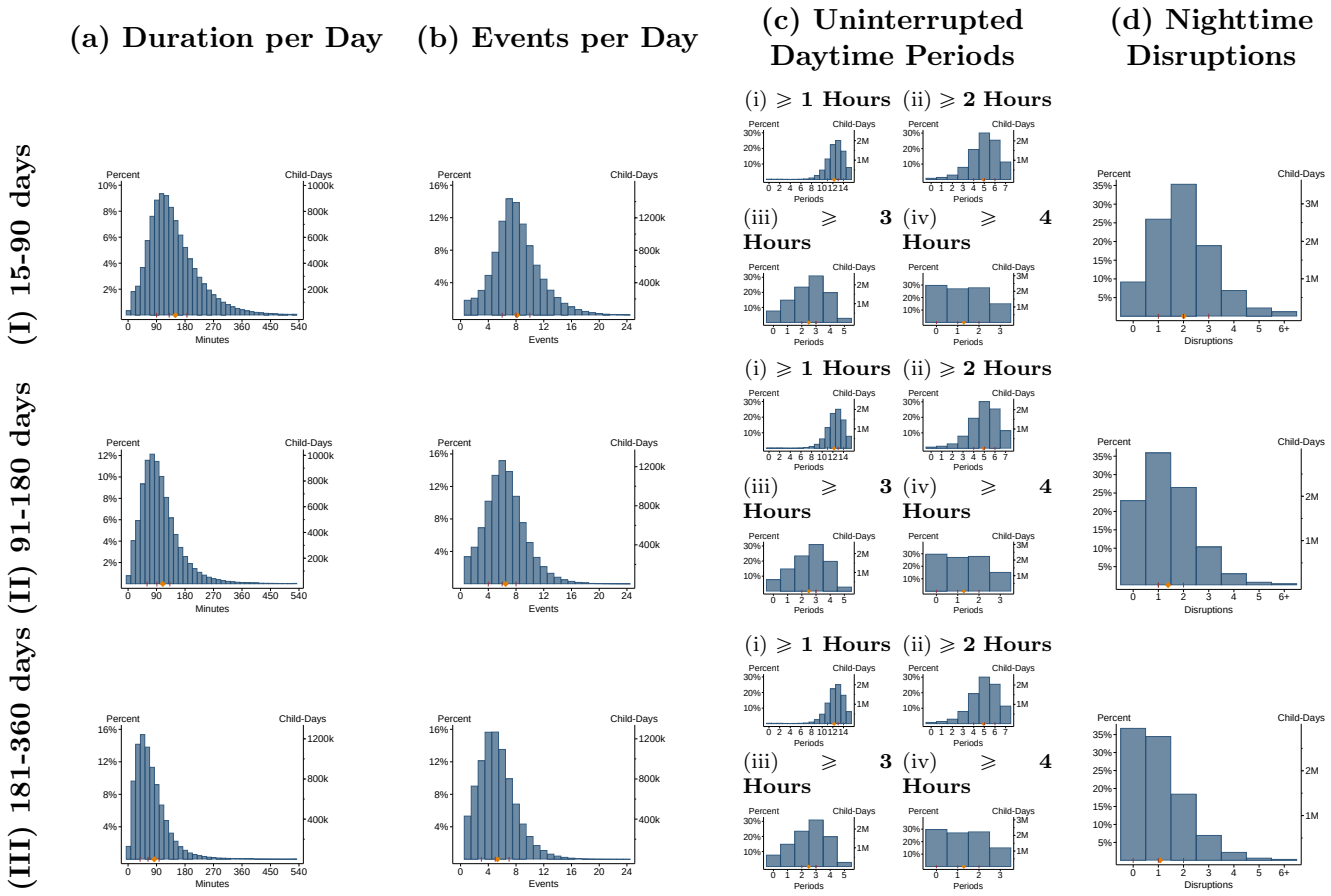
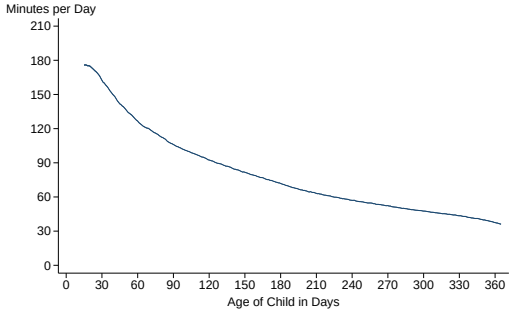


Figure 2: Milk Production by Age Cohort

Notes. ◆ denotes the mean, and | denotes the 25th, 50th, and 75th percentiles. Daytime is defined as being from 6am to 10pm. Nighttime is defined as being from 10pm to 6am. "k" in panels (a) and (b) refers to thousand (e.g., 700k means 700,000). "M" in panels (c) and (d) refers to million (e.g., 3M means 3,000,000).

(a) Estimated Relationship Between Child Age and Duration



(b) Total Duration and Economic Value of Time

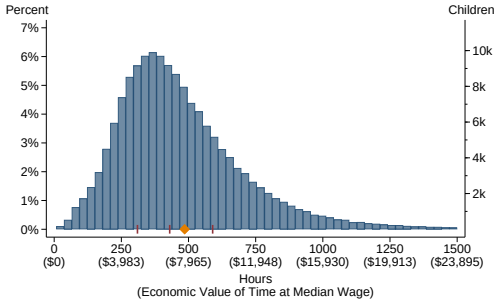


Figure 3: Milk Production in the First Year

Notes. ◆ denotes the mean, and | denotes the 25th, 50th, and 75th percentiles. Panel (a) shows the estimates from a regression of daily milk production duration on child age controlling for child-level fixed effects. 95% confidence intervals are included but may be too small to be seen. Panel (b) shows a histogram of the total duration and the economic value of time (VOT) associated with milk production in the child's first year. The VOT ($15.93/hr) uses the median wage of working women aged 25-34, taken from table 8 of BLS, 2020. "k" in panels (a) and (b) refers to thousand (e.g., 700k means 700,000). "M" in panels (c) and (d) refers to million (e.g., 3M means 3,000,000).

5 Economic Cost of Milk Production in the First Year

Understanding the economic cost of time is important for understanding labor involved in breastfeeding. Time-intensive caregiving activities, such as milk production, significantly impact a mother's ability to maintain uninterrupted focus time and sleep, which can influence her overall quality of life and economic opportunities. The value of time (VOT), a well-established economic measure, provides a framework for quantifying the opportunity costs associated with these activities. We next leverage VOT estimates from the literature to quantify its economic impact.

To do this, we first estimate a regression model of milk production (i.e., nursing or expression) over a child's first year. Importantly, this model includes child fixed effects, which allows the relationship to be estimated using only within-child variation in how much time in hours is spent on milk production for the same child as she ages. In addition to showing the time in hours, we also show the value of this time in dollars based on a $15.93/hr VOT derived from the BLS estimate of the median wage of working women aged 25-34.

Figure 3(a) depicts this average relationship estimated from the model. At the start of child's life, mothers spend an average of 3 hours producing milk, and this value gradually decreases as the child gets older, averaging 1.4 in month 5 and 38 minutes at the end of the first year. This trend

[1]Note, however, that this only considers milk production and not other child-related activities.

likely reflects a number of factors including an increase in mothers' efficiency in milk production post-partum, some attrition to formula instead of breastmilk, and a shift towards solid food as the child ages.

Figure 3(b) depicts the model-implied distribution of total time mothers spend on milk production during the first year of the child. The median associated value is approximately $6850, where the interquartile range spans from $4938 to $9398 and where more than 5% of mothers have values exceeding $15134.

6 Time Savings From Switching to bottle-feeding

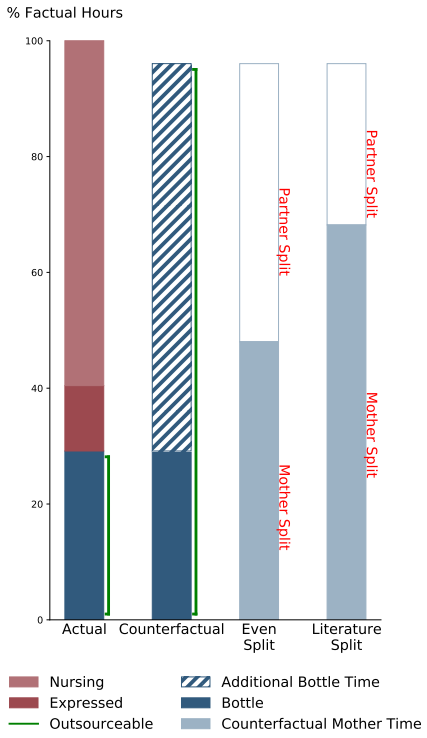
Bottle-feeding is inherently an outsourceable activity and can therefore be tasked to a partner or other caregiver, representing even more time saved for the mother. We conduct a counterfactual analysis to examine the time saved from shifting the child's feeding modality from a mix of nursing and bottle-feeding to exclusively bottle-feeding. [2]

Figure 4(a), we plot a stacked bar graph that describes the time allocation of feeding activities in the first 360 days across four different scenarios. The y-axis indicates the relative percent of factual hours (i.e., actual hours spent on feeding). The first bar on the left is the factual time allocation towards feeding activities. The second bar is the counterfactual time allocation towards feeding, assuming the scenario where the mother exclusively switches to bottle-feeding. The third bar and fourth bar represent different theoretical allocations of outsourceable time between the mother (shaded in blue) and their partner (no shading), where the third bar is an even-split between a mother and their partner, and the fourth bar uses a split of 71% mother and 29% father. This split is computed using the basic childcare time allocation that prior work has found using survey data (2003-2006) of individuals between ages 21 and 55 with at least one child under age 18 (Guryan et al., 2008).

In the first bar, the actual time allocation is 29% for bottle-feeding, 11% for expressed, and the remaining 60% for nursing. In the second bar, the counterfactual of exclusively using bottle-feeding

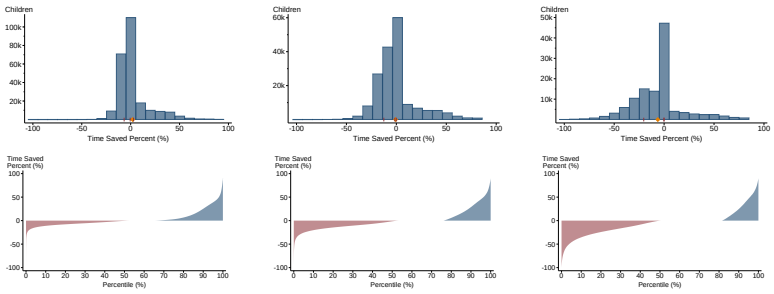
[2] In the counterfactual setting, we assume a complete switch to bottle-feeding, meaning the mother ceases all nursing. As a result, due to physiological changes, lactation would naturally stop over time. Consequently, in our counterfactual, we set expressed milk time to zero, as the mother would no longer be producing milk. This scenario does not account for any transitional phases between breastfeeding and bottle-feeding, nor does it consider partial bottle-feeding where nursing is reduced but not entirely eliminated.

(a) Counterfactual Conversion of Feeding Times to Fully Outsourceable Activities



(b) Distribution of Feeding Time Difference After Converting to Bottle Activities

(I) 10-90 days **(II) 91-180 days** **(III) 181-360 days**



(c) Distribution of Feeding Time Spent on Non-Outsourceable Milk Production

(I) 10-90 days **(II) 91-180 days** **(III) 181-360 days**

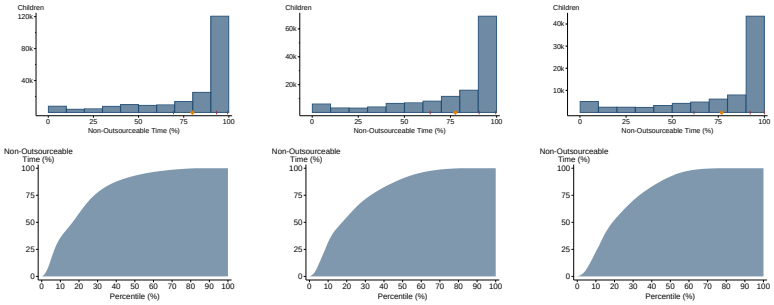


Figure 4: Time Adjustments to Switching to Bottle Feeding

Notes. ◆ denotes the mean, and | denotes the 25th, 50th, and 75th percentiles. Subfigure (a) contrasts the factual time expenditure for nursing, expressed, and bottle within the first year to the counterfactual time expenditure when switching fully to bottle. The third and fourth bars are hypothetical examples, where time is split evenly (50-50) and based on the literature (71-29) between the mother and the partner. The 71% is computed using $7.69/(7.69 + 3.17) \sim 71\%$, using values from Guryan et al., 2008. (b) Time saved percent is calculated by taking the proportional difference in time after switching fully to bottle feeding. (c) Non-outsourceable time percent is calculated by taking the fraction of time on activities that could be outsourced. "k" in panels (b) and (c) refers to thousand (e.g., 60k means 60,000).

reduces total time spent to 96% of the original, with 4% of the original time saved. Additionally, the amount of outsourceable time (indicated by the green) increases substantially, from 29% of their factual time to 100% of their counterfactual time. In the third and fourth bars, which represent theoretical allocations, there is a significant time reduction for the mother. In the even split from the third bar and the 71-29 split from the fourth bar, the mother would respectively allocate 48% and 68% of their original time towards feeding.

Figure 4(b) shows the distribution of time saved for different age cohorts when switching to bottle-feeding. In particular, it focuses solely on the potential time conversion gains from switching from nursing to bottle-feeding rather than on gains from outsourcing. The top row of graphs are histograms of the time saved percent for each child in the respective age cohort, and the bottom row of graphs are time saved distributions across all children, arranged in increasing order of time saved with the x-axis indicating the percentile of children. The time saved percentage is defined as the relative difference between the observed feeding time and the estimated counterfactual feeding time, expressed as a proportion of the observed time. [3] For example, a positive time saved percentage of 50 means that switching to exclusive bottle-feeding is estimated to reduce feeding time by 50%. Note that the factual time consists of nursing, expressed, and bottle-feeding while the counterfactual is only comprised of bottle-feeding.

Looking at the children between ages of 10 days and 90 days in 4b.I, the median child is associated with 0% time saved from swapping to bottle-feeding. There is some variation, with the 10th percentile at -11% and the 90th percentile at 25%. Moving across age cohorts, we find that while the median time saved remains at 0%, the mean time saved percentage declines, beginning at 2.1% and dropping to -0.8% in the 91-180 day cohort and -6.3% in the 181-360 day cohort. This suggests that the potential for saving time by switching to exclusively bottle-feeding is largely concentrated in the earlier years. Regardless, much of the benefit of switching to bottle-feeding comes not from the time saved but rather from the outsourceable nature of bottle-feeding, which is explored in Figure 4(c).

Figure 4(c) describes the evolution of the amount of time spent on non-outsourceable milk production over the age cohorts, where non-outsourceable milk production events consist of nursing

[3] Time saved is visually bounded between –100% and 100%, where the 100% is a true bound but the –100% is arbitrary, i.e. in theory, if the time spent more than doubles, then the parent will experiences a time increase more than 100%.

and expression events. Similar to the structure of Figure 4b, the top row of graphs are histograms of non-outsourceable time for each child in the respective age cohort. The bottom row of graphs are cumulative distribution plots, where children are arranged in ascending order based on their non-outsourceable time percentage. [4] We observe that for the median mother, a large majority of their feeding time could be outsourced if they switch exclusively to bottle feeding. In particular, the mother of the median child in the youngest age cohort (10-90 days) spends more than 93% of time on activities that could be outsourced by switching exclusively to bottle-feeding. This holds similarly for older cohorts, at 91% and 92% for ages 91 to 180 days and ages 181 to 360 days, respectively. We also note that the distribution is relatively constant over the three age cohorts, with minimal variance in the first and third quartile. This suggests that the gains from outsourcing remain stable and high over the first year.

7 Conclusion

Our study provides a detailed analysis of the impact of milk production activities on maternal time use. Using smartphone data on millions of children feedings, we quantify the time commitment required of mothers in the first year after childhood, shedding light on a key aspect of parental labor that has largely been invisible.

Our findings reveal that the average mother spends 18462 minutes on milk production activities in the first year of childbirth. This time use results in an average of 0 periods of at least four uninterrupted hours a day and 2 nighttime disruptions over the first 12 weeks. Our analysis further shows that by switching to bottle-feeding, which can be more easily shared with other caregivers, significantly reduces the time burden on mothers. Currently, the average employer provides 12 weeks of maternity leave. Given that a mother with a child at 12 weeks experiences 7 milk production events per day, implementing such policies could be beneficial not merely for health and well-being, but also for economic productivity and gender equality.

More broadly, our findings offer valuable insights for public policies aiming to provide parental support. By detailing time usage for milk production activities, we can better understand their economic significance. As policymakers and organizations seek to develop policies to promote

[4] In this case, non-outsourceable time is bounded between 0 and 100%, where 100% means that all of the mother's time is going towards activities that are not-outsourceable.

parental and employee well-being, incorporating detailed, high-frequency time use data on time use should be an integral part of their decision making. This approach not only aids in understanding the demands placed on parents but also helps the creation of meaningful policies that can assist them.

Appendix A: Data Preparation

To prepare our analysis sample, we use a series of data restrictions. We remove any activities that have a reported duration of less than 1 minute or over 12 hours, which are assumed to be misreports. Additionally, to avoid capturing any child-days that are associated with non-breastmilk feeding, we remove any child-days with at least one formula bottle feeding event.

For any of the focal activities (i.e. bottle, expression, or nursing) with a missing duration, we impute these by first taking the winsorized values of the respective activity at the 99th percentile and then predicting using a linear regression. For expression and bottle events, the linear regression includes the interaction of child age (in days) and reported quantity (in milliliters), while for nursing events, the regression only includes child age.

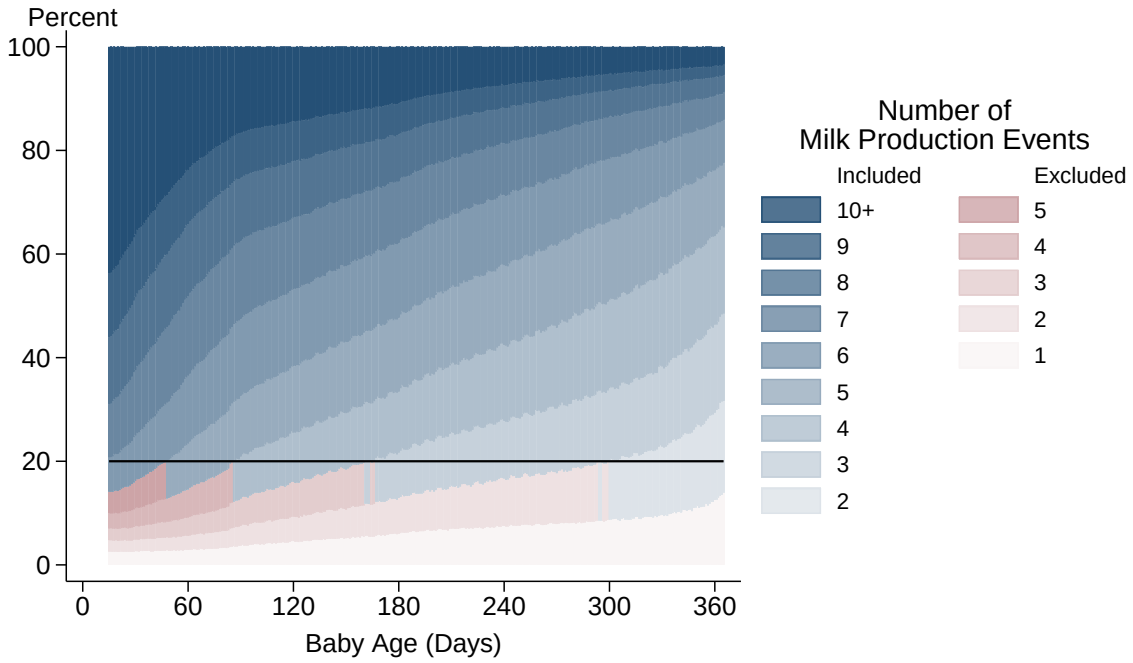


Figure 5: Milk Production Activity Count Percentile Graph

Notes. This graph displays for each age (in days), the percentile distribution of milk production events per day. For example, at the start point at 15-days of age, the median (50th percentile) child is associated with 9 milk-production events per day, and the 20th percentile corresponds to 6 milk-production events. The 20th percentile sample restriction therefore excludes those age-days that fall below the 20th percentile bin. Observe that this decreases with age, as it starts off with excluding 5 or less in the early baby ages, but then drops to 4 and so on. The black line represents the 20th percentile. Blue shades indicate groups that are included, while red shades indicate groups that are excluded.

We subsequently remove the bottom 20th percentile of children by number of events per day and require at least 1 feeding-related observation per daytime (defined as 8 AM to 8 PM). As mentioned, this is to ensure that each day in the sample is well-recorded. Moreover, this helps restrict to parents who are accurately recording the times in which activities are done, as all parents are expected to be feeding the baby during the daytime. See figure 5. This results in our main sample, which has approximately 203 million observations for ages between 2 weeks and 1 year.

In Figure 4, to conduct our counterfactual analyses, we prepare a separate data sample to estimate the conversion rate in time usage between nursing and bottle-feeding. This conversion rate is then applied to our main sample. To prepare the conversion rate sample, we apply a similar but different set of data restrictions. In particular, we (1) restrict to only nursing and bottle events, (2) allow for formula events, (3) drop any days that have missing bottle durations, (4) apply our 20th percentile restriction but to only bottle and nursing, and (5) remove the one observation per daytime requirement. When estimating the conversion rate, we restrict to ages between 15 and 360 days, and estimate the coefficient for the conversion rate between nursing vs. bottle on total logged time at the child-day level, controlling for day-of-week, age, recorded events, as well as child-age fixed effects. These coefficients are then used to predict the total feeding time per child-day if an individual were to shift completely from their factual nursing and bottle-feeding times to only bottle-feeding. These coefficients are also used to generate the model predicted factual duration at the actual bottle share. This allows us to estimate the difference in the model-predicted total time when an individual switches to exclusive bottle feeding. The counterfactual total time is then calculated as the sum of the original nursing time, the original bottle time, and the estimated difference. Since we assume expressed duration is zero in exclusive bottle feeding, expressed time is excluded in the counterfactual scenario.