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Mortality from Nestlé’s Marketing of Infant Formula in Low and Middle-Income Countries
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ABSTRACT

Infant formula use has been implicated in tens of millions of infant deaths in low and middle-income countries over the past several decades, but causal evidence of its link with mortality remains elusive. We combine birth record data from over 2.6 million infants across 38 countries in the Demographic and Health Surveys (DHS) with reconstructed historical data from annual investor reports on the timing of Nestlé entrance into infant formula country markets. Consistent with the hypothesis that formula mixed with unclean water could act as a disease vector, we find that infant mortality increased in households with unclean water sources by 19.4 per thousand births following Nestlé market entrance, but had no effect among other households. This rate is equivalent to a 27% increase in mortality in the population using unclean water and amounts to about 212,000 excess deaths per year at the peak of the Nestlé controversy in 1981.

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1 Introduction

Infant formula was first developed and patented by a German chemist in 1865 and marketed as a medically endorsed product ”closest to mother’s milk” (Stevens et al., 2009). The emergence of formula as a widespread breastmilk substitute occurred during the Industrial Revolution in response to the large number of women who left home to enter the labor market where breastfeeding was much more difficult.[1] Infant formula use rose steadily in subsequent decades, peaking during the post-World War II baby boom (Akhter, 1994). Most of the leading brands for infant formula were established by the 1920s with Nestlé as the market leader (Rollins et al., 2023).

In the 1960s, infant formula sales began to decline in high income countries due to lower birth rates and a growing belief in the positive health effects of breastfeeding (Stevens et al., 2009). In response, infant formula companies began to explore new markets in the developing world with aggressive marketing campaigns that depicted infant formula as scientific, modern, prestigious, and (falsely) nutritionally superior to breastmilk (Hicks, 1981). This strategy appears to have paid off, as sales of commercial milk formula grew from US$1.5 billion in 1978 to $55.6 in 2018 (Baker et al., 2023) and global sales are projected to increase by 9% per year through 2027 (WHO, 2018).

The ensuing introduction of infant formula into low- and middle-income country (LMIC) markets has since become one of the most notorious corporate controversies in history. Controversial marketing practices used by the large international formula producers, and Nestlé in particular, gave rise to sustained accusations of corporate malfeasance, with public health advocates attributing tens of millions of infant deaths to formula’s unsafe introduction (Joseph, 1981; WHO, 2009; Grant, 1983; Victora et al., 2016). These accu-

[1] The literature identifies a number of reasons as to why a mother may rationally choose to use infant formula instead of breastfeeding, including working outside the home, the perception of insufficient production of breast milk, the inability to pump breast milk at work, HIV/AIDS infection, lack of family support, depression, poverty, and other socio-cultural and structural factors (Balogun et al., 2016; Bazzano et al., 2017; Beasley and Amir, 2007).

sations largely focused on deceptive and unethical marketing practices that have distorted the benefits of infant formula and minimized the potential costs of mothers choosing infant formula over breastmilk (Stevens et al., 2009).

There are two primary channels through which formula could plausibly affect infant mortality. First, the increased use of infant formula could cause a decline in breastfeeding (Pérez-Escamilla et al., 2023), and there is a strong consensus in the medical community that the substitution of formula for breastmilk compromises a child's physical health and immune response (Victora et al., 2015). Based on the belief that breastfeeding leads to better child development outcomes,[2] the World Health Organization (WHO) recommends that infants be breastfed within the first hour of birth, exclusively breastfed for the first 4-6 months of life, and that they then receive breastmilk for up to two years of age (WHO, 2009).

Second, the public health literature has noted the risk from caregivers mixing infant formula powder with unclean water (Dobbing and Falkner, 1988), resulting in bacterial infection and diarrheal disease that increases the risk of infant mortality through sickness and dehydration (Pérez-Escamilla et al., 2023). Given the high prevalence of exposure to unclean water sources in LMICs, there are clear pathways connecting poor quality water with poor infant health outcomes (Marino, 2007; VanDerslice et al., 1994; Weisstaub and Uauy, 2012; Schuster et al., 2020). These problems may be elevated among caregivers with low literacy who may have difficulty understanding directions on packaging labels, putting infant lives at risk (Muller, 1975).

In this study, we provide new population-level evidence exploring these claims by estimating the plausibly casual effect of Nestlé's marketing of infant formula on infant mortality

[2] Much of the evidence to support this belief is based on cross-sectional correlations. Specifically, children who receive breastmilk instead of formula have lower all-cause mortality (Sankar et al., 2015), lower severity of diarrhea and respiratory infections (Horta et al., 2013), better cardiovascular health (Bernardo et al., 2013) and higher cognitive scores (Victora et al., 2015, 2016). These results are generally consistent with the few studies that use methods that more credibly control for potential selection bias, e.g., maternal fixed effects (Der et al., 2006; Evenhouse and Reilly, 2005) and plausible instrumental variables (Del Bono and Rabe, 2012; Baker and Milligan, 2008; Fitzsimons and Vera-Hernández, 2022).

in LMICs. We do so by assembling a dataset, described in section 3, with over 2.6 million infant births across 38 countries from the Demographic and Health Surveys (DHS), matching children's year of birth to data on the timing of Nestlé entrance into country infant formula markets collected from the Nestlé corporation's annual investor reports. Since Nestlé was the largest and typically the first international formula producer to enter LMIC markets during the 20$^{\text{th}}$ century (Dobbing and Falkner, 1988), its entry into a country's market can plausibly be inferred to represent a substantial increase in the availability of infant formula.

We estimate both difference-in-differences and event study models of the effect of Nestlé market presence on infant mortality. We use the Borusyak et al. (2024) imputation estimator that controls for potential biases introduced from differential treatment over time. We leverage the birth panel recall structure of the DHS to use maternal fixed effects.[3] Our empirical approach, then, is to compare the change in infant mortality between children born to the same mother before and after Nestlé market presence in treatment countries to the change in infant mortality over the same time period for mothers in control countries. Maternal fixed effects control for time-invariant characteristics of the mother, household, and location over the period between births; this period is relatively short with an average of 29 months between births.

We conduct separate analyses of the impact of infant formula availability on infant mortality for households that had access to clean versus unclean sources of water in order to identify the mechanisms by which the availability of formula likely caused infant mortality to increase. An increase in mortality among households in both samples would be consistent with reduced breastfeeding driving effects on infant mortality. On the other hand, if contaminated water is the primary risk, then mortality effects should be concentrated in households using unclean water, consistent with concerns that formula prepared with unclean water provides a vector for enteric diseases.

[3]Maternal fixed effects is a common approach to address exactly these issues and is used extensively in the early childhood human capital development literature. See Currie and Almond (2011) for a review of the use of maternal fixed effects to investigate human capital development before age 5.

Our results, reported im section 5, reveal marked increases in infant mortality following Nestlé's entrance into infant formula markets among households with unclean water sources, but none among households with clean water. This suggests that changes in breast feeding behavior related to the introduction of formula have little effect on infant mortality compared to the larger health risk posed by mixing unclean water with formula, in which case it acts as a deadly disease vector. We estimate that infant mortality increased by 19.4 infant deaths per year per 1000 live births among caregivers using unclean water sources in the five years following Nestlé exposure. This is equivalent to a 27% increase in the infant mortality rate for this population and amounts to about 212,000 infant deaths per year at the peak of the Nestlé controversy in 1981. We also find, as predicted by public health advocates, that the mortality effects were higher among less educated mothers than among higher educated mothers in the sample of households that used unclean water. Finally, we reject differential pre-intervention trends in infant mortality for both samples.

Identification rests in part on whether Nestlé market entrance can be considered plausibly exogenous to infant mortality, conditional on maternal fixed effects. Hence, the extent to which Nestlé made market entry decisions based on infant health is of central interest. In section 5.6.1, we investigate Nestlé's market strategy by first studying Nestlé annual investor reports (Nestlé, 2018), which contain extensive discussions of the company's market strategy. We reviewed sixty years of annual reports to identify the factors communicated to shareholders that influenced Nestlé decisions to enter specific infant formula markets. The narrative that emerged was that Nestlé strategy was to target countries based on the potential market size and profit potential. The reports regularly stated that specific market expansion decisions were driven by population size and disposable income. We found no mention of health or health care infrastructure or any other related factor. We then investigate the picture painted in the annual reports empirically by estimating Cox proportional hazards models of Nestlé entry into country infant formula markets using a 50 year panel of 171 countries. The results are consistent with the story painted in Nestlé's annual reports.

2 The Nestlé Infant Formula Controversy

By the early 1960s, Nestlé had come to regard LMICs as key to expanding infant formula sales in the face of waning markets in Europe and other high-income countries. For example, Nestlé annual reports from the early 1960s note the firm's growing market for infant formula in South Africa under the *Lactogen* brand name:

> "Increased sales of Lactogen reflect the growing awareness amongst African races of the need for improving the nutrition of young children." (**?**, 1961, p.10)

> "The native population is realizing more than ever the practical advantages and nutritional value of the milk specialties in the infant food range, which established new records over the past year." (**?**, 1962, p.14)

By the mid-1970s, public health activists began to warn of large numbers of "formula-induced" infant deaths in LMICs (Jelliffe, 1975).[4] Many in the public health community accused the infant formula firms of promoting formula to mothers in LMICs unlikely to have access to clean water sources and with limited technical understanding of nutrition, physiology, or mechanisms of disease transmission (Dobbing and Falkner, 1988). Likewise, concern arose over the decline in breast feeding associated with the introduction of infant formula across LMICs (Kent, 2015). Indeed there is evidence that the introduction of infant formula into a country's market was correlated with a substantial reduction in breastfeeding (see Figure 1). Latham (1977), for example, documents the dramatic decline in breastfeeding in Chile, where breastfeeding declined from 90% of all children in 1960 to only 10% by 1968 after the introduction of formula.

Nestlé emerged at the center of the controversy because the company was accused

[4] The beginning of the controversy over the marketing of infant formula in the developing world most likely began with the publication of Michael Muller's (1974) highly influential pamphlet *The Baby Killer: A War on Want Investigation into The Promotion and Sale of Powdered Baby Milks in The Third World*, which cited numerous abuses in the corporate marketing of infant formula in LMICs and even identified some of the channels through which substitution of infant formula for breastmilk could negatively impact infant health.

of unethical marketing practices (Dobbing and Falkner, 1988), and because it was an early entrant into LMIC markets and was by far the largest infant formula supplier worldwide, where at the time, Nestlé's market share was approximately 40% worldwide (Sethi, 1994). Nestlé was accused of providing free or low-cost supplies of infant formula in hospitals and maternity centers, often dispensed by "milk nurses" (saleswomen dressed in nurses uniforms) to encourage new mothers to use infant formula (Jelliffe, 1975; Gilly and Graham, 1988; Austin, 2008). Formula use among newborns increases the risk that mothers release prolactin-inhibiting hormones, which signal milk production to shut down, creating a future dependence on breastmilk substitutes (Latham, 1977).

By the 1960s, the company already viewed marketing of formula in hospitals as a strategic approach to encouraging adoption of infant formula, as seen in an excerpt from its 1969 annual report:

> "... some factors are more favorable such as the increased buying power in the developing countries, and the rising number of births in maternity hospitals where it is easier to reach mothers. This is due to the fact that the medical staff there is more likely to influence mothers with regard to the food most suitable for their babies." (**?**, 1969, p.16)

The infant formula industry has historically exploited and pathologized normal patterns of infant development in order to exacerbate parental insecurities about feeding, making parents feel like they needed to use formula in order to have a child who grows and develops appropriately (Pérez-Escamilla et al., 2023). The formula industry's marketing strategies have blocked and disrupted access to truthful information about the benefits and costs of formula, and they have a history of systematically misrepresenting facts about breastfeeding (Rollins et al., 2023).

Infant formula is classified as a food product, meaning the industry is not required to justify claims in the same way as they would be for a medical intervention. As such, images, labels, and advertisements have featured unsubstantiated claims about the ability of infant formula to alleviate fussiness, improve infant sleep, or increase a baby's intelligence and improve school performance (Rollins et al., 2023). Formula companies have also systematically enlisted midwives, doctors, nurses and other trusted health professionals as key influencers and experts to promote infant formula. In these ways, the formula industry has distorted the costs and benefits of infant feeding choices in order to grow and sustain markets for commercial infant formula (Baker et al., 2023).

The increasing attention paid to Nestlé's marketing practices led to an international boycott of Nestlé organized by INFACT (Infant Formula Action Committee) starting in 1977 (Akhter, 1994). Pressure from the public health community and intense media coverage prompted U.S. Senate hearings in May 1978 chaired by Senator Edward Kennedy. During those hearings, Senator Kennedy questioned Nestlé's CEO over their corporate responsibility for the consequences of mothers mixing formula with unclean water and the CEO responded that Nestlé had no repsonsibiity.[5] Senate testimony included a claim by Derrick Jelliffe from UCLA that "10 million infant deaths per year" could be directly attributed to the introduction of infant formula, a figure also given in an academic publication (Jelliffe, 1975) and in press interviews (e.g. Chicago Tribune, 4/25/1981). Other estimates of infant deaths resulting from the marketing of infant formula were lower, yet still alarmingly high. Stephen Joseph of USAID testified that up to 1 million infant deaths per year could be attributed to contaminated infant formula (Joseph, 1981), and UNICEF director James Grant estimated that 1 million infant lives could be saved annually through "controlling irresponsible promotion and marketing of artificial infant formulas" and assuring mothers that "breastfeeding is best" (Grant, 1983).

More recent estimates of infant deaths attributed to the substitution of infant formula for traditional breastfeeding remain very high. An official 2007 estimate by UNICEF

[5]See Senator video of Kennedy questioning a Nestlé executive during the 1978 Senate hearings on global sales of infant formula: https://www.youtube.com/watch?v=ME6U-zIv6SA.

contended that 1.3 million children's lives could be saved by curtailing the marketing of infant formula and other breastmilk substitutes (UNICEF USA, 2008). In 2009, the WHO estimated this figure at 1.4 million lives saved (WHO, 2009), with more recent official WHO publication putting this estimate at 820,200 lives saved (Victora et al., 2016), and estimated worldwide economic losses from shortened breastfeeding to $302 billion (Rollins et al., 2016). These infant mortality figures, like earlier estimates, are based on a simulated modeling approach rather than on causal estimates. Rigorous causal evidence has not yet been able to attribute specific numbers of infant deaths to the infant formula industry, or to any particular infant formula firm.

Growing public concern prompted a 1979 meeting hosted jointly by the World Health Organization and UNICEF. Attending the meeting were government representatives, health organizations, activist groups, and the formula companies. The result was the creation of an international code of conduct for marketing infant formula, enacted in 1981. In 1984, after several years of openly refusing to meet the standards laid out in the code, Nestlé finally agreed to alter its marketing practices to comply with rules established in the code. As a result, the boycott was temporarily lifted.

This commitment notwithstanding, concerns over unethical marketing practices remained. Evidence soon emerged that Nestlé was continuing to provide health clinics across the developing world with free and low-cost supplies of formula, an accusation that was upheld by the 43rd World Health Assembly. As a result, a number of activist groups including Baby Milk Action and IBFAN (International Baby Food Action Network) called for a reinstatement of the boycott in 1988, and the boycott continues today.

Violations of acceptable marketing practices have continued to be revealed over subsequent decades. In 2007, an article in *The Guardian* (Moorhead, 2007) reported violations in Nestlé's infant formula marketing in Bangladesh. A 2013 Save the Children report found evidence of marketing malpractices by infant formula companies, specifically requesting Nestlé and the French conglomerate Danone to recommit marketing practices to compliance with the WHO infant formula code (Mason et al., 2013). Nestlé's own report on compliance with the WHO code found 107 violations of the code in its global operations (Nestlé Corporation, 2019). In 2019, an investigation into Nestlé's marketing of infant formula by the Changing Markets Foundation and the Globalization Monitor found that even after commitments to reform, the company had continued with marketing initiatives in LMICs that compared its infant formula products favorably with breastmilk, an activity that is prohibited by the WHO infant formula marketing code (Changing Markets Foundation, 2019).

In 2008, Nestlé acquired Gerber and re-branded its infant formula product under the widely trusted Gerber name. While its market share today is substantially smaller than in the past, Nestlé remains the largest supplier of infant formula worldwide at a 22% market share followed by Danone (12%), Abbott (7%), and Meade (5%) (Affertsholt and Pedersen, 2017). Nestlé continues to be a lightning rod in the public discourse, however, as they are the leading global infant formula supplier and often first movers into new country markets.

3 Data

We conduct three sets of analysis. The first is the impact of Nestlé entry into a country's infant formula market on infant mortality. This uses information from Nestlé's annual corporate reports to identity the countries and years of Nestlé marketing, the Demographic and Health surveys for information on births and infant deaths plus co-variates. The second set of analyses examines the country-level correlates of Nestlé market entry using data from the World Bank, and the third looks at association of Nestlé marketing and infant formula use and breastfeeding at the country level. We describe each of these data sets in detail below.

3.1 Nestlé Infant Formula Market Entry

A central contribution of this paper is the creation of a historical dataset capturing Nestlé's international market activity over time. We construct a country-by-year panel of Nestlé's presence in country infant formula markets by referring to Nestlé's public Annual Reports to investors for the years 1966 through 2018.[6] Annual data on Nestlé's infant formula production and import activities were provided consistently by country in the Annual Reports from at least 1966 onward, with a varyingly titled section describing international market activity and factory locations by country;[7] an example table from an Annual Report is shown in Figure A1. Nestlé consistently reported several key market segments in each report, and further divided those market segments into imports, local production, or both, though in nearly all cases imports precede local production. We are thus able to track each country's first appearance across market segments over time and construct a variable identifying the first year in which a country registers Nestlé market presence in the market segment capturing baby formula.[8]

3.2 Demographic and Health Surveys

Household data on infant health are taken from the Demographic and Health Surveys (DHS). The DHS are nationally and regionally representative surveys of women between the ages of 15 and 49, covering a large sample of LMICs over time. The DHS have the advantage of asking many of the same questions in the same or similar ways across countries over time.

[6] We obtained annual reports for years 2000-2018 from Nestlé's investor relations website (`http://www.Nestlé.com/investors/publications`), and physical copies of Annual Reports for 1966 (the earliest available) through 1999 via inter-library loan.

[7] Data on the timing of market entry were taken from the section describing international operations in each report titled, respectively: "Manufacturing and Distribution of Products" (1966), "Manufacturing and Selling of Products" (1967-1972), "Manufacture / sales" (1973-1974), "Manufacture and Sale of Products" (1976-2003), "People, products, places" (2004), "Geographic data: people, products, sales" (2005), "Geographic data: people and factories" (2006), "Geographic data: people, factories and sales" (2007-11), "Geographic data: factories" (2012-2014), and "Factories" (2015-2018).

[8] This category was labeled as "Dietetic milk foods" prior to 1985, explicitly as "Infant formulae" from 1985-1992, and "Milk products and dietetics" from 1993-1994, "Milk Products Dietetics and Ice Cream" 1995-1996, and "Milk products, nutrition and ice cream" 1997-2012, "Milk products, Ice cream, Nutrition and Health Care" in 2013, and "Nutrition and Health Science" 2014-2018.

3.2.1 Infant Mortality

The DHS include maternal recall data about all births including date of birth as well as age at death if the child died, allowing us to construct a mother-level annual panel of infant births and deaths. We designate any death of a child age 12 months or younger as infant mortality and rescale the variable to deaths per thousand live births in order to yield rate-comparable estimates. All births at least a year before the survey are eligible to be included in the sample.

The maternal birth (and death) recall history forms our panel data. Since we will include maternal fixed effects in the analysis, the sample in treatment countries will include mothers who have births both before and after Nestlé's entrance in their country's market. The DHS surveys in the treatment group therefore needs to have been administered after Nestlé entry to obtain births both before and after Nestlé entrance for each mother.

3.2.2 Water Quality

The DHS includes questions on the quality of household water sources, typically coded as country-specific strings that mainly correspond to the categories and types of standardized international health organizations. We use these questions to construct an easily interpretable and cross-country comparable definition of clean versus unclean water based on the joint WHO/UNICEF definitions of "Improved" and "Unimproved" water sources UNICEF-WHO (2006). "Improved"/clean water sources are those defined as coming from piped water, pub taps or standpipes, tubewells, protected wells and springs, or rainwater. "Unimproved"/unclean water sources include unprotected wells and springs, water transported by tanker or cart, and surface water. We assign each water source in the DHS to one or the other category based on this rubric, and default to unimproved in the small number of cases where multiple water sources are listed but at least one is unimproved.

Water source quality information is collected at the time of the DHS survey. However, questions on infant mortality are retrospective and apply to all births of mothers. We assign the water source at the time of the survey to all of these retrospective births. We discuss the potential bias from the retrospective assignment of water quality status to previous birth outcomes later in Section 5.6.2 as part of the discussion on threats to identification.

3.2.3 Other DHS Characteristics

We use several other relevant variables as controls in the mortality analyses; specifically children's basic demographic characteristics (sex, birth order, birth year), and mother's education. Children's demographic characteristics are collected for each birth. We also use mother's education measured as completed primary school over which we estimate split samples, but is subsumed with the use of mother fixed effects.

3.2.4 Breastfeeding and Other Infant Health Outcomes

The DHS collects information on breastfeeding, infant health (i.e. illness symptoms and anhtroprometrics) and, in a few countries, infant formula use. These data are typically only collected on the youngest living child. Since this youngest child was born post-Nestlé entry, we have no formula or breastfeeding data for pre-Nestlé births in treatment countries and cannot construct birth panels pre- and post-entry for these outcomes. Moreover, the data are not collected for non-living children, creating a selected sample. As such, we are unable analyze the impact of Nestlé market entry on these outcomes.

3.2.5 Sample of Countries

We combine our historical data on Nestlé's country-level market presence with the universe of DHS birth data to identify suitable treatment and control countries.

Treatment Countries. We first identify all DHS countries in which Nestlé was either importing or locally producing goods in the infant formula product category between 1966 and 2018. In nearly all cases, imports of a good arrive first, with local production then occurring in a subset of countries after imports are established. We exclude several countries in which Nestlé infant formula was already being marketed at the start of our observation period in 1966. We then exclude countries that did not have a DHS survey after Nestlé entry but less than five years after in order to have births of sufficient sample size by the same mother before and after Nestlé market entrance.

Control Countries. We limited our set of potential control countries to those with DHS data from the same regions as our treatment countries (sub-Saharan Africa, Middle-East/North Africa, Asia, and Latin America). Then we chose the subset of these countries in each region for whom the years of DHS data collection overlapped with the time period of Nestlé entry into treatment countries.

Analysis Sample. Our final sample is comprised of 18 Nestlé treatment countries and 20 control countries, for a total sample of 2,622,663 births in those 38 countries. The treatment countries along with the year in which Nestlé entered their respective markets and the control countries are presented in Tables 1 and 2, respectively. Overall, treatment and control countries have similar average prevalence of unimproved/unclean water source and low maternal education, with control countries having similar if slightly elevated infant mortality rates (Table 1 and Table 2).

3.3 World Bank Development Indicators.

In a separate analysis of country-level correlates of Nestlé market entry, we use macroeconomic data from the World Bank Development Indicators for the universe of LMIC countries as defined by the World Bank.[9] The indicators include annual Gross Domestic Product (GDP) per capita, population, birth rate, and infant mortality rate data, as well as the cross-sectional Ease of Business score.

[9]World Development Indicators. Washington, D.C.: The World Bank. https://data.worldbank.org/indicator/

3.4 UNICEF Global database on Infant and Young Child Feeding.

In a separate analysis to assess whether Nestlé market entry increased formula use and/or reduced breastfeeding, we incorporate data from the UNICEF Global database on Infant and Young Child Feeding,[10] which provides standardized country level population estimates of various infant feeding behaviors starting in 1998. We take the first observation for each country in the UNICEF data and match it to the corresponding year it is observed in the Nestlé formula panel data.

4 Methods

Our research uses a difference-in-differences design with staggered adoption of treatment, exploiting Nestlé's entry into different country markets over time as a source of variation in the availability of infant formula. We follow the now-standard practice of correcting for differential weighting of average treatment effects in panel data with staggered treatment[11] by implementing the general difference-in-differences imputation estimator of Borusyak et al. (2024).

4.1 Identification.

We estimate separate models for households with access to clean and unclean water sources in order to identify the mechanisms by which formula can plausibly drive an increase in infant mortality. An increase in infant mortality among all households without respect to clean water access would be consistent with reduced breastfeeding causing an increase in infant mortality. On the other hand, an increase in mortality only among households without clean water access would be consistent with an increase in infant mortality due to

[10] United Nations Children's Fund, Division of Data Research and Policy (2018). Global UNICEF Global Databases: Infant and Young Child Feeding. New York, January 2018. https://data.unicef.org/resources/dataset/infant-young-child-feeding/

[11] See for example De Chaisemartin and d'Haultfoeuille (2020); Goodman-Bacon (2021); Borusyak et al. (2024).

the contamination of formula by unsanitary water.

Identification of formula availability's effects rests on whether Nestlé entry can be considered plausibly exogenous to infant mortality, conditional on a number fixed effects. The extent to which Nestlé made market entry decisions based on infant health is of central interest. In section 5.6.1, we investigate Nestlé's market strategy by first studying 60 years of Nestlé annual investor reports (Nestlé, 2018). The narrative that emerged was that Nestlé targeted countries based on the potential market size and profit potential as indicated by population and disposable income. We found no mention of health or health care infrastructure or any other related factor. We then confirm this representation of Nestle's market strategy quantitatively by estimating Cox proportional hazard models of the determinants of market entry.

We also make several choices in specification to maximize a plausibly causal interpretation of our estimates. First, we leverage the birth panel recall structure of the DHS to include maternal fixed effects. Maternal fixed effects is a common approach to address exactly these issues and is used extensively in the early childhood human capital development literature.[12] This estimation strategy essentially compares differential rates of infant mortality between children born to the same mother just before and just after Nestlé entry in treatment countries to the differences in sibling infant mortality in control countries at the same points in time. Since median birth spacing is only 29 months, family location and socio-economic conditions are unlikely to have changed significantly between siblings and therefore should be captured by the maternal fixed effect.[13] Doing so allows us to identify changes in infant formula availability across births within the same family, absorbing average differences in mortality risk for each mother due to time-invariant aspects of self, household, situation, or location.

[12] See Currie and Almond (2011) for a review of the use of maternal fixed effects to investigate human capital development before age 5.

[13] There is relatively little selection from using maternal fixed effects. Of the 801,830 mothers in the sample, 87% have at lease one birth before and one birth after and therefore remain in the sample once we restrict it to be able to include maternal fixed effects.

Second, we include infant sex-by-birth order fixed effects in order to obviate any potentially confounding effects of child birth order on treatment, a particular concern given that treatment is identified only among latter-born children due to the event study-type (pre- and post-) research design and mother fixed effects.

We additionally include child birth year fixed effects in order to adjust for any secular trends that might be common to the global sample in terms of development, health, or Nestlé activity. In section 6 below, we analyze Nestlé market choices by analyzing 60 years of Nestlé annual corporate reports and quantitative analysis of a panel of country level data.

Our identification of causal impacts for the formula-mixed-with-unclean-water hypothesis thus lies across three layers of differences: 1) treated countries vs. untreated countries, 2) siblings born to a given mother after vs. before Nestlé formula entry, and 3) households with only unclean water access vs. clean water access, forming an added layer of robustness against endogeneity concerns.

4.2 Estimation

We use the Borusyak et al. (2024) imputation estimator for the following difference-in-differences model:

$$m_{\mathrm{ijkct}} = \beta Nestl\acute{e}_{\mathrm{ic}} + \alpha_j + \gamma_t + \varphi_i + \epsilon_{\mathrm{ijkct}} \tag{1}$$

where m_{ijkct} is an indicator variable capturing whether child i born to a mother j in DHS region *k,* in country *c,* and in year t died during or prior to their 12^{th} month of life; β is the treatment effect coefficient on $Nestl\acute{e}_{\mathrm{ic}}$, which indicates whether the child i was born in the five-year period after the first year Nestlé began selling formula in country c; α_j is a fixed effect for mother j; γ_t is a fixed effect for year of the child's birth; φ_i is a vector of indicators for birth order (truncated at 7) interacted with child sex for child i; and ϵ_{ijkct} is the error term. Standard errors are clustered at the country level.

To study the *dynamic effects* of Nestlé market entry, we also use the Borusyak et al. (2024) imputation estimator to estimate an event study (Binder, 1998) version of the difference-in-differences imputation estimator that allows the treatment effects to vary in the years prior to and following formula introduction. Specifically, we estimate:

$$m_{\mathrm{ijkct}} = \alpha_j + \gamma_t + \varphi_i + \sum_{T=\bar{t}-m}^{\bar{t}+m} \tau_T T_{cT} + \epsilon_{ijkct} \tag{2}$$

where coefficients in (2) are as in (1) except that τ_T is a set of $2m + 1$ coefficients that represent a child's birth in different years within the event window surrounding the introduction of infant formula within a country.

Lead and Lag Structure. We use an event window in (2) that estimates three years of pretrend data (T = -3) and five years of post-entry year data (T = 1-5). This specification allows us to examine and test for pre-treatment trends before formula introduction and the evolution of treatment over a five-year period.

The choice of five of leads years post and three years of lags pretreatment for the event history specification is driven by sample size concerns. We were interested in making sure that as many countries as possible had sufficient sample size in all of the periods. Given that the DHS had to be collected post treatment and using the birth histories construct the panel of births for each mother limited the number of pretreatment period supported by the data. Since we limited the treatment sample to countries with DHS surveys no more than five years post entry, we can only include five years post in the analysis. Second, the number of mothers who have a birth a post-Nestlé entry and birth more than three years before Nestlé is small given median birth spacing is only 29 months. Hence the sample of births more than three years pre-Nestlé is small and driven by just a few countries.

Weighting. We address differential sample size within countries over time, different populations across countries, and the DHS sampling approach by weighting the data in two steps: first using the DHS survey weights to aggregate up to survey-wave level, and then combining DHS surveys within each country. Finally, we assign each country equal weight. Doing so allows us to interpret effects as representative at the level of treatment, i.e., at the country level, and not to bias the global individual-level regression results by countries' population and/or DHS sample size. Standard errors are then calculated using the difference-in-differences imputation estimator.

Interpretation. We interpret our results as Intent-to-Treat (ITT) estimates that capture the average mortality response to the change in market availability of infant formula associated with Nestlé market entry. Our estimated treatment effects represent both the changes associated with infant formula adoption by households within the exposed population (which may include, e.g., changes in mother's labor supply, changes in sibling dynamics, etc.) as well as the physical effects on infants from consuming the formula. The impact on infant mortality will also vary depending on whether formula is combined with clean water, diluted or concentrated inappropriately, or whether it substitutes for breastmilk or for some other nutritional supplementation such as water, diluted milk, evaporated or condensed milk, juice, rice water, or another low-quality substitute.

5 Mortality Results

Our main difference-in-differences estimates of the relationship between Nestlé entry into country formula markets and infant mortality are reported in Table 3. The first two columns report estimates of the average annual treatment effect during the five years after Nestlé entry, separately for the clean and unclean water samples. The coefficient for the clean water sample is 3.6 deaths per thousand births, which is small relative to the mean infant mortality rate of 65.3 and not statistically different from zero. The coefficient for the unclean water sample is markedly different, with Nestlé entry being associated with an increase of 19.4 deaths per thousand births, statistically significant at the 0.01 level. This effect represents an increase of 27% of the average infant mortality in the unclean water population. These results show large effects on mortality from marketing formula in households that not have access to clean water and no significant effect in households with access to clean water. This is consistent with the hypothesis that the mechanism through which formula availability affected mortality was unclean water being mixed with formula, and not a reduction in breastfeeding.

5.1 Are the estimated effect sizes biologically plausible?

In this section, we use a back-of-the-envelope calculation to assess if the biological plausibility of the estimated effect size of an increase of 19.4 infant deaths per thousand is consistent with the mortality risks associated with unsanitary conditions and diarrheal disease.[14] We estimate increased infant mortality from Nestlé entry using this disease-based formula:

$$\textit{Increase in IMR} = \textit{(Infant Formula Market Penetration)} \times \textit{(Nestlé Market Share)} \times \textit{IMR} \times \textit{(Fraction of Infant Deaths due to Diarrhea)} \times RR_{Diarrhea},$$

where IMR denotes the infant mortality rate and $RR_{Diarrhea}$ denotes the increased risk ratio of diarrheal death from formula feeding relative to exclusive breastfeeding.

For the model parameters, we use estimates from the epidemiological and medical literatures. Specifically, we make the following assumption: (i) infant formula market penetration into our LMIC study region at 63% based on Victora et al. (2016) and related studies; (ii) Nestlé infant formula market share in LMICs lying in a range between peak historical estimates by Sethi (1994) of 40% and the more current Fortune Business Insights (2020) estimates of 22%; (iii) the baseline infant mortality rate of 56 per 1000 births for the full sample in our study countries; (iv) the fraction of infant deaths from diarrheal disease in LMICs to be in alignment with the WHO estimate of 18.7% (Boschi-Pinto et al., 2008);[15]

[14] The major infectious diseases with consequences for the human population are the fecal-oral, water-borne infectious diseases, which are transmitted by ingestion of causal agents released into water through feces (Jofre et al., 2010). These water-borne pathogens include giardia, cholera, *Escherichia coli*, *Cryptosporidium*, hepatitis viruses, salmonella and shigella (Sharma et al., 2003).

[15] This estimate is lower than those in more recent reports documenting that 33.1% of infant deaths are from diarrhea caused by water-borne pathogens (Prüss-Ustün et al., 2019).

and (v) Lamberti et al. (2011)'s estimate of the increased risk ratio of death from diarrhea due to formula feeding relative to exclusive breastfeeding of 10.51.

Based on these parameter assumptions, we would expect the market entry of Nestlé infant formula into LMICs to increase infant mortality by between 15.2 and 27.7 deaths per 1000 births, where our estimate of an increase of 19.4 per 1000 births due to Nestlé market entry (Table 3) lies within this interval.

5.2 Dynamic Effects

The next two columns in Table 3 report event study estimates, which allow the treatment effects to vary over time following exposure. This allows for infant mortality effects to be deferentially estimated over time, in keeping with Nestlé expanding its market coverage within a country. For the clean water sample, in the years post Nestlé's entrance, we observe some spotty evidence of slightly increased mortality in a few years, reduced mortality in one year and unchanged mortality in others (column 3). The results are consistent with a small and statistically insignificant average annual impact on infant mortality over the full 5-year treatment period (column 1). They stand in marked contrast with effects observed in the sample of households using unclean water sources (column 4). There, we see strong evidence of an increase in the effect on mortality over time leveling out after three years post-entry.

These patterns are clearly visible in Figures 2a and 2b. Prior to Nestlé entry in year 0, there is no difference in mortality or mortality trends between treatment and control groups. After entry, in the unclean water sample (Figure 2b), we observe a large increase in mortality in the treatment group relative to the control group, with the difference increasing with time of exposure. However, we do not see similar patterns in the clean water sample (Figure 2a).

5.3 Maternal Education

A key early concern of public heath researchers during the introduction of formula centered on education because formula was a novel nutritional technology, and less educated women may have had trouble following directions and/or ensuring the formula was only mixed with clean water. To test this hypothesis we re-estimate the model on the sample of households without access to clean water separately for women who have either no education or only primary education, and compare these results with those for women who completed secondary school or higher. Those results are presented in Table 4, where columns 1 and 2 report treatment effects for the 5 years after Nestlé market entry for both more and lesseducated mothers, while columns 3 and 4 show corresponding event study specifications. Our results are broadly consistent with public health concerns, with large and significant effects concentrated among less-educated mothers. Effects are smaller and insignificant, albeit still positive at the end of the five-year period, for the much smaller sample with secondary or higher education.

5.4 International Code of Marketing of Breast-milk Substitutes

Alarm over infant formula's possible negative effects on child outcomes led to substantial action on behalf of international civil action groups as outlined above. In particular, Nestlé agreed to abide by the International Code of Marketing of Breast-milk Substitutes in 1984.[16] We test for any effect of Nestlé's agreement to abide by the International Code of Marketing of Breast-milk Substitutes in 1984 by repeating our main difference-in-differences imputation estimator limiting the sample to designate Nestlé market entry after 1984 (columns 1 and 2 in in Table A1). We again find no evidence of mortality increase among clean water source households, but an increase in mortality among unclean water households, with a coefficient that is somewhat smaller, at 12.42 deaths per 1000 rather than the main sample's 19.35, but still high and significantly different from zero. We thus conclude that even after Nestlé's 1984 agreement to abide by the breastmilk marketing code, high rates of infant mortality

[16] Whether they actually did abide is contoversal as discussed above.

continued to follow the introduction of formula among households without access to clean water.

5.5 Number of Infant Deaths

How many infant deaths resulted from the introduction of Nestlé infant formula to mothers without access to clean water? We use 1981 as a benchmark, the year when media attention on the controversy was arguably at its peak. We multiply the 53.8 million live births that occurred in LMICs where Nestlé formula was available in 1981 by the fraction of households in these countries with DHS-defined unimproved water sources and by our estimate of the net impact of formula on infant mortality on these households (19.35 per thousand births from Table 3, column 2). This yields an estimate for 1981 of approximately 212,000 infant deaths with a 95% confidence interval of [114,000, 310,000].

We perform a similar exercise for the years 2000 and 2015. Because current DHS water source data is not available for all countries, in its place we use the conservative WHO measures of surface water data for 2000 and 2015. We likewise use estimates of births from the World Bank Development Indicators in countries importing Nestlé formula and the same estimated impact coefficients from column 2 in Table 3. Using this approach for the year 2000, we estimate a mortality figure of approximately 284,000 infant deaths with a 95% confidence interval of [152,300, 415,900]. By 2015, the estimated infant death toll falls to 206,700 (95% confidence interval [110,800, 302,600]). This reduction in global infant mortality from Nestlé formula stems from both improvements in clean water access as well as declining birth rates, which offset the wider availability of the product. These figures and their confidence intervals are given in Figure 3.

How do our estimates compare to the broader informal estimates of global infant mortality from formula adoption in developing countries? At the peak of the crisis public health officials estimated that 1 million infant deaths could be attributed to the introduction of infant formula in LMICs (Joseph, 1981; Grant, 1983). Recall that Nestlé's infant formula market share in the early decades of entry into LMICs has been estimated to be approximately 40% (Sethi, 1994), falling in more recent decades with new entrants into the market to about 22% (Fortune Business Insights, 2020). Thus, if the early public health appraisals of global infant mortality from formula were roughly correct, we would expect Nestlé's share of these infant deaths to lie within an annual range of 200,000 to 400,000. The estimates we present here lie in the lower half of this range.[17]

To obtain estimates of the total number of worldwide infant deaths resulting from the use of Nestlé infant formula with unclean water from 1960 to 2015 (when the best Nestlé product data by country are available), we assume a linear increase from zero in 1960 to our 1981 estimate, and take linear averages between our 1981, 2000, and 2015 estimates. Based on calculations from these linear averages, our estimate of the number of infant deaths between 1960 and 2015 resulting from the introduction of Nestlé formula among mothers in LMICs without clean water sources is 10,870,000 total infant deaths with 95% confidence interval [5,825,000, 15,907,000].

5.6 Threats to Identification.

We consider four potential threats to causal identification: 1) Nestle's choice of countries was determined by infant mortality or factors correlated with infant mortality, 2) bias from the retrospective assignment of water quality status, 3) violation of parallel pre-intervention trends, and 4) omitted factors correlated with infant mortality.

5.6.1 Nestlé's Strategy for Choice of Country Markets

The extent to which Nestlé made country entry decisions based on infant health is of central interest in determining the causal role of formula marketing per se. If Nestlé based its choice

[17] However, this is likely to be a lower bound as market entry of other international infant formula producers is highly correlated with Nestlé market entry.

of which countries' to enter based on time-varying factors that are correlated with infant mortality, then our estimates might be biased. As discussed earlier, the use of maternal fixed effects controls for factors that do not change over short periods of time including country level criteria that may have been used by Nestlé in its choice of countries. In this section, we investigate whether Nestlé's market strategy was based on factors related to infant mortality using both their own written documents and empirical tests of what they claimed in those documents.

Fortunately, Nestlé's annual investor reports (Nestlé, 2018) contain extensive discussion of the company's strategic decisions, including the characteristics and rationales behind market expansions. We reviewed sixty years of Nestlé annual investor reports to best understand the factors communicated to shareholders that influenced Nestlé to enter specific infant formula markets in new LMICs. Several themes emerge, all related to the potential country market size and hence profit potential of the market. The reports regularly comment on how specific expansion decisions were driven by population size, birth rates, and disposable income, and intermittently mention business stability and investment environment. We found no mention of health or health care infrastructure or any other factor in any of the 60 investor reports.

Together, the reports paint a picture of a methodical expansion based on economic opportunities and not health or health care. It is difficult to believe that Nestlé would not have mentioned any other factors, including those health related, driving the market choices in the their investor reports. There would be no economic or political costs to doing so and hiding such strategic information could have opened Nestlé up to investor questions and concerns.

We investigated empirically the picture painted in the annual reports of Nestlé's country market entrance behavior over time. Specifically, we estimate Cox proportional hazards models of Nestlé entry into infant formula markets in a 30-year annual panel of countries, merging Nestlé country-level entry data from the annual reports with country-level macroeconomic data from the World Bank Development Indicators. The sample includes all countries the World Bank defines as LMIC (N=171).

Table 5 reports the estimation results. Overall, regardless of specification, we find that Nestlé indeed preferentially entered countries with larger populations and higher per capita incomes, both statistically significant as well as economically meaningful. The estimated coefficients are reports in logs odds, so that from our base specification in Model 1, a 10% increase in population is associated with a 3% increase in the probability of Nestlé entry and a 10% increase in GDP is associated with 3.7% increase in the probability of entry.

The remaining models add other factors to the basic specification in Model 1. The addition of these factors does not affect the basic relationship between entry with population and GDP, and all other factors are not statistically associated with Nestlé entrance. Specifically, despite Nestlé's reference to higher birth rates being better for business, neither birth rates nor infant mortality rates predict entrance (Model 2). GDP and population growth are similarly unassociated with entry (Model 3), as are a measure of average business environment measured by the WDI's Ease of Business score[18], and the average number of physicians per 1000 people, a measure of health care access(model 4). Market choice then appears to be driven by population and GDP and not by infant mortality and health care infrastructure.

5.6.2 Retrospective assignment of water quality status

Water source quality information is collected at the time of the DHS survey, and we assign the water source at the time of the survey to all births. If a mother's water source is reported *unclean* at the time of the survey, it is highly likely to have been unclean for prior births, and so we expect the estimates to remain unbiased for the *unclean* water sample.

[18]Ease of Business score and physicians per capita calculated as averages for entire panel due to extremely sparse annual reporting.

However, if the water source was reported *clean* at the time of the survey, it may have been unclean for some or all previous births. This may have introduced bias into the estimates for the clean water sample. There are three cases to consider. First, if the household switched from unclean to clean before her first birth, then the clean-water estimates also remain unbiased. Second, if the household switched from unclean to clean after her last birth but before the survey, then the clean-water estimates would be biased in the direction of the effects for the unclean unclean water. Finally, if water switched from unclean to clean between births of her first and last children, it could create a downward bias in our clean-water estimates of Nestlé impact on infant mortality due to the older children's exposure to unclean water. This means that any mismeasurement of water quality would likely bias the estimated treatment effects upwards.

To assess the extent of potential bias, we first estimate the share of households with clean water that likely had unclean water at some point earlier than the time of the DHS survey. In our sample, 30 out of 38 countries had two DHS surveys in the relevant time period. From these data, we estimate that on average 0.41 percent of households in the treatment group converted from unclean water to clean water each year. This translates into 3.28 percent converting from unclean to clean water over an 8-year period covering the three preintervention periods and five postintervention periods used in the analysis, which translates into 4.4% of the clean water sample.

We assign the group that converted from unclean to clean water the treatment effect of the unclean sample 19.4. Since the estimated effect for the clean water treatment is equal to a weighted average of the true effects in the clean and unclean samples, we can solve for the true effect in the clean sample as (3.6 - 0.044*19.4)/0.956 = 2.9. The bias from misassignment of water would reduce the estimated treatment effect from 3.6 to 2.9. Hence, the potential bias in the clean sample estimates from misassignment is likely relatively small.

5.6.3 Parallel Pre-intervention Trends

A key advantage of implementing difference-in-differences estimators using Borusyak et al. (2024) imputation weights is that it allows us to formally test whether the standard identifying assumption of parallel trends in difference-in-differences indeed holds. We implement the version of this test given in Borusyak et al. (2024). The results are reported in the lower panel below the dotted line in Table 3. We find no systematic evidence of pretrends in our data, and a joint test of the pretrend coefficients shows that none of them are statistically significantly different from zero. These results support an assumption of parallel trends, and hence a causal interpretation of our estimates.

5.6.4 Omitted Factors

One might be concerned with omitted factors outside our estimation model that could be correlated with both infant mortality and Nestlé market presence, such socio-economic factors, low levels of household income and parental education, or location characteristics such as the disease enviornment or the factors that drove Nestlé's choice of markets. We use maternal fixed effects to control for these unobservables under the assumption that these omitted factors are common across siblings. These fixed effects control for factors that are fixed between births, a relatively short period of time since median birth spacing is 29 months in our sample.

In addition, it is important to keep in mind that we test two distinct hypotheses put forth by the public health community related to the introduction of infant formula into LMICs. These are that increases in infant mortality were caused through (a) a reduction in breastfeeding, where infant mortality surged through reduced immunity levels, and (b) the mixing of formula with unsanitary water by mothers without access to clean water. Because we find much stronger evidence for the second than the first hypothesis, any plausible endogenous entry by Nestlé into formula markets that would influence these results would not merely have to be correlated with infant mortality trends, but specifically correlated with infant mortality trends *only* among households with unclean water sources.

6 Breastfeeding and Formula Use

In this section we provide descriptive evidence that formula consumption is correlated with the presence of Nestlé marketing formula in a country. A principal hurdle is the relative lack of retrospective breast feeding data compared to mortality within the DHS. The DHS collects extensive data on breastfeeding, infant formula consumption, diarrhea, and a host of other salient measures, but unfortunately only does so for children under the age of five (or age three, depending on the survey) years old at time of survey, meaning that we are unable to match the overwhelming majority of Nestlé entry events with breastfeeding or similarly reported or measured infant health outcomes. While it would clearly be preferable to directly estimate how breast feeding responds to Nestlé market entry within the DHS data themselves, we are thus forced to consider other data sets with better coverage.

Our data source is the 2018 UNICEF Global database on Infant and Young Child Feeding, which provides standardized country level population estimates of various infant feeding behaviors starting in 1998. Observations are cross-sectional.[19] We merge these data with the Nestlé Annual Reports data and report on the cross-sectional associations between Nestlé market presence and measures of various infant feeding behaviors in Table 6. While these data prevent us from estimating a causal relationship between formula consumption and breastfeeding, they do provide an opportunity to test the hypothesis that Nestlé marketing of formula in a country is associated with increased formula use.

The data are reported in common combinations of food groups consumed together rather than item-by-item. Those groups include (i) exclusive breastfeeding and breastfeeding

[19] In cases with more than one observation we limit to the earliest available year to ensure countries are observed at roughly the same time.

combined with other non-formula liquids, (ii) formula and other non-formula liquids combined with breastmilk, and (iii) formula or other non-breastmilk liquids not combined with breastmilk. An increase in formula would be reflected in (ii) and (iii), and a reduction in breastfeeding in (i) and (ii). We analyze these outcomes separately for 3 age groups: 0-1 month olds, 2-3 month olds, and 4-5 month olds. We report the results of simple OLS regressions between Nestlé market presence and infant feeding practices in the sample of 103 UNICEF countries in Table 6. The constant is the average for countries without a Nestlé presence, and the coefficient on the indicator for Nestlé market presence is the difference between countries with and without Nestlé presence.

We find that Nestlé formula market presence is unequivocally associated with the dietary patterns consistent with significantly higher consumption of formula and other milks alongside breastmilk, with a 5.7 percentage point increase in use of formula among 0-1 month-olds, a 7.6 percentage point increase among 2-3 month-olds, and a 5.4 percentage point increase among 4-5 month-olds, corresponding to 40%, 42%, and 32% increases relative to mean prevalence, respectively. The incidence of breastmilk consumption without formula, either exclusively or with other liquids, is negatively associated with Nestlé presence, albeit not significantly, across all age groups. Nestlé formula availability is also significantly associated with a 1.6 percentage point higher prevalence of not breastfeeding at all among infants, a 45% increase over the non-Nestlé baseline of 3.5%. Together, our results imply that the presence of Nestlé in the market is strongly associated with a higher consumption of infant formula.

7 Conclusions

Nestlé's entry into infant formula markets in LMICs caused large increases in infant mortality among households with unclean water sources, but not among households with clean water sources. The pathway by which this finding increases mortality, therefore, appears to be the large health risk posed by mixing unclean water with powdered formula, as opposed to reductions in breastfeeding. We estimate that infant mortality increased by 19.35 infant deaths per year per 1000 live births among mothers using unclean water sources, a 27% increase in the infant mortality rate in treatment countries for this population. We estimate that Nestlé's entry into LMIC formula markets caused approximately 212,000 infant deaths per year among mothers without clean water access at the peak of the Nestlé controversy in 1981 and approximately 10.9 million infant deaths between 1960 and 2015.

The strengths of our study include its incorporation of longitudinal birth recall data, a large sample of more than 2.6 million births spanning 38 countries and over four decades, and the use of Nestlé public corporate filings data to identify the company's entry into infant formula markets over time. Together, these data allow us to exploit Nestlé's phased entry into LMIC markets to identify causal effects of formula market availability using difference-in-differences models, confirm parallel pretrends in the event study specifications, and verify that our estimates are robust to a variety of alternative specification choices.

There are a number of limitations to our analysis. First, while Nestlé had and still has the largest market share of infant formula in LMICs, it was not the only firm that introduced infant formula in LMICs. Nestlé's practice of detailing international production and marketing operations in public records is unusual among firms, and thus we cannot capture mortality effects of other firms' activity, nor can we speak to the difference between exposure to Nestlé formula marketing alone versus the marginal entry of Nestlé into an existing formula market. However, Nestlé was typically the first to enter these markets or entered concurrently with other manufacturers.

Secondly, the data in Nestlé's public filings only reveal whether infant formula, or products in its market segment, were being imported into a country, with no standard measure of intensity or penetration of formula marketing. Our measures are thus classic intent-to-treat estimates, i.e. of the effect of the availability of formula, and not the effects of the actual consumption of formula. This approach allows us to sidestep concerns about modeling complicated and poorly documented take-up behaviors. Because these intent-to-treat estimates include households who did not use Nestlé infant formula, they are less than the average treatment effects of formula use among households who did use it.

We further note that our focus on mortality is driven by data availability, and stress that one cannot interpret the lack of mortality effect among clean water households as evidence that there were no adverse health effects from substituting formula for breastfeeding. DHS data on morbidity, anthropometrics, breastfeeding practices, and similar outcomes are available for a smaller sample of children than mortality data, and only for children 3-5 years old at the time of the survey. Thus, we are limited in our ability to conduct similar analyses for different types of morbidity outcomes or to disentangle the complicated set of infant feeding substitution decisions being made by mothers and households.

Our results suggest that one way to reduce the number of deaths from infant formula is by making sure that the most vulnerable populations are fully informed about the risks of improper formula use, particularly in relation to quality of water used to mix formula, as well as removing barriers to initiating breastfeeding. One message that emerges from our analysis is the critical importance of making sure that parents who use formula, use it safely. Clear instructions comprehensible to mothers of all education levels need to be included in marketing and packaging materials. In regions where many households do not have access to clean water, infant formula companies may consider premixing formula with clean water, or perhaps including chlorine tablets with formula packaging.

The international community's response to concerns over marketing was to create the International Code of Marketing Breastmilk Substitutes (ICMBS) (WHO, 1981), which has recently been extended to include inappropriate marketing of all foods to infants and young children (WHO, 2016). However, compliance with ICMBS is voluntary and violations of banned marketing practices continue. In fact, a recent systematic review reported inappropriate marketing by formula companies in 95 countries and all WHO regions in a variety of settings, including health systems, public spaces, points of sale, media, emergency programs, and direct to mothers (Becker et al., 2022). Documented violations include promotional claims that mislead consumers and surreptitious methods to influence doctors and other health professionals, such as sponsoring medical conferences and partnering with health-promoting NGOs, misleading and inaccurate health claims, along with the growing use of social media and other digital platforms. To combat these abuses, WHO, UNICEF and the International Baby Food Action Network have called for countries to enact ICMBS legislation with stringent enforcement mechanisms with penalties for nonadherence, to closely monitor adherence (WHO, 2018), and to increase focus on new digital marketing strategies and differentiated types of breastmilk substitutes and associated products (Becker et al., 2022).

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Table 1: Descriptive Statistics for Treatment Countries

Continent	Country	N	First Year Nestlé Sales	Infant Mortality (per 1000)	WHO Unclean Water (%)	Mother Did Not Complete Primary (%)
Africa	Angola	13,226	2012	103.3	37.2	58.8
Africa	Cameroon	29,457	1992	78.8	43.9	52.2
Africa	Dem. Rep. Congo	28,578	2011	98.5	54.1	48.0
Africa	Egypt	91,543	1988	35.2	1.6	72.1
Africa	Guinea	28,328	1993	94.4	37.5	92.4
Africa	Madagascar	4,765	1972	63.1	42.2	87.4
Africa	Morocco	17,099	1992	38.3	7.5	87.8
Africa	Senegal	12,042	1974	56.9	5.6	90.7
Africa	Zambia	3,592	1969	75.8	37.8	72.5
Asia	Bangladesh	78,907	1993	58.0	3.6	77.5
Asia	Cambodia	1,619	1998	61.2	46.8	72.8
Asia	Indonesia	38,318	1972	38.3	14.0	60.2
Asia	Jordan	55,931	1999	21.2	19.3	8.4
Asia	Pakistan	27,218	1990	81.4	7.2	81.3
Asia	Sri Lanka	6,628	1981	13.2	37.0	34.4
Asia	Turkey	15,274	1984	28.0	16.3	52.3
Asia	Vietnam	7,766	1997	23.1	8.9	27.1
North America	Dominican Republic	12,600	1971	32.7	26.1	65.2
Total/Average		472,891	1988	55.6	24.8	63.4

Notes: Descriptive statistics for year before Nestlé entry. Source: Demographic and Health Surveys. All estimates weighted using DHS sample weights.

Table 2: Descriptive Statistics for Control Countries

Continent	Country	N	Infant Mortality (per 1000)	WHO Unclean Water (%)	Mother Did Not Complete Primary (%)
Africa	Benin	164,305	81.9	31.1	87.2
Africa	Burkina Faso	139,392	82.6	19.2	93.9
Africa	Burundi	71,338	81.9	21.5	75.8
Africa	Chad	79,617	94.8	47.4	89.1
Africa	Ethiopia	191,762	77.5	48.9	90.5
Africa	Malawi	194,471	83.0	21.0	64.5
Africa	Mali	215,226	93.2	31.0	91.1
Africa	Mozambique	43,337	103.1	44.0	79.5
Africa	Niger	130,386	87.4	41.0	93.8
Africa	Rwanda	138,714	78.5	26.0	66.7
Africa	Sudan	15,983	61.9	0.0	83.3
Africa	Tanzania	157,547	68.6	37.9	49.7
Africa	Uganda	143,362	73.3	25.0	59.7
Asia	Afghanistan	125,044	82.9	32.9	92.5
Asia	Azerbaijan	13,557	51.6	21.2	2.4
Asia	Nepal	88,552	55.2	8.2	77.8
Asia	Tajikistan	41,351	58.4	23.6	5.2
Asia	Yemen	90,916	61.3	43.1	96.2
North America	Haiti	80,427	72.5	34.3	70.9
North America	Honduras	24,485	27.9	85.6	24.9
Total/Average		2,149,772	73.9	32.1	69.7

Notes: Source: Demographic and Health Surveys. All estimates weighted using DHS sample weights.

Table 3: Effect of Nestlé Marketing Infant Formula on Infant Mortality by Clean and Unclean Water Source

	(1) Clean Water ATE	(2) Unclean Water ATE	(3) Clean Water Event Study	(4) Unclean Water Event Study
0-5 Years Post-Entry	3.60	19.35***		
	(2.26)	(4.58)		
0 - Year of Entry			-7.76**	6.00
			(3.10)	(6.56)
1 Year Post-Entry			3.00	12.41
			(3.87)	(8.49)
2 Years Post-Entry			10.11***	14.83**
			(3.41)	(6.12)
3 Years Post-Entry			9.99**	37.69***
			(4.76)	(10.15)
4 Years Post-Entry			0.75	25.68**
			(4.55)	(10.43)
5 Years Post-Entry			10.95**	33.47***
			(4.569)	(9.303)
$Pretrend_1$	-4.32	4.61	-4.32	4.61
	(3.70)	(7.02)	(3.70)	(7.02)
$Pretrend_2$	-5.98	-5.98	-5.98	-5.98
	(3.96)	(7.75)	(3.96)	(7.75)
$Pretrend_3$	1.37	2.62	1.37	2.62
	(3.74)	(8.69)	(3.74)	(8.69)
Observations	1,843,004	779,659	1,843,004	779,659
Pretrends F-Statistic	1.47	0.37	1.47	0.37
Pretrends Chi-Squared Statistic	4.41	1.11	4.41	1.11
Pretrends p-value	0.22	0.78	0.22	0.78
Mean Infant Mortality	65.26	72.67	65.26	72.67

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Notes: Weighted difference-in-differences imputation event study estimates of infant mortality per 1000 births surrounding time of Nestlé market entry, estimated coefficients and clustered standard errors in parentheses. Infant birth and mortality data are from the Demographic and Health Surveys, Nestlé entry data taken from Nestlé Annual Investor Reports. All specifications include mother, birth order by gender, and birth year fixed effects, and are weighted equally by country using DHS sample weights.

Table 4: Effect of Nestlé Marketing Infant Formula on Infant Mortality by Level of Education in Unclean Water Sample

	(1) More than Primary ATE	(2) Up To Primary ATE	(3) More than Primary Event Study	(4) Up To Primary Event Study
0-5 Years Post-Entry	9.96	19.15***		
	(11.93)	(5.47)		
0 - Year of Entry			16.02	1.05
			(19.24)	(7.85)
1 Year Post-Entry			9.87	11.89
			(16.19)	(10.40)
2 Years Post-Entry			-1.08	14.04*
			(14.70)	(7.252)
3 Years Post-Entry			6.97	42.88***
			(19.27)	(12.08)
4 Years Post-Entry			12.64	26.92**
			(21.83)	(12.18)
5 Years Post-Entry			18.72	32.67***
			(18.32)	(10.98)
$Pretrend_1$	-2.71	3.84	-2.71	3.84
	(18.24)	(8.32)	(18.24)	(8.32)
$Pretrend_2$	-17.18	-5.93	-17.18	-5.93
	(20.04)	(8.82)	(20.04)	(8.82)
$Pretrend_3$	3.96	-1.87	3.96	-1.87
	(18.42)	(10.43)	(18.42)	(10.43)
Observations	61,224	685,656	61,224	685,656
Pretrends F-Statistic	0.32	0.25	0.32	0.25
Pretrends Chi-Squared Statistic	0.95	0.75	0.95	0.75
Pretrends p-value	0.81	0.86	0.81	0.86
Mean Infant Mortality	53.13	77.07	53.13	77.07

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Notes: Weighted difference-in-differences imputation event study estimates of infant mortality per 1000 births surrounding time of Nestlé market entry, estimated coefficients and clustered standard errors in parentheses. Infant birth and mortality data are from the Demographic and Health Surveys, Nestlé entry data taken from Nestlé Annual Investor Reports. All specifications include mother, birth order by gender, and birth year fixed effects, and are weighted equally by country using DHS sample weights.

Table 5: Cox Proportional Hazard Models Nestlé Market Entry

	(1)	(2)	(3)	(4)
Total Population, log	1.30***	1.25***	1.29***	1.25***
	(0.08)	(0.08)	(0.08)	(0.08)
GDP per capita, log	1.37***	1.23	1.37***	1.31***
	(0.12)	(0.18)	(0.13)	(0.13)
Infant Mortality Rate		1.00		
		(0.01)		
Birth Rate		0.98		
		(0.02)		
GDP Growth (pp)			1.00	
			(0.01)	
Population Growth (pp)			0.99	
			(0.10)	
Ease of Business Score (1-100, avg)				1.01
				(0.01)
Physicians per 1000 (avg)				1.12
				(0.15)
Observations	5,554	5,124	5,461	5,260
Number of Countries	171	159	169	159

Notes: Hazard ratios from Cox Proportional Hazard model estimates of first Nestlé market entry for 171 countries observed in an annual panel from 1966-2018. Nestlé entry data taken from Nestlé Annual Investor Reports, all over covariates from World Development Indicators. Annual GDP and GDP per capita shown in constant 2019 US$, infant mortality rate shown per 1000 births, birth rate shown per 1000 people, GDP and population growth rates shown in percentage points; Ease of Business Score (1-100) and physicians per thousand shown calculated as averages over entire panel due to data sparsity. Heteroscedasticity-robust standard errors reported in parentheses. *** p <0.01.

Table 6: Difference in Infant Feeding Practices by Nestlé Presence

Infant age range	0-1 month old	2-3 months old	4-5 months old
	Breastmilk, exclusive or with non-formula		
Nestlé formula (0/1)	-0.7%	-4.2%	-3.9%
	(4.6)	(4.0)	(4.4)
Mean share fed	71.3%	69.0%	67.9%
	Breastmilk and other milks or formula		
Nestlé formula (0/1)	5.7%**	7.6%**	5.4%*
	(2.9)	(2.9)	(3.0)
Mean share fed	14.3%	18.0%	16.7%
	Other milks or formula but no breastmilk		
Nestlé formula (0/1)	1.6%**	2.1%	3.6%
	(0.8)	(1.5)	(2.6)
Mean share fed	3.5%	6.2%	9.4%
Number of countries	103	103	103

Notes: Coefficients reported from OLS regression of country-level infant feeding practice shares on an indicator for whether Nestlé was present in the country. Nestlé entry data taken from Nestlé Annual Investor Reports, breastfeeding data are from UNICEF Global database on Infant and Young Child Feeding. Breastmilk, exclusive or with non-formula category includes exclusive breastfeeding as well as breastfeeding complemented with water, non-milk liquids, or foods. Robust standard errors reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Figure 1: Decline in Breastfeeding with Formula Introduction

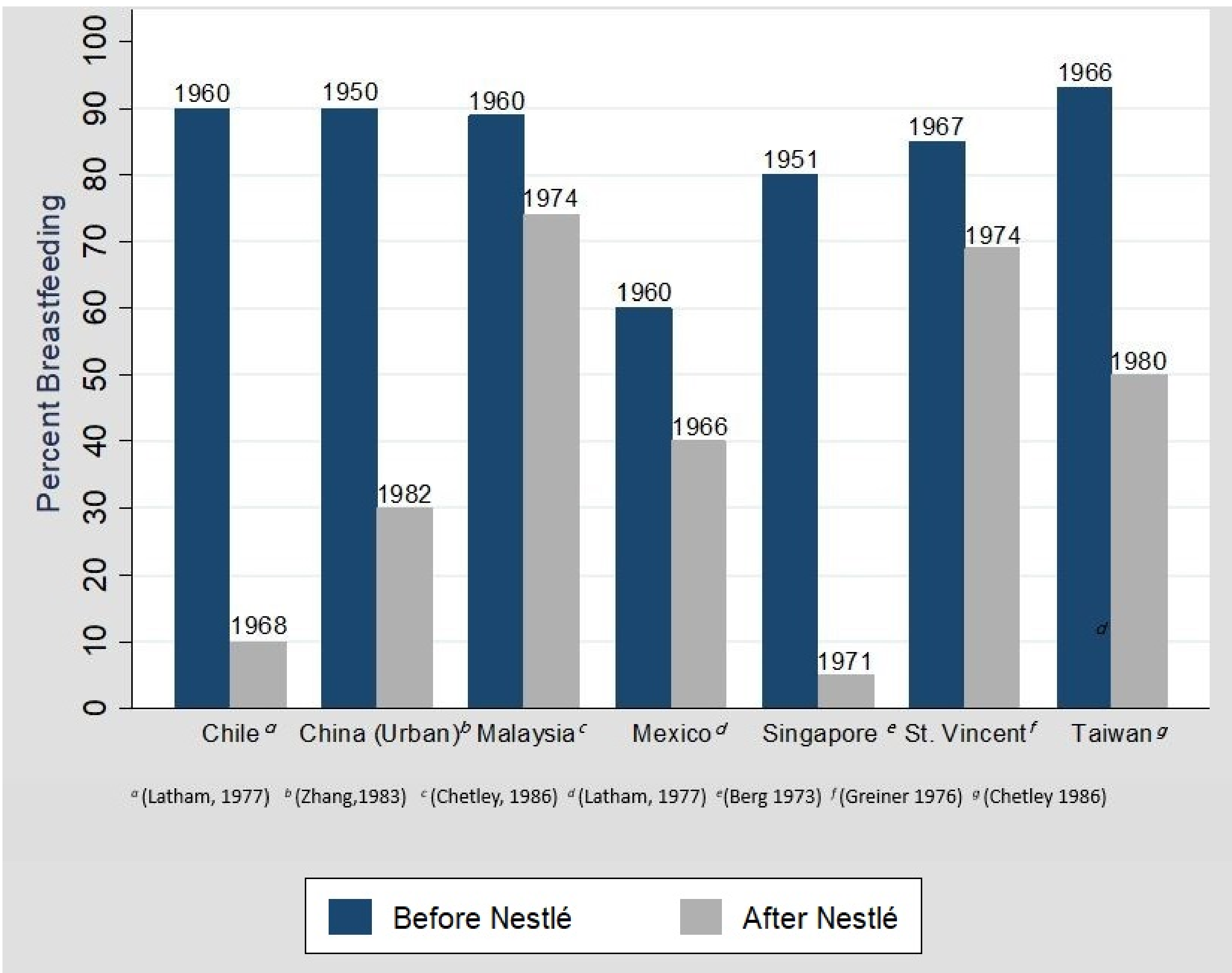
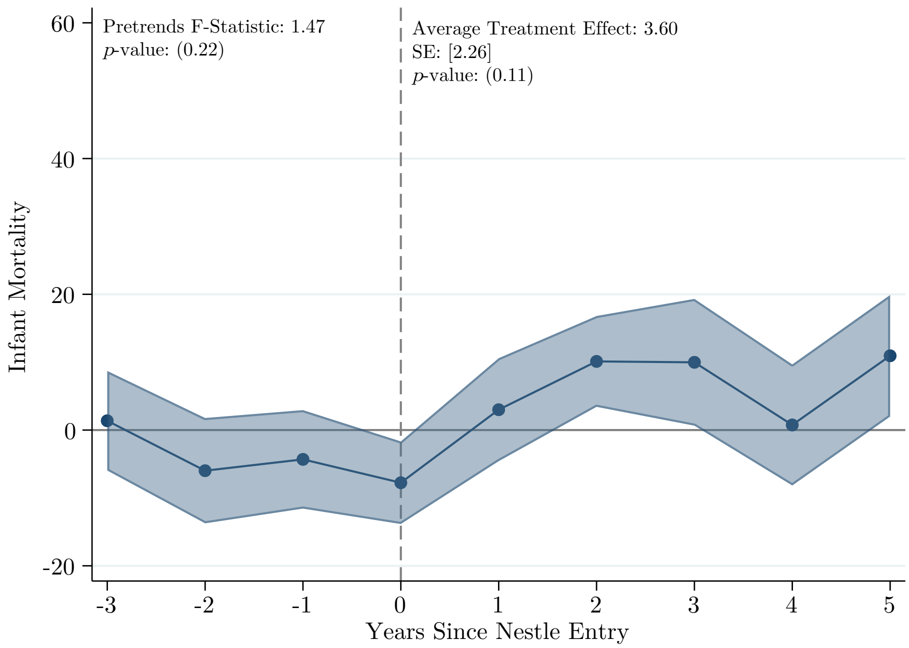
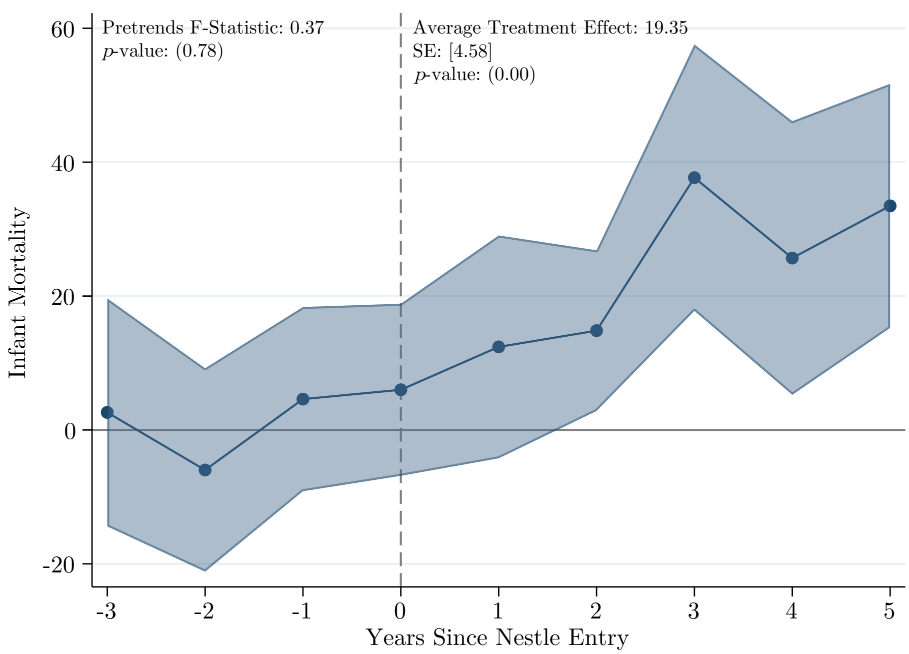


Figure 2: Effect of Nestlé Marketing Infant Formula on Infant Mortality

(a) Clean Water Sample

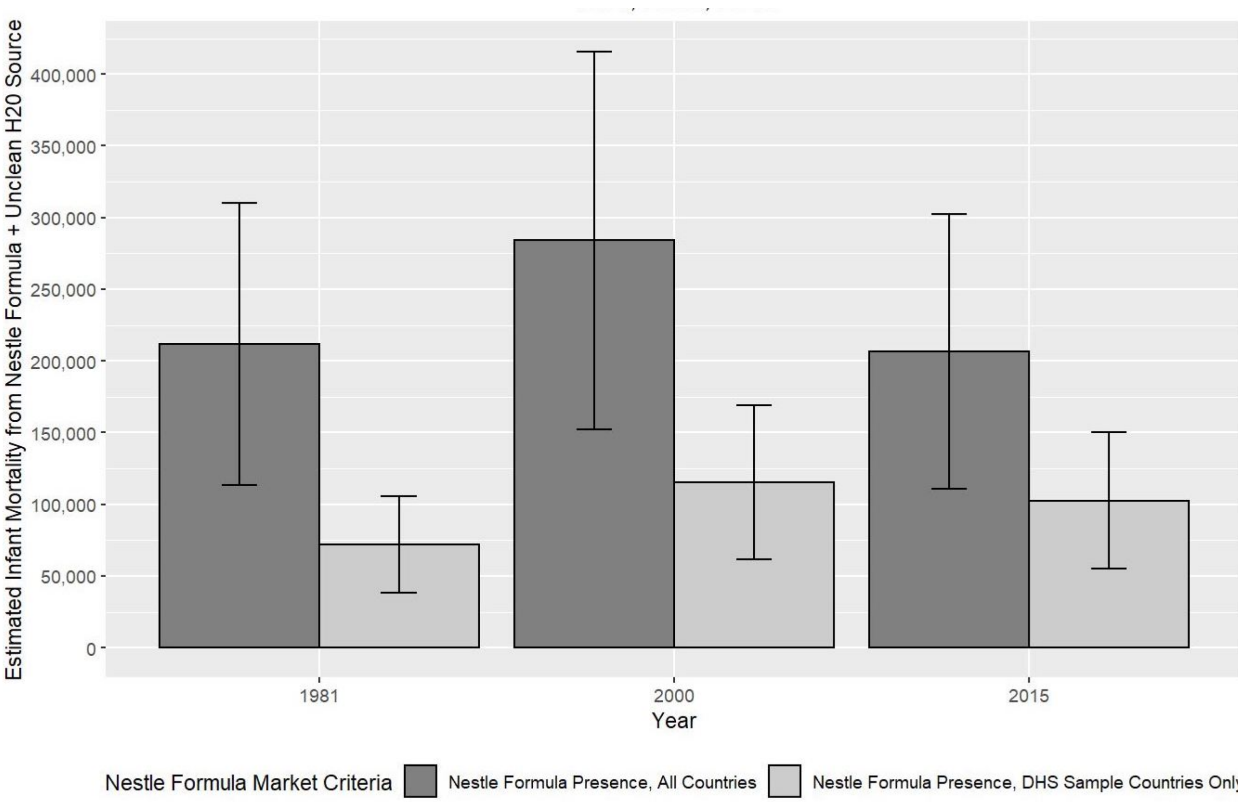


(b) Unclean Water Sample



Notes: Weighted difference-in-differences imputation estimates. "k Years Post-Entry" is the average treatment effect in year k or across years 0-5. "$Pretrend_k$" is the difference between infant mortality in eventually-treated and never-treated units k years prior to Nestlé entry, with all periods before 3 years prior to Nestlé entry as the reference group. Infant birth and mortality data are from the Demographic and Health Surveys, Nestlé entry data taken from Nestlé Annual Investor Reports. All specifications include mother, birth order by gender, and birth year fixed effects, and are weighted equally by country using DHS sample weights. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

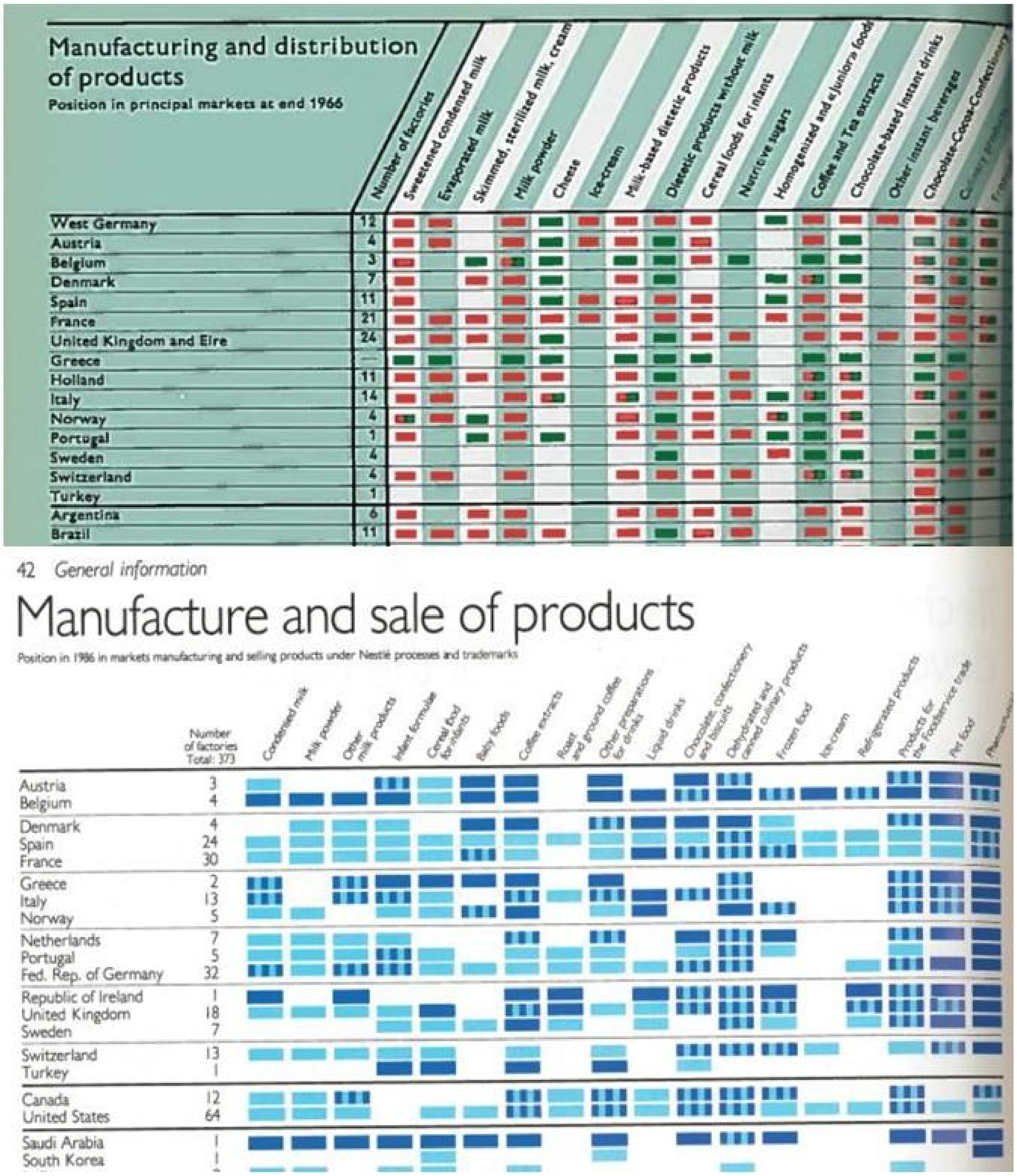
Figure 3: Estimated Infant Mortality from Nestlé Formula Market Entry: 1981, 2000, 2015



Notes: Estimated number of infant deaths attributable to Nestlé formula availability in 1981, 2000, and 2015 for the universe of countries where Nestlé was present (dark grey) and for only those countries in the DHS sample (light grey). Estimates based on average treatment effect among unclean households, as estimated number of births from World Bank Indicators for each country in each year, and either DHS (for 1981) or WHO (for 2000 and 2015) definitions of water quality.

Supplemental Online Appendix

Figure A1: Sample International Market Presence Tables in Nestlé Annual Reports



Notes: Example pages from Nestlé Annual Investor Reports for two years, 1966 and 1986. While market segment definitions change somewhat over time, country-level reporting on segment-specific import and production activity remains constant.

Table A1: Subsample Effects of Nestlé Marketing Formula on Infant Mortality

	(1)	(2)
	1984	
	Clean Water	Unclean Water
0-5 Years Post-Entry	1.09	12.42***
	(2.07)	(3.60)
$Pretrend_1$	-5.16	7.30
	(4.06)	(7.09)
$Pretrend_2$	-6.00	-3.01
	(4.31)	(8.08)
$Pretrend_3$	-0.26	-6.23
	(4.15)	(9.62)
Observations	1,765,279	764,165
Pretrends F-Statistic	1.18	0.82
Pretrends Chi-Squared Statistic	0.27	11.90
Pretrends p-value	0.32	0.48

Standard errors in parentheses
*** p <0.01, ** p <0.05, * p <0.1

Notes: Weighted difference-in-differences imputation estimates for subsamples where Nestlé treatment is restricted to years after 1984 (columns 1-2) and where the sample is restricted to only births born with 20 years of the DHS survey (columns 3-4). "$Pretrend_k$" is the difference between infant mortality in eventually-treated and never-treated units k years prior to Nestlé entry, with all periods before 3 years prior to Nestlé entry as the reference group. Infant birth and mortality data are from the Demographic and Health Surveys; Nestlé entry data are from Nestlé Annual Investor Reports. All specifications include mother, birth order by gender, and birth year fixed effects, and are weighted equally by country using DHS sample weights.