Title: The economic cost consequences of suboptimal infant and young child feeding practices: A scoping review

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Authorship note: At the time we started this study targeting this journal, a LMIC author was not a requirement, and our colleagues from LMIC countries did not feel it was appropriate to join the study at this late stage. Further, it is impractical to have an LMIC author so specific to this topic. Global research expertise on costs of not breastfeeding remains confined to a small number of authors from high income countries. As our review illustrates, there are very few authors from LMICs who have conducted studies in this area and have only done one off studies; there is a general lack of economists interested in the ‘female’ issue of breastfeeding in all countries. Lastly, we are three women who have led research in this area, are regarded as experts in this area and are well placed to conduct the research which purposefully included global coverage. The study was not funded and thus finding another co-author to join an unfunded project without remuneration is unlikely given the pressures of academic institutions across the globe.

3. Keywords and an abbreviated running title

Keywords: suboptimal early feeding, not breastfeeding, cost consequence

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4. 2-4 Key messages, detailing the main points made in the paper

In studies that examine the cost of suboptimal infant feeding, there is considerable diversity in disciplinary approaches and methodologies. Greater interdisciplinary collaboration may strengthen the prioritisation of the economic importance of this topic.

The optimal infant feeding practice of breastfeeding requires maternal time. Yet almost all studies, even those from a ‘societal’ perspective neglect the time costs to mothers.
The cost of suboptimal infant feeding practices is consistently high, around $100 billion USD annually for the US alone. Costs from child cognitive losses make up the bulk of the costs of suboptimal infant feeding practices, and costs from premature maternal deaths are larger than medical costs in the identified studies.

5. Reflexivity and Contributions Statement

We have reflected on how our situation influences our choice of topic and how it was conducted. We are three female researchers from high income countries none of whom was funded to do this research. Our interest and commitment to this research topic arises because as health researchers and practitioners who work to support women to breastfeed, we are concerned at the lack of visibility of breastfeeding in health economics research, and at the relatively low level of global research and policy priority given to investments in enabling breastfeeding according to health authority recommendations. Our experience as clinicians, breastfeeding peer counsellors, and previously breastfeeding mothers motivates us to ensure that the many barriers to breastfeeding including its invisibility and lack of public policy investments are addressed from an evidence base showing its economic importance.

We distributed the work in this article across all of us. Specific contributions are as follows: Conception or design of the work and critical revision of the article: BJ, JS, MB. Article collection and abstraction: JS and MB, BJ served as tie breaker. Analysis, interpretation, and drafting the article: BJ, JS, and MB. All authors have read and agreed to the published version of the manuscript.

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ABSTRACT

Breastfeeding is important for women and children’s health, but less than half of infants worldwide begin life with optimal breastfeeding. A growing literature shows consistently large economic costs of not breastfeeding, with global studies showing economic losses of around US$300 billion globally. However, existing studies are highly diverse in approaches, methods, data sources, and country results.

Building on a landmark 2012 UNICEF UK review focused on high-income countries, we conducted a scoping review to map and characterize the expanding literature and identify future research directions in this research area. We included studies (n=36) in diverse country settings and outcomes for women and children. We used PubMed, Web of Science, EMBASE, MEDLINE, ProQuest, and manual searches of cost of not breastfeeding studies published between 1996 and 2023. Articles were excluded if they were macroeconomic evaluations, did not assign monetary values, or only evaluated breastfeeding or formula feeding costs and not outcomes, or were cost of programs studies.

We found considerable diversity in disciplinary approaches and differences in methodologies. Though there were different cost measurement perspectives (societal, institutional/payer, and individual), all but two excluded the costs of unpaid care. Studies typically measured costs of medical treatment, with more recent studies using dynamic simulation models.
The largest economic costs were derived from lifetime estimates of human capital losses, namely cost of premature death and loss of IQ points. Medical and death costs varied widely depending on method of calculation, but total costs consistently exceeded $US 100 billion annually for the United States, and around $US300 billion in global studies.

Our findings suggest that greater interdisciplinary collaboration is needed particularly to better define infant feeding exposures, and advance comprehensive measurement of costs and outcomes across lifetimes, in order to prioritise breastfeeding as a public health strategy of economic importance.

INTRODUCTION

Globally, less than half of infants begin life with optimal breastfeeding (UNICEF 2019) and this has economic and financial consequences. Breastfeeding is important for public health in all country settings because its premature cessation generates avoidable health risks and costs related to the health and development of children and the health of women. Specifically, breastfeeding is associated with decreased maternal risk for breast and ovarian cancer, myocardial infarction, hypertension, diabetes, and stroke and with decreased infant/child risk for otitis media, gastrointestinal illnesses, obesity, leukaemia, necrotising enterocolitis (NEC), and sudden infant death syndrome (Meek et al. 2022; Rollins 2016; Victora et al. 2016).

These conditions have significant economic costs to families, employers, and society. The 2016 *Lancet* series demonstrated the global loss of life attributable to suboptimal breastfeeding for 96 high, middle, and low income countries was 823,000 child and 20,000 maternal deaths, and resulted in in cognitive losses of US$302 billion annually (Rollins 2016; Victora et al. 2016). The economic cost of lower cognition was modelled using estimates that any breastfeeding duration to 6 months is associated with a ~3 point increase in intelligence quotient (IQ) score, with subsequent effects on educational attainment and adult labor force earnings. Rollins et. al. also demonstrated substantial direct treatment costs of childhood illnesses in high- and middle-income countries.

This accumulation of evidence for health and economic losses attributable to suboptimal breastfeeding results both from improved access to methodological tools involving complex economic modeling software, and to better epidemiological evidence delineating impacts of breastfeeding on health and development outcomes. Further, from 2015 the World Bank acknowledged evidence of inadequate global investment in breastfeeding (Holla-Bhar et al. 2015), with strong statements from its leadership (Hansen 2016) and publication of its Investment Framework for Nutrition in 2017 (Shekar et al. 2017) showing potential economic gains (net present value of ~ US$298 billion annually) of reaching the 2025 global nutrition targets for exclusive breastfeeding, by preventing child cognitive losses and child mortality, with a return of $35 on each dollar invested in increasing breastfeeding (Kakietek et al. 2017). The World Bank analysis also indicated that the global nutrition targets for exclusive breastfeeding were unambitious, signaling that even greater economic gains were feasible if targets were revised (Shekar et al. 2017).
Heightened awareness of the economic costs of not breastfeeding according to WHO/UNICEF global recommendations has spurred development of accessible online tools to measure global and/or country-level impacts (Smith et al. 2023; Stuebe et al. 2017; Walters et al. 2019). The most recent tool for investigating both global and country-level economic impacts of not breastfeeding is a collaboration led by Walters with the international not-for-profit, Alive & Thrive (Walters et al. 2019). This study reported aggregate global economic losses of US$341.3 billion, arising from health system treatment costs (US$1.1 billion annually), premature deaths of women and children (US$53.7 billion), and child cognitive losses (US$285 billion), using an online tool.

Stuebe and colleagues offer an interactive online calculator to estimate the effects of changes in breastfeeding rates on healthcare costs of infectious illnesses for the first year of life. The online tool developed by Smith et al. (2023) identifies the global and country-level quantities of human milk production that are lost at current breastfeeding rates, alongside estimates of quantities of milk produced by women at current breastfeeding rates, and uses market prices to indicate monetary values of these indicators.

These new summative works and tools are a boon to researchers and policymakers as they help assemble the case for global agencies and countries to invest in breastfeeding protection, support, and promotion. However, because of differences in approaches, methods, and data sources, and how costs are identified, measured, and valued, this literature can generate inconsistent or conflicting economic cost estimates at the country level and confusion about their conceptual and empirical basis. No existing review has drawn together the literature on the economic costs of not breastfeeding to help navigate the growing number of disparate and complex cross-disciplinary studies. Thus, this study aimed to bridge this critical gap by comprehensively mapping and summarizing the important features of the existing research and identifying the main implications for future research.

METHODS

We chose to conduct a scoping review because our purpose was to characterize the literature and identify research gaps, which best aligns with the definition of a scoping review (Grant & Booth 2009; Munn et al.). Additionally, there are a relatively small number of very heterogeneous and cross-disciplinary studies, making strict adherence to the PRISMA checklist problematic. Our review follows the ethos of PRISMA by using a documented and structured approach in our review as far as practicable to ensure our mapping and synthesis of the literature is replicable and robust.

We took a multifaceted approach to identifying the recent evidence on the economic costs of not breastfeeding. The basis of our approach was a simplified update and expansion of the first major systematic review of cost of illness studies and breastfeeding performed by Renfrew and colleagues for UNICEF UK (Renfrew et al. 2012). Renfrew’s team used standard economic evaluation techniques identified by Drummond et al. to review cost of illness for ‘the UK and comparable industrial countries’ published between 1950-2010. Renfrew’s study was the most comprehensive analysis at the time that included a thorough review of the relevant economic literature. Since its publication, there have been a number of additional studies - some with newer and more sophisticated economic modeling. Our study built on that report by expanding the scope of the eligible literature, to include a more diverse geography (non-OECD countries), more child health and development outcomes (such as for obesity and chronic disease and
cognitive development), a wider range of study types (including grey literature), and a general updating to include publications since 2010. We also include studies of chronic disease and maternal health outcomes which have utilized advances in computer software and techniques for dynamic modeling. One study used by Renfrew et al. was excluded from this analysis because it was limited to donor milk costs (Wight 2001).

We surveyed the published peer reviewed literature and grey literature from 1996 to 2023 for all analyses which had an abstract in English that put a monetary value on cost savings of breastfeeding, the cost of not breastfeeding, the cost of suboptimal breastfeeding, or the cost of artificial feeding. The year 1996 was selected as the starting point for our study because that is when the landmark paper by Horton et al. (1996) was published. This was the first health economic study to call attention to the cost-effectiveness of maternity services supporting breastfeeding, identifying both the costs and the impacts of breastfeeding promotion programmes.

Our search strategy for relevant literature was as follows. For peer-reviewed literature, we searched PubMed, Web of Science, EMBASE, and MEDLINE, using the following keywords: suboptimal breastfeeding, inadequate breastfeeding, formula, artificial feeding, cost, and cost analysis. For the grey literature, we searched breastfeeding and economic reports produced by national and international agencies including UNICEF, WHO, International Monetary Fund, and the World Bank and we searched dissertation & theses abstracts available through the ProQuest service using their subject categories “breastfeeding & lactation” and “costs”. We also examined references for both the peer-reviewed and grey literature to identify additional potential articles and reports.

Figure 1 summarizes our search process.

Articles were excluded if they:

1) were only a commentary or editorial (Langabeer 2018; Smith 2019);
2) had economically relevant outcomes but did not have a monetary value assigned to them, such as cost minimization studies only reporting hospital length of stay, or the number of potential lives saved (Bhutta et al. 2013);
3) were studies of the cost of programs to increase breastfeeding, often referred to as costing studies (Frick et al. (2011), Carroll et al. (2020); Holla-Bhar et al. (2015)(Renfrew et al 2009);
4) examined only donor human milk (Ganapathy et al. (2012), Hair et al. (2016), Arnold (2002) or only formula feeding (Pennock, 2002) or only infant feeding supplies (Berridge, 2004);
5) had insufficient information included (e.g., were only a conference abstract; (Jegier 2016));
6) could not be retrieved (Riedel 2000); and
7) were a macroeconomic valuation, for example, Smith (1999), Gupta and Khanna (1999), Oshaug and Botten (1994) Hatloy and Oshaug (1997)) which have a different conceptual basis and measurement approach to cost of illness studies, and are considered elsewhere (Smith et al. 2023).

DEFINITIONS
We have provided the definitions used in this literature area for feeding practices, breastfeeding, and early nutrition for ease of reference when comparing studies reviewed. Our study inclusion and exclusion criteria did not consider these definitions when determining eligibility. Our detailed data extraction tool included reporting on infant feeding exposures such as ‘any’ or ‘exclusive’ breastfeeding as these are crucial for interpreting results, and potential upward or downward bias in estimates.

*Suboptimal infant and young child feeding practices* was defined as a feeding behavior and practices that did not meet recommended standards. WHO and UNICEF recommend:

- early initiation of breastfeeding within 1 hour of birth;
- exclusive breastfeeding - meaning no other foods or liquids are provided, including water for the first 6 months of life; and
- introduction of nutritionally-adequate and safe complementary (solid) foods at 6 months together with continued breastfeeding up to 2 years of age or beyond (World Health Organisation (WHO) 2021).

*Suboptimal breastfeeding* was defined as no breastfeeding, or breastfeeding for less than the current recommended duration or exclusivity according to medical definitions set by the WHO. The medical definition within individual papers may have been defined according to country specific organizations. For example, most papers conducted by authors from the US used the American Academy of Pediatrics medical standards (AAP) at the time of their publication.

*Early feeding or early nutrition* refers to the age group 0-36 months.

A longstanding and important issue in epidemiological research on the impacts of not breastfeeding is the precise measurement of ‘breastfeeding’ (see Labbok and Krasovec (1990) and Smith and Harvey (2011)). Breastfeeding in this study was defined both as an infant or young child suckling at the breast of a self-identified woman, and the provision of expressed milk. This definition is the most commonly used definition, although there are others in the published literature (American Academy of Pediatrics et al. 2012; World Health Organization (WHO) 2008).

Table 1 sets out our categorization and definitions of costing approaches evident in the literature. We have included the definition for all four categories although this study excluded macroeconomic papers.

The definitions we used to characterize the disciplinary approaches used in Table 2 were:

1) ‘Epidemiological’: evaluation derived primarily from the identification of comparative costs of treating cases and non-cases of disease based on an early feeding exposure such as not breastfeeding.

2) ‘Health economics’: evaluation derived primarily from the cost consequence of treating a given condition based on an exposure such as not breastfeeding. Cost consequences included direct and indirect costs of disease or mortality and/or used health loss or health gain measures such as disability-adjusted life years (DALY), quality-adjusted life year (QALY), or value of a statistical life (VSL).
3) ‘Nutritional economics’: evaluation derived primarily from the cost consequence of a feeding exposure such as not breastfeeding on cognition losses (loss of IQ points) and lifetime work productivity, from a societal perspective.

PROCEDURES AND ANALYSIS
Each paper was independently reviewed by J.S. and M.B. A shared electronic spreadsheet was used for data extraction. Data extraction used an expanded version of the template used by Renfrew et al. in their 2012 review of cost of illness studies (Renfrew et al. 2012). Data extraction for the review by Renfrew et al included study characteristics, aspects of data and methods, including perspective, treatment cost and outcome measurement, and findings on the economic impact of breastfeeding (Renfrew et al. 2012). We recorded the details of the study purpose, hypothesis, process, disciplinary approach, cost methods used, and outcomes.

Once extraction was complete, the entries were assessed for accuracy, completeness, and consistency by B.J., who also resolved any discrepancies and finalized data extraction. Table 2 summarizes each of the studies reviewed. An expanded review is provided as a supplementary appendix.

Ethical approval was not required by our institutions as our research did not involve human subjects.

RESULTS
We found 90 studies that potentially met the inclusion criteria (Figure 1). We reviewed and excluded 54 studies primarily because they were either macroeconomic evaluations or were studies which only measured the costs of intervention programs. Of the 36 studies included, 25 were additional to those identified in Renfrew et al., as indicated in the summary table (Table 2 and Supplementary Table).

Also, as can be seen in Table 2, the majority of the studies were conducted in the past 15 years, with 24 completed since 2010. Further, Renfrew et al. focused on studies from 4 industrialized countries which excluded the earlier economic studies that identified health costs of suboptimal breastfeeding in developing countries such as India (Gupta & Khanna 1999) and Indonesia (Rohde 1981). Our analysis covered a wider range of study types and reflects 20 individual countries, including 16 in the US, 3 in the UK, and in Spain, and 2 per country in Australia, Mexico, and South Korea. Five studies evaluated more than 1 country, and 2 provided global estimates. The provision of multi-country estimates has increased since 2016 including through grey literature and journal publications by researchers in international agencies and non-government organizations (Kakietek et al. 2017; Rollins 2016; Walters et al. 2016; Walters et al. 2019).

Disciplinary and methodological approaches used in studies have expanded over the period 1995-2023, with recent studies drawing from economics, public health, and health, medical, and nutrition science disciplines, using concepts and methods from epidemiology, health economics, and nutritional economics. Prior to 2010, most studies used an epidemiological frame as the primary disciplinary approach (17 of 36). After 2010, additional disciplinary approaches were more commonly utilized as the primary approach including health economic and nutritional
economics. The specific distribution of primary disciplinary was 17 epidemiologic, 17 health economic, and 2 nutritional economics in the human capital tradition (Hanushek and Woessmann 2008). Health economics, (typically using DALY, QALY or VLS to indicate health loss or gain, disease burden or mortality impacts of not breastfeeding/breastfeeding) was used as a secondary disciplinary lens in 11 of the 36 papers.

Methodological approaches utilized both microeconomic analysis and statistical modeling, categorized here for simplicity as, ‘micro-costing,’ ‘static modeling,’ and ‘dynamic modeling’. Pre-2010, studies used micro-costing methods although a couple of studies from the US and Australia used static modeling. Studies from 2010 forward, used dynamic modeling and incorporated chronic disease at the country and global level. The specific distribution of costing methods used in the studies evaluated were: 12 micro-costing, 18 static modeling, 4 dynamic modeling, and two multi-methods. The two papers that used multiple methods both used the static approach as one of their methods.

The scale and the scope of the studies has also increased since 2010 with more recent studies including maternal health costs of not breastfeeding (Bartick et al. 2017; Bartick et al. 2013). For example, the 1997 Australian study by Drane focused on hospital treatment costs for premature infants, while the 2017 study led by Bartick for the US comprehensively included maternal health and morbidity costs. The specific distribution of the scope of studies is: 15 studies measured child outcomes only, 7 studies measured maternal outcomes only, 13 studies measured both child and maternal outcomes, and 1 study measured the institutional cost of acquiring maternal milk. The distribution of perspectives used included societal (20), institutional/payer (13), and individual (3).

Early cost of not breastfeeding studies focused on the cost impact of short-term acute illnesses such as otitis media and gastrointestinal illness and conditions that occurred in the first year of infant life such as NEC (Ball & Wright 1999; Hyun et al. 2002; Riordan 1997; Weimer 2001). However, with increasing availability of longitudinal data and electronic health records, and simulation modeling, more recent cost studies have included chronic illnesses such as childhood obesity (Bartick & Reinhold 2010; Bartick et al. 2017; Büchner et al. 2008; Mahon et al. 2016; Renfrew et al. 2012; Rollins 2016; Walters et al. 2019) and leukaemia (Bartick & Reinhold 2010; Bartick et al. 2017; Büchner et al. 2008; Mahon et al. 2016; Oliveira et al. 2019; Rollins 2016; Stuebe et al. 2017), as well as maternal breast cancer (Bartick et al. 2017; Bartick et al. 2013; Büchner et al. 2008; Oliveira et al. 2019; Pokhrel et al. 2015; Renfrew et al. 2012; Rollins 2016; Shin 2010; Stuebe et al. 2017; Unar-Munguia et al. 2017; Walters et al. 2019), heart disease (Bartick et al. 2017; Bartick et al. 2013; Oliveira et al. 2019; Stuebe et al. 2017), and diabetes (Bartick et al. 2017; Bartick et al. 2013; Oliveira et al. 2019; Stuebe et al. 2017; Walters et al. 2019).

Technical economic techniques varied across studies. Specifically, 15 studies identified a discount rate, 13 studies did not require discounting, and 8 studies did not explicitly discuss discounting. Twelve studies did not identify a cost year used for their analysis. For sensitivity analyses, 20 studies did not include a sensitivity analysis, 14 did include a sensitivity analysis on at least one portion of their economic model, and 2 were unable to be determined.
Costs varied depending on methodology and perspective. Medical costs were dwarfed by cognitive losses and the economic costs of premature death. The cost of premature death could also vary, depending on if it were measured using the value of a statistical life, or the cost of potential lost earnings, which is much lower. Using different methods, estimates for the annual cost of not breastfeeding for the United States came to the range of $US 100 billion by different estimates. Some estimates used a combination of medical, death, and cognition losses, and the cost of purchasing formula or the resources to produce it (Walters 2019, Rollins 2016). In these, the cognition losses comprised three quarters of the total cost and mortality cost (measured by lost earnings) compromised most of remaining costs. Medical costs were only a tiny fraction of these total costs. A few studies measured the indirect cost of lost earnings for women undergoing treatment for illnesses like breast cancer. Only 2 studies considered the economic cost of unpaid time by women and families in caring for sick children (Bartick et al. 2017; Stuebe et al. 2017).

**DISCUSSION**

This study is the first to review the breadth of the literature on the costs of not breastfeeding since the landmark report by Renfrew et al in 2012. We have mapped the diverse studies at the intersection of breastfeeding and economics between 1996-2023 and widened the scope of that report to include grey literature. We addressed a gap in the current literature on the economic costs of suboptimal feeding by characterising and summarising the key features and findings of the literature including classification of each identified study by approaches and data sources used, study team disciplinary makeup, and costing methods and measurement. We also identified and reviewed some earlier empirical studies and major reports on the costs of not breastfeeding published between 1996-2012 that were not included in or postdated the Renfrew report. We found that since 2012, studies have become more diverse in geography and scope and more multidisciplinary in approach and methodology. They also have increasingly measured societal benefits like increased cognition and preventable deaths of women and children. This likely reflects the increased recognition of breastfeeding as the foundation for optimal population health, a public health and prevention priority, and a widely available, renewable commodity. It also reflects the increased availability of more complex modeling tools and software. Our analysis highlights the need for more engagement from the economics disciplines as many papers used epidemiologic methods as the primary approach and had some technical methodological weaknesses. Our analysis also highlighted a consistent disregard for the economic value of unpaid work, particularly maternal and family time. Thus, this scoping review demonstrates that while the literature has expanded and improved our understanding of the economics of breastfeeding, it needs more interdisciplinary collaboration and improved methods, particularly in the measurement of breastfeeding and maternal health impacts. This improvement will assist policymakers and others to prioritize breastfeeding as a fully funded primary strategy for population health because of its economic and health advantages.

**Increase in Geographic Diversity in Studies**

Geographic diversity in studies is important because of the impact of geography on both costs and health outcomes. We found that most studies (22 of 36) were conducted in the United States (US), Australia, or the United Kingdom (UK). The heavily skewed geographic spread of studies perhaps reflects concerns that among the Organisation for Economic Co-operation and Development (OECD) (Organization for Economic Cooperation and Development (OECD) 2021a), the US has the highest health expenditures (Organization for Economic Cooperation and
Development (OECD) 2021b), worst maternal and child mortality outcomes, and has among the lowest breastfeeding rates (UNICEF 2018). This growing awareness of the health cost implications is reflected in the recommendations of the US Surgeon General’s 2011 Call to Action on Breastfeeding. (United States Department of Health and Human Services 2011) Australia has a mixed public and private health system, with high initiation but short duration of breastfeeding; nevertheless, there is a high level of awareness as the economic benefits of optimal breastfeeding have underpinned its national dietary guidelines for infant feeding since 2003 (National Health and Medical Research Council 2003). The UK have very low breastfeeding rates but a publicly funded health system; hence, studies for the UK focus on the potential cost savings for the National Health System of improving infant feeding practices. Future research should encompass wider ranges of countries to ensure robust and more generalisable cost estimates of the impact of not breastfeeding. These are necessary to reflect the plurality of health system and social contexts that influence health costs and their distribution between the formal and informal health sectors as well as breastfeeding initiation and duration.

Continued Challenges to Breastfeeding Exposure Methodologies

Most cost of not breastfeeding studies had a clear framework for identifying the health impact of breastfeeding/not-breastfeeding, using robustly developed epidemiological methods. However, an important weakness in that area of literature was an unclear definition of the ‘exposed’ population. To some extent this is unavoidable because early feeding practices (e.g. definition of breastfed) are poorly specified in many epidemiological studies so underestimating impacts (Smith & Harvey 2011). This is something that Renfrew et al. 2012 also noted. The difficulty in defining breastfeeding in part arises because randomised trials are unacceptable when the health consequences of not breastfeeding are so profound. Thus, we must rely on well controlled observational studies. A decade later this remains a concern and underscores what Renfrew et al. concluded in 2012 that “Research into the extent of the burden of disease associated with low breastfeeding rates is hampered by data collection methods; this can be addressed by investment in good quality research.” In fact, much of the research agenda Renfrew et al. identified remains unfulfilled in the decade since 2012 due to lack of high-quality epidemiological evidence related to measuring early feeding dose-response exposures, and outcomes. This is despite the ambitions of major review studies in 2016 and 2019 (Rollins et al. 2016; Walters et al. 2019), which drew on several meta-analyses in 2015 that confirmed the exposure-outcome relationships, but highlighted the ongoing lack of investment in high-quality research in this area. Our study supports this conclusion as most studies after 2012 either identify breastfeeding measurement as a limitation to their study findings or assume that existing epidemiological estimates of the impact of breastfeeding/not-breastfeeding are causal. Addressing this challenge requires urgent and increased investment in quality epidemiological research, and cross-disciplinary research collaborations between epidemiologists and health economists.

Expanded availability of cost estimates

Our analysis reveals that the coverage and scope of cost estimates has increased considerably from 2012 when Renfrew et al noted that multiple adverse health outcomes could not be included in their economic quantitative modeling due to limitations of current evidence on prevalence and costs such as for Sudden Infant Death Syndrome (SIDS), cognition losses, and early years obesity. Renfrew et al. also identified a range of other child and maternal health
outcomes that were excluded, despite plausible links to early feeding (asthma, diabetes, leukaemia, coeliac disease, cardiovascular disease, and sepsis in the child, and ovarian cancer and type 2 diabetes in the mother) because data was inadequate to inform an economic analysis. Some gaps have been filled, such as on maternal conditions (Bartick et al. 2017; Bartick et al. 2013). The most recent studies measure the economic impact of not breastfeeding at global levels in both acute illnesses and chronic diseases, as well as maternal and child outcomes. This is a marked improvement in the literature though much work remains to quantify the impact of not breastfeeding on child and maternal health, particularly an emerging area in mental health.

In terms of specific costs estimated, most of the reviewed studies measured the paediatric or maternal medical treatment costs of ‘breastfed’ compared to ‘non-breastfed’ infants with a smaller number measuring cognitive losses and lower productivity of the future labour force, and costs of premature death associated with not breastfeeding. In fact, 34 out of 36 studies measured the direct medical costs of diseases associated with not breastfeeding. Early studies focused narrowly on health sector and treatment costs such as in neonatal intensive care settings while more recent empirical studies measured the broader economic consequences of not breastfeeding related to cognitive development and the cost of premature maternal mortality.

It is notable in the reviewed studies that estimates for cognition losses dwarf treatment costs. For example, for the US, the latter amounted to upwards of SUS 84 billion a year in 2012 dollars, while for Australia it is around SUS 6 billion a year. The UK is estimated to incur cognition losses of around SUS 15-16 billion a year from its low rates of breastfeeding (Rollins et al. 2016; Walters et al. 2019). This approach is aligned with well-established literature on the future income losses of early life malnutrition in low and middle income countries (LMICs) (Lutter & Lutter 2012). For outcomes of not breastfeeding, this is particularly relevant to high income country (HIC) settings where breastfeeding prevalence and duration is low (Victora et al. 2016). Although not as large as paediatric cognition losses, the maternal productivity and mortality costs are also especially pertinent for HIC for the same reason. The economic impact of these factors is important because they underscore the foundational nature of breastfeeding as a building block for population health and as an important tool for maximizing maternal workforce productivity and longevity. These are all necessary to optimal long-term global economic growth and vitality.

Technical and assumption weaknesses

There were several areas of economic technical weaknesses or common assumptions that put limitations on the literature. Specifically, and with few exceptions, studies took perspectives which ignored unpaid maternal time costs associated with different types of early feeding, or the indirect costs to households (e.g. lost wages) caring for sick children associated with not breastfeeding (Jegier et al. 2010; Smith 2019; Smith & Forrester 2013). This choice results in a consistent undervaluing of the economic impact of breastfeeding/not breastfeeding. It also may reflect biases in existing economic methodological norms that minimize or ignore the value of caregiving and unpaid work, an area that is disproportionately provided by or expected of women. There was also a common lack of clarity and consistency about the stakeholder perspective of the study; some studies relied on charges by healthcare providers to estimate disease treatment costs, while others used payments made by insurers. In fact, most health economic studies (11 of 17) took a narrow institutional view that measured direct costs from an insurance or government payer or cost-saving perspective, while a smaller number took a broad societal perspective on the indirect or lifetime economic costs associated with not breastfeeding.
Sometimes, these values were added together to arrive at final cost impact despite their lack of common perspective or source. This is important because of the cost externalities and long timeframes involved and the potential perception of inflated cost measurement.

There was also considerable variability in the estimated cost values due partly to inconsistent application of economic methods. For example, in China estimates of cognition losses from low breastfeeding rates cost the economy between $US 26 billion (Rollins et al.) and $US 60 billion (Walters et al. 2019) a year. From these same studies, estimates were more consistent for Australia at just over $US 6 billion dollars (0.6% of gross national income) and the UK at around $US 15-16 billion (around 0.7% of national income) (Rollins et al. 2016; Walters et al. 2019). The methodological summaries in the expanded Table 2 in the appendix highlight that only a small number of the micro-costing, and static or dynamic modeling studies clearly identified the year or basis for discounting of future values. Taken together, these weaknesses and diverse assumptions make it difficult to compare across studies. Such variation in methods, complexity, and lack of coverage of unpaid work may also cause confusion among readers unfamiliar with epidemiology and economic methods, and points to the need for clear communication with non-specialist audiences.

**Authors disciplinary background and the need for more collaboration**

Lastly, it is worth noting that much of the economic work done in breastfeeding is led by non-economists (e.g. healthcare providers, epidemiologists, public health researchers). This may explain the robustness of the ability to estimate the epidemiologic counts of disease and health impacts. It also may explain the less developed econometric modeling that has been done to date. Less robust econometric modeling particularly limits the ability to extrapolate to the financial, insurance, and tax policy research on obesity and chronic disease and related productivity impacts that is needed for the impacts of low breastfeeding rates to be fully recognized in current economic and health financing policy discussions. It also lends urgency to the need for cross disciplinary collaboration. Collaboration among current breastfeeding researchers and economists would improve our knowledge and ability to account for the impact of low breastfeeding rates on health systems. Addressing such economic methodological issues in the epidemiological literature may also improve the comparability of the economic work to other preventative health measures, such as reducing lead exposure in children, or assisting smoking cessation, and may encourage greater acceptance among policymakers of the findings and importance of breastfeeding as a health policy priority.

**Strengths and Limitations**

This study is the first comprehensive review of economic studies on the value of breastfeeding or the cost of not breastfeeding, and their methodologies, and crosses disciplinary boundaries. It excluded the emerging area of macroeconomic evaluation (Smith et al. 2023), cost-effectiveness studies or economic evaluations of interventions to reduce premature weaning from optimal breastfeeding, which is an important future study.

As indicated by previous reviews, the study is informed by being multidisciplinary; it is conducted by a multidisciplinary and multisectoral, cross country collaboration of academic health economists, working with experienced lactation and health administration practitioners and clinicians. Its scope also included some articles in languages other than English if there was an English abstract. However, the heterogenous literature meant that there was a needed to use
hand-searches as much as systematic database searchers so a weakness is that we may have missed some studies, especially those with no English abstract or translation.

The time period for the review excludes some of earlier pioneering studies in related areas conducted during the 1970s with a focus on developing countries. For example, Oshaug, Almroth, and Berg and their colleagues (Almroth et al. 1979; Berg 1973; Oshaug & Botten 1994) led important early contributions on the economic costs and benefits of formula vs breastfeeding, as did others focusing on specific economic or financial aspects such as McKigney (1971), Popkin (1978), Butz (1978), and Gupta and Rohde (1993).

Our review excludes a small but growing number of economic studies of the costs of policy or program interventions to increase breastfeeding (Carroll et al. 2020; Crossland et al. 2015; Hoddinott et al. 2014; Hoddinott et al. 2015; Moran et al. 2015; Morgan et al. 2015; Relton et al. 2018; Thomson et al. 2012; Washio et al. 2020; Whelan et al. 2014). Some of this emerging research investigates the effects of offering women specific financial incentives for breastfeeding, though the economic or financial incentives created by structural determinants of breastfeeding behaviours is rarely considered (Smith 2015). This is a future area for research which is important for translation of evidence on the costs of not breastfeeding into implementation of cost-effective programs to address the problem.

Conclusions

In the past decade, the low or declining rates of breastfeeding among infants and young children have emerged as an issue of economic as well as public health importance, at global and country level. This study brings new knowledge and insights from mapping and characterising an expanding body of existing economic literature on the cost-consequences of not breastfeeding. It has built on the landmark Renfrew report by identifying new studies in a wider range of country settings, expanding the types of studies that were eligible to include grey literature, and including maternal health outcomes and a wider number of child health and development outcomes. Our review has shown a growing emphasis on cognition and mortality related costs and their magnitude in such studies, assisted by more sophisticated methodologies, wider coverage of countries and health or development outcomes, and more extensive cross disciplinary collaborations of researchers in this area.

While earlier studies focused on preventable paediatric treatment costs, more recent literature shows that the largest economic costs arise from human capital costs - premature deaths of mothers such as from reproductive cancers, and economic losses from poorer cognition among children not breastfed in infancy. Such costs are less visible than treatment costs, and thus may be given less attention by policymakers. While the literature provides clear evidence that increased breastfeeding can mitigate rising trends in health treatment costs, these other larger cost impacts are less understood and require better communication to the public and by policymakers, as well as an enhanced epidemiological base for estimates of exposures to insufficient breastfeeding. This underscores the importance of collaboration among researchers including to explain complex economic simulation methodologies and to translate research findings to policy initiatives. Our review also highlighted the lack of attention to costing the unpaid work burdens of those caring for unwell infants or adults, usually women.

Further, we identified that methodological improvement is needed in the foundational economic techniques in these studies including the clarity and reporting of the study perspective, as well as standardization of the value of money across countries, and consistent use of conventional discounting and inflation adjustment techniques. This also requires more cross-
disciplinary collaboration between researchers and practitioners in epidemiology and public health, with those in health economics.

Taken together, our broad review suggests that there remain important opportunities for useful economic analyses across multiple health outcomes and country settings, and economic perspectives. Such research should prioritise:

- Interdisciplinary approaches and comprehensive conceptual frameworks, including societal as well as health system perspectives, and accounting for unpaid work.
- The framing of breastfeeding within a preventive health paradigm so that use of breastmilk substitutes is the deviation from norm and the appropriate exposure variable.
- Full consideration of human capital, with attention to mortality costs in appropriate balance with medical and financial costs.
- Impacts on maternal health are also a key priority for economic analysis.
- Enhanced economic approaches which account appropriately for price inflation and time discounting of benefits of investments.
- Consistent costing frameworks and methodologies, both across countries and time horizons, and clarifying intangible versus financial costs, as well as greater consistency in the scope and type of costs considered.

These future research directions would expand and strengthen the evidence-base for greater global and country level investments in policies and programs to better enable women to breastfeed.

References


Smith JP. 2019. Counting the cost of not breastfeeding is now easier, but women's unpaid health care work remains invisible. Health Policy Plan, 34: 479-481.


UNICEF. 2018. BREASTFEEDING A Mother’s Gift, for Every Child. UNICEF.


List of Figure, Table, and Supplementary File

Figure 1. Article Inclusion and Exclusion Matrix

90 articles identified by keyword and hand search

- 76 articles peer-reviewed literature
- 8 articles grey literature - organizations
- 6 articles grey literature – dissertations/theses and conference abstracts

- 44 excluded
  - 5 commentaries
  - 8 economically relevant outcomes but did not have a monetary value assigned
  - 14 cost of program studies
  - 4 only measured donor human milk, formula feeding, or infant feeding

- 4 excluded
  - 1 commentary
  - 1 cost of program study
  - 2 macroeconomic evaluations

- 6 excluded
  - 2 only measured formula feeding or infant feeding supplies
  - 3 insufficient information included
  - 1 unable to obtain
Table 1. Definition and Description of Costing Approaches.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Common methods of measurement</th>
<th>Limitations to method</th>
<th>Examples of this type of study</th>
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<tbody>
<tr>
<td>Micro-costing (“bottom up” approach)</td>
<td>Direct measurement of actual financial costs using cost-accounting data.</td>
<td>Relies on risk ratios which may not accurately define infant feeding exposure. Does not have prescriptive, universally accepted methodological approach to defining or measuring costs. May use insurance payment or provider charge data, but neither may represent actual costs. Rarely encompasses costs of mother’s time.</td>
<td>Ball and Wright 1999</td>
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<td>Dynamic modelling (“top down” simulation approach)</td>
<td>Builds on the static modelling, but using a dynamic probabilistic (eg Markov chain) computer simulation (eg Monte Carlo) model. Usually measures cost impacts of multiple diseases in a large hypothethical population of women and/or</td>
<td>As above for static computation. Relies on probabilistic assumptions about risk ratios by age Discounting rate choices more influential on cost outcomes.</td>
<td>Bartick et al. 2013</td>
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<tr>
<td>Macroeconomic (&quot;Replacement cost; foregone value&quot;)</td>
<td>Cost to a country of replacing maternal human milk at contemporary breastfeeding rates with breastmilk substitutes or donor human milk. Suboptimal breastfeeding cost may be calculated by subtracting this cost from the cost at an ideal or target breastfeeding rate, which would be the value of “lost” milk due to low breastfeeding rates.</td>
<td>Relies accurately defining infant feeding exposure. Willingness to pay as a measure of value may not capture utility, or social value. Prices and valuation based on willingness to pay may understate the economic value of breastmilk due to imperfect scientific knowledge of the health impacts of formula feeding. The cost of women’s time to breastfeed or express donor milk is not accounted for so it measures gross not net value-added.</td>
<td>Aguayo and Ross 2002, Smith 2013</td>
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Table 2. Summary of Reviewed Articles

<table>
<thead>
<tr>
<th>Author and Date</th>
<th>Country</th>
<th>Disciplinary Approach, Methodology, and Perspective</th>
<th>Breastfeeding or Formula Milk Exposure Measured</th>
<th>Cost Outcomes Measured</th>
<th>Outcomes</th>
<th>Main Findings</th>
<th>Author stated limitation</th>
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<tr>
<td>Horton et al., 1996</td>
<td>Brazil, Honduras, Mexico</td>
<td>Disciplinary Approach Primary: Health Economics Secondary: None Methodological Approach Static Modelling Perspective Societal</td>
<td>1) Breastfeeding practices in hospital 2) Breastfeeding at follow-up (1 month for all countries, 2 months in Brazil, 3 months in Honduras, and 4 months in Mexico)</td>
<td>1) Annual cost of breastfeeding promotion program 2) Annual cost per birth 3) Incremental cost per birth 4) Net cost per diarrheal case averted 5) Net cost per diarrheal death averted 6) DALY gained from diarrheal cases and deaths averted 7) Summary of comparison costs per case and costs per death for other intervention programs</td>
<td>Pediatrics Outcomes 1) Diarrhea Maternal Outcomes None Other Outcomes 1) DALY gained</td>
<td>1) Cost per birth in the control hospitals ranged from $0.09 to $8.74 and in the program hospitals from $2.70-$11.47. 2) Programs that focus on reducing formula feeding cost $0.30 to $0.40 per birth and generate reduced cases and deaths, and gain DALY respectively of $0.65-$1.10, $100-$200, and $2-$4. 3) Programs that have already eliminated formula that invest $2-$3 per birth can generate reduced cases and deaths, and gain DALY respectively of $3.50-$6.75, $550-$800, and $200-$400</td>
<td>Wherever a choice was available, the authors chose to use a conservative measure for estimates of morbidity, mortality, DALY, breastfeeding impact and cost. For example, their estimates were lower for disease and death than other literature estimates. This raises the risk that the findings are an underestimate from the true impact of breastfeeding on diarrheal morbidity and mortality.</td>
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<td>Author and Date</td>
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<td>Disciplinary Approach, Methodology, and Perspective</td>
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<tr>
<td>Drane, 1997</td>
<td>Australia</td>
<td>Disciplinary Approach: Epidemiological Primary: Secondary: None Methodological Approach: Static Modelling Perspective: Societal</td>
<td>Prevalence of exclusive breastfeeding at 3 months</td>
<td>$12-$19.</td>
<td>Pediatrics Outcomes 1) NEC in LBW 2) Gastrointestinal Illness in term 3) Eczema in term 4) Eczema in term 5) Insulin dependent diabetes in children and adolescents 6) IQ in LBW Maternal Outcomes None Other Outcomes None</td>
<td>1) $11.75 million cost savings for health and social service systems with increase from 60% to 80% exclusive breastfeeding at 3 months 2) $14.79 cost per QALY for the cheap lactation support model to $58.32 cost per QALY for the expensive lactation support model for preterm infants</td>
<td>The analysis is likely an underestimate of the economic impact because the analysis relied on precision of published estimates. Breastfeeding is often poorly defined in the literature (e.g., any, exclusive, total duration) and the estimates available may underestimate the impact of breastfeeding.</td>
</tr>
<tr>
<td>Hoey and Ware, 1997</td>
<td>United States</td>
<td>Disciplinary Approach: Health Economics Primary: None Methodological Approach: Micro-costing Perspective</td>
<td>Breastfed or Formula fed exclusively for 6 months of life</td>
<td>1) Total utilization and costs on fee for service schedule for office visits by feeding type 2) Total utilization and costs for hospitalization</td>
<td>Pediatrics Outcomes 1) Visits to the office for medical care 2) Prescriptions 3) Hospitalizations Maternal Outcomes None Other Outcomes None</td>
<td>1) Formula fed infants cost the health plan $200 more on average per infant for during the first year of life. This difference was not statistically significant. 1) Small sample size 2) Unable to control for demographic variance between infant feeding types 3) Did not measure</td>
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<td>Montgomery and Splett, 1997</td>
<td>United States</td>
<td>Disciplinary Approach: Primary: Health Economics Secondary: None</td>
<td>Breastfed exclusively for at least 3 months of life or Formula fed exclusively for the first 6 months of life</td>
<td>1) Total food costs by feeding type 3) Total utilization and costs for prescriptions by feeding type</td>
<td>Pediatrics Outcomes 1) Health claims paid by Medicaid 2) Formula and cereal costs incurred by WIC</td>
<td>1) Compared to formula-fed infants, breastfed infants saved WIC and Medicaid US$478 per infant before accounting for the formula rebate and US$161 after accounting for the formula rebate. 2) Breastfed infants saved Medicaid a not statistically significant US$112 per infant in the first 6 months of life. 3) The combined cost for WIC and Medicaid to the taxpayer</td>
<td>1) Medicaid data was incomplete and did not allow for capture of costs from plans that paid in non-fee for service methods like health maintenance organizations 2) WIC costs were tied to use of the voucher which may not always be captured</td>
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<td>Riordan, 1997</td>
<td>United States</td>
<td>Disciplinary Approach: Epidemiological Primary: None Secondary: None</td>
<td>Methodological Approach: Static Modelling Perspective: Societal</td>
<td>Not explicitly stated (potentially varied by condition)</td>
<td>1) Cost savings to health system for 4 pediatric health conditions 2) Marginal cost to WIC for formula package</td>
<td>Pediatrics Outcomes 1) Diarrhoeal/Gastrointestinal illness in first year of life 2) RSV in first year of life 3) Otitis Media in first year of life 4) Insulin dependent diabetes in childhood</td>
<td>was statistically lower for breastfed infants (US$795) compared to formula fed infants (US$956).</td>
</tr>
<tr>
<td>Ball and Wright, 1999</td>
<td>Scotland and United States</td>
<td>Disciplinary Approach: Breastfeeding exposure during the</td>
<td>Pediatrics Outcomes 1) Lower</td>
<td>1) Total utilization and costs</td>
<td>The analysis is likely an underestimate of the economic impact because the analysis relied on precision of published estimates. Breastfeeding is often poorly defined in the literature (e.g., any, exclusive, total duration) and the estimates available may underestimate the impact of breastfeeding.</td>
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<td>Barton, Danek, and Owens, 2001</td>
<td>United States</td>
<td>Health Economics Primary: Health Economics Secondary: None</td>
<td>Exclusive breastfeeding or formula feeding during the NICU stay</td>
<td>1) Direct variable costs to the hospital 2) Net revenue to the hospital 3) Length of stay in days</td>
<td>Pediatrics Outcomes 1) Weight gain 2) Length of stay 3) Days of parenteral nutrition Maternal Outcomes None Other Outcomes None</td>
<td>1) Compared to infants exclusively breastfed during the NICU stay, formula fed infants had excess direct cost of approximately US$3300 dollars and higher net revenue of approximately US$ 10,800. Neither</td>
<td>the use of cost data from a single site.</td>
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<td>States</td>
<td>Health Economics Secondary: None</td>
<td>first 3 months of life (never, partial, exclusive)</td>
<td>direct costs from practice records 2) Total utilization and contractual daily rate for hospitalization from hospital records 3) Total utilization and costs for prescriptions from pharmacy records 4) Total utilization and costs for radiographs from hospital records</td>
<td>respiratory tract infection 2) Otitis media 3) Gastrointestinal infection Maternal Outcomes None Other Outcomes None</td>
<td>exclusively breastfed for 3 months, infants not breastfed had excess costs of between $331 to $475 during the 1st year of life.</td>
<td>the use of cost data from a single site.</td>
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<td>Weimer, 2001</td>
<td>United States</td>
<td>Disciplinary Approach Primary: Epidemiological Secondary: Health Economics Methodological Approach Static Modelling Perspective Societal</td>
<td>Prevalence of in-hospital breastfeeding and prevalence of any breastfeeding at 6 months</td>
<td>1) Excess cases and cost savings to health system for 3 pediatric health conditions 2) Cost savings due to parental time and lost wages 3) Cost of premature death</td>
<td>Pediatrics Outcomes 1) Diarrheal/Gastrointestinal Illness in first year of life 2) Otitis Media in first 6 months of life 3) NEC during NICU stay 4) NEC deaths Maternal Outcomes 1) Parental lost earnings Other Outcomes None</td>
<td>1) $3.1 billion cost savings attributable to preventable NEC death 2) $2.5 billion cost savings due to direct medical and indirect non-medical costs related to 3 pediatric illnesses</td>
<td>The analysis is likely an underestimate of the economic impact because the analysis relied on precision of published estimates. Breastfeeding is often poorly defined in the literature (e.g., any, exclusive, total duration) and the estimates available may underestimate the impact of breastfeeding.</td>
</tr>
<tr>
<td>Hyun et al., 2002</td>
<td>South Korea</td>
<td>Disciplinary Approach Primary: Health Economics Secondary: None Methodological Approach Micro-</td>
<td>Breastfeeding and formula feeding during the first year of life</td>
<td>1) Cost of formula 2) Cost of formula supplies including bottles, teats, cleansers, sterilizers, brushes, cases for</td>
<td>Pediatrics Outcomes 1) Respiratory disease (&quot;cold&quot;) 2) Otitis media 3) Gastrointestinal disease 4) Allergy Maternal Outcomes None</td>
<td>1) Compared to breastfed infants, formula fed infants cost an extra ¥1.73 million per infant during the first year of life.</td>
<td>The article was not in English and thus this was not able to be determined.</td>
</tr>
<tr>
<td>Author and Date</td>
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<td>Smith, Thompson, Ellwood, 2002</td>
<td>Australia</td>
<td>Disciplinary Approach: Health Economics Secondary: None</td>
<td>Exclusive breastfeeding, predominant breastfeeding, and formula feeding for the first 24 weeks of life</td>
<td>dried formula, and washing liquid 3) Cases and hospital costs for 4 pediatrics illnesses. 4) Additional food costs for lactating mother 5) Cost of maternal absenteeism due to illness</td>
<td>1) Food Other Outcomes 1) Formula 2) Bottles 3) Washing liquid 4) Sterilizers 5) Brushes 6) Teats 7) Case for dried formula</td>
<td>2) The mean cost of formula feeding was ₩ 1,870,125 compared to extra food costs for lactation of ₩ 203,004 during the first year of life. 3) Excess medical cost for formula fed infants was ₩ 62,920 for respiratory illnesses</td>
<td>The modeling matched hospital data to population risk estimates which may underestimate the impact of feeding type. The literature on the impact of breastfeeding versus formula feeding includes a lack of precision for duration and exclusivity</td>
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<tr>
<td>Author and Date</td>
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<td>Cattaneo et al., 2006</td>
<td>Italy</td>
<td><strong>Disciplinary Approach</strong>&lt;br&gt;Primary: Health Economics&lt;br&gt;Secondary: None</td>
<td><strong>Methodological Approach</strong>&lt;br&gt;Micro-costing&lt;br&gt;Perspective Individual</td>
<td>Breastfeeding and formula feeding during the first year of life</td>
<td><strong>Pediatrics Outcomes</strong>&lt;br&gt;1) Episodes of care for conditions potentially related to breastfeeding or formula feeding (e.g., not related to congenital anomalies or accidents/trauma)</td>
<td><strong>Maternal Outcomes</strong> None</td>
<td><strong>Other Outcomes</strong> None</td>
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<td>1) Cost paid by the family for inpatient, outpatient, and emergency hospital care&lt;br&gt;2) Cost paid by the family for private pediatrician visits&lt;br&gt;3) Cost paid by the family for drugs from the pharmacy&lt;br&gt;4) Estimated family cost for formula using market</td>
<td>1) Fully breastfed infants at 3 months had a lower cost of ambulatory care (€34.69 versus €54.59 per infant/year) and hospital (€133.53 versus €254.03 per infant/year) health care compared to infants not breastfed or not fully breastfed.&lt;br&gt;2) Fully breast fed infants had statistically lower utilization of ambulatory care</td>
<td>measurement error due to the inability to cost healthcare visits not paid by the family was the primary limitation stated. Missclassification error on infant feeding type was the second limitation because infant feeding data relied on self-report.</td>
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which may mean an underestimate of the impact of early weaning on the risk of illness. The economic is limited to hospital costs and thus does not account for indirect and intangible costs.
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<tr>
<td>Büchner, Hoekstra, van Rossum, 2008</td>
<td>Netherlands</td>
<td><strong>Disciplinary Approach</strong>&lt;br&gt;Primary: Epidemiological&lt;br&gt;Secondary: Health Economics&lt;br&gt;<strong>Methodological Approach</strong>&lt;br&gt;Static Modelling&lt;br&gt;<strong>Perspective</strong>&lt;br&gt;Societal</td>
<td>Prevalence of any breastfeeding through 6 months (measured monthly).&lt;br&gt;1) Excess cases and cost savings to health system for 8 pediatric health conditions&lt;br&gt;2) Excess cases and cost savings to health system for 3 maternal health conditions&lt;br&gt;3) Change in DALY per Pediatrics Outcomes&lt;br&gt;1) Otitis media&lt;br&gt;2) Gastrointestinal infection&lt;br&gt;3) Asthma&lt;br&gt;4) Respiratory infection&lt;br&gt;5) Eczema&lt;br&gt;6) Chron's disease&lt;br&gt;7) Leukemia&lt;br&gt;8) Obesity&lt;br&gt;Maternal Outcomes&lt;br&gt;1) Rheumatic arthritis&lt;br&gt;2) Premenopausal breast cancer</td>
<td>Prices and number of days of formula feeding</td>
<td>and hospital healthcare. 3) The median cost for formula per infant per year was €247.90. 4) After adjusting for other factors that impact cost, breastfeeding for an additional month reduced the cost of healthcare by €20.79 and the cost of healthcare plus formula costs by €144.36.</td>
<td>Model simulations use many assumptions and relies on precision of published estimates. Breastfeeding is often poorly defined in the literature (e.g., any, exclusive, total duration) and the model</td>
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<td>Author and Date</td>
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<td>Bartick and Reinhold, 2010</td>
<td>United States</td>
<td>Disciplinary Approach: Primary: Epidemiological Secondary: Health Economics Methodological Approach: Static Modelling Perspective: Societal</td>
<td>Any and exclusive breastfeeding were modeled for up to 12 months of age</td>
<td>$1,000 newborns 4) Change in health care costs per newborn</td>
<td>3) Ovarian cancer Other Outcomes None</td>
<td>savings of 250 euro per newborn. 3) Worst Case: 100% formula feeding generates a loss in DALY of 25 per 1000 newborns and excess health care cost of 220 euro per newborn. 4) A 5% shift in current breastfeeding behavior would generate a cost savings of 20 euro per newborn and .002 DALY gain per newborn.</td>
<td>could not capture impact of mixed feeding.</td>
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**Outcomes:**

- **Pediatrics Outcomes**
  - 1) Gastroenteritis
  - 2) Lower respiratory track illness
  - 3) Otitis media
  - 4) NEC
  - 5) SIDS
  - 6) Obesity
  - 7) Atopic dermatitis
  - 8) Asthma
  - 9) Leukemia
  - 10) Type 1 Diabetes

- **Maternal Outcomes**
  - None

**Main Findings:**

- 1) If 90% of US families met medical recommendations to breastfeed exclusively for 6 months, we would see cost savings of $13 billion and prevent 911 excess deaths.
- 2) Cost savings include: $9.6 billion for premature

**Author stated limitation:**

Model simulations use many assumptions and relies on precision of published estimates. Breastfeeding is often poorly defined in the literature (e.g., any, exclusive, total duration).
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<tr>
<td>Jegier et al., 2010</td>
<td>United States</td>
<td><strong>Disciplinary Approach</strong>&lt;br&gt;Primary: Health Economics Secondary: None</td>
<td>Not applicable</td>
<td>1) Cost per 100 mL of human milk for mothers of VLBW infants during the NICU stay</td>
<td>Pediatrics Outcomes&lt;br&gt;No outcomes</td>
<td>1) The cost per 100mL of human milk was $0.95-$1.55 excluding maternal opportunity cost and was $2.60 to $6.18 including maternal opportunity cost. 2) Mean daily milk output for mothers of VLBW infants was 558.2mL (SD: 320.7) and mean time spent pumping was 98.7 minutes (SD: 38.6). 3) The cost per 100mL was most sensitive to the cost of the breast pump rental and the breast pump kit.</td>
<td>The analysis was limited to only those items universally required by all mothers for the provision of human milk to a NICU infant.</td>
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<tr>
<td>Shin, 2010</td>
<td>South Korea</td>
<td><strong>Disciplinary Approach</strong>&lt;br&gt;Primary: Epidemiological Secondary: Health</td>
<td>Exclusive breastfeeding</td>
<td>1) Cost of formula 2) Cost of formula supplies including bottles,</td>
<td>Pediatrics Outcomes&lt;br&gt;1) Otitis media 2) Pneumonia 3) Other respiratory infections</td>
<td>By increasing exclusive breastfeeding rates from 35% to 50%, 1) ₩216.4</td>
<td>The article was not in English and thus this was not able to be</td>
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<td>Author and Date</td>
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<td>Disciplinary Approach, Methodology, and Perspective</td>
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<tr>
<td>Renfrew et al., 2012</td>
<td>UK</td>
<td><strong>Disciplinary Approach</strong> Primary: Epidemiological Secondary: Health Economics</td>
<td>Any and exclusive breastfeeding were modeled for up to 6 months of age</td>
<td>1) Excess cases and direct treatment costs for 5 pediatrics illnesses. 2) Excess cases and direct treatment costs for 1</td>
<td><strong>Pediatrics Outcomes</strong> 1) Gastroenteritis 2) Respiratory disease 3) Otitis media 4) NEC 5) SIDS 6) Obesity 7) IQ</td>
<td>1) Improving breastfeeding would result in avoiding £17 million in health costs for infant illness and £31 million in incremental</td>
<td>Model simulations use many assumptions and relies on precision of published estimates. Breastfeeding is often</td>
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<td></td>
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<td><strong>Methodological Approach</strong></td>
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<td><strong>Perspective</strong> Societal</td>
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<td>Economics and Macroeconomics</td>
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<td><strong>Methodological Approach</strong> Static Modelling</td>
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- **Main Findings**

  1. Excess cases and hospital costs, and hospital days for 7 pediatrics illnesses.
  2. Excess cases, hospital costs, and hospital days for 3 maternal illnesses.
  3. Cost of maternal absenteeism due to illness.
  4. Gastroenteritis
  5. Urinary tract infection
  6. Sepsis
  7. NEC

- **Other Outcomes**

  1. Formula
  2. Bottles
  3. Cleansers
  4. Bottle sterilizers
  5. Brushes
  6. Clamps

- **Cost Outcomes**

  - to ₩407.5 billion wons can be saved per year overall.
  - to ₩162 to ₩294 billion wons can be saved per year related to formula and formula equipment.
  - to ₩7.9 to ₩13.8 billion wons can be saved per year related to infant illness.
  - to ₩24.8 to ₩57.7 billion wons can be saved per year related to maternal illness.
  - to ₩21.6 to ₩42.5 billion wons can be saved per year related to maternal absenteeism from work.
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<th>Author and Date</th>
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<tbody>
<tr>
<td>Bartick et al., 2013</td>
<td>United States</td>
<td>Static Modelling, Societal Perspective</td>
<td>maternal illness.</td>
<td>Outcomes 1) Breast cancer</td>
<td>None</td>
<td>Benefit would be gained annually among 1st time mothers. 2) Improving breastfeeding would annually avoid £4.7 million in family cost and £1.3 million QALYs. 3) Future research is needed on additional maternal and infant health conditions and improved methodological and data measurement is needed in breastfeeding research.</td>
<td>Poorly defined in the literature (e.g., any, exclusive, total duration)</td>
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<td></td>
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<td>Dynamic Modelling, Epidemiological Perspective</td>
<td>breastfeeding rates in 2008 compared to a defined optimal breastfeeding rate of 90% breastfed for 12 months with 40% of those continuing to</td>
<td>Pediatrics Outcomes None</td>
<td>Maternal Outcomes 1) Breast cancer 2) Premenopausal ovarian cancer 3) Type 2 diabetes 4) Hypertension 5) Myocardial infarction 6) Premature</td>
<td>1) Suboptimal breastfeeding results in statistically significant excess cases of breast cancer (4,981), hypertension (53,847), and myocardial infarction</td>
<td>Model simulations use many assumptions and rely on precision of published estimates. Breastfeeding in the published literature is often poorly defined.</td>
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<td>Jegier et al, 2013</td>
<td>United States</td>
<td><strong>Disciplinary Approach</strong>&lt;br&gt;Primary: Health Economics&lt;br&gt;Secondary: None</td>
<td>Societal breastfeeding up to 18 months.</td>
<td>reported in the literature for 5 maternal conditions&lt;br&gt;4) Cost of premature death, defined as death before age 70, using value of a statistical life cost methodology</td>
<td>death&lt;br&gt;<em>Other Outcomes</em> None</td>
<td>(13,946).&lt;br&gt;2) The cost of suboptimal breastfeeding is $17.4 billion in cost to society resulting from premature death, $733.7 million in direct medical costs, and $126.1 million in indirect costs.</td>
<td>defined (e.g., any, exclusive, total duration). Complete cost from all perspectives, particularly maternal time, was not able to be measured</td>
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</table>

1) Cost per 100 mL of human milk from the infant's mother for VLBW infants during the NICU stay<br>2) Cost per 100 mL of preterm formula for VLBW infants during the NICU stay<br>3) Cost per 100 mL of donor human milk for VLBW<br>**Pediatrics Outcomes** None<br>**Maternal Outcomes** None<br>**Other Outcomes**<br>1) Pump rental<br>2) Pump kit<br>3) Milk containers<br>1) The median cost to the hospital per 100mL of human milk was US$0.51 for those who produced >700mL per day to US$7.93 for those who produced <100mL per day.<br>2) Providing a pump, kit and containers for mothers who produced at least 100 mL per day cost the hospital less...
Ma, Brewer-Asling, Magnus, 2013  
**United States**  
**Disciplinary Approach**  
Primary: Epidemiological  
Secondary: Health Economics  
**Methodological Approach**  
Static Modelling  
**Perspective**  
Societal  

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<td></td>
<td>Any and exclusive breastfeeding were modeled for up to 12 months of age</td>
<td>Infants during the NICU stay</td>
<td>than the hospital would pay to procure donor human milk (US$14.84 per 100mL) and commercial preterm formula ($3.18 per 100mL). 3) The cost per 100mL of human milk was most sensitive to the cost of the containers, with cost increasing 55% when container cost was doubled and 109% when container cost was tripled.</td>
<td></td>
<td>Model simulations use many assumptions and relies on precision of published estimates. Breastfeeding is often poorly defined in the literature (e.g., any,</td>
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</table>

1) Excess cases, direct costs, and indirect costs for 3 pediatric illnesses. 2) Excess cases and VSL costs of premature death for 3 pediatric conditions.  

**Pediatrics Outcomes**  
1) Gastroenteritis  
2) Lower respiratory track illness  
3) NEC  
4) SIDS  

**Maternal Outcomes**  
None  

**Other Outcomes**  
None  

1) If 90% of Louisiana families met medical recommendations to breastfeed exclusively for 6 months, we would see cost savings of $216 million and prevent 18 infant deaths.
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<td>Patel et al, 2013</td>
<td>United States</td>
<td><strong>Disciplinary Approach</strong> Primary: Health Economics Secondary: None <strong>Methodological Approach</strong> Micro-costing <strong>Perspective</strong> Institutional (Hospital)</td>
<td>1) Average daily and cumulative dose of human milk in on day of life 28 during the NICU stay</td>
<td>1) Cost for each chargeable item during the infant's hospital stay</td>
<td><strong>Pediatrics Outcomes</strong> 1) Sepsis <strong>Maternal Outcomes</strong> None <strong>Other Outcomes</strong> None</td>
<td>1) Increasing average daily dose of human milk at 28 days of life reduced the risk of sepsis by 1.9% (p=0.008). 2) Infants who had an average daily dose of human milk at 28 days of life of 50mL/kg/day or more had the statistically lowest hospital costs (adjusted costs US$114,870 ± US$24,782) compared to those who received &lt;25mL/kg/day (adjusted costs US$146,384 ± US$38,988).</td>
<td>This was a single-center study and thus may not be generalizable to other centers and the selection of day 28 as the interval to measure average daily dose of human milk may not be the only or best interval to capture protection from sepsis.</td>
</tr>
<tr>
<td>Colcher o et al., 2015</td>
<td>Mexico</td>
<td><strong>Disciplinary Approach</strong> Primary: Epidemiological Secondary: Health</td>
<td>Any and exclusive breastfeeding, partial breastfeeding, and formula</td>
<td>1) Fixed treatment costs, and variable treatment costs for 5 pediatrics</td>
<td><strong>Pediatrics Outcomes</strong> 1) Gastroenteritis 2) Lower respiratory track illness 3) Upper</td>
<td>1) Inadequate breastfeeding costs $746.6 million to $2.42 billion, Model simulations use many assumptions and relies on precision</td>
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<td>Johnson et al., 2015</td>
<td>United States</td>
<td>Economics Static Modelling Societal</td>
<td>feeding at 3 days of life, from 0-6 months and from 6-12 months. illnesses. 2) Excess cases and costs of premature death for 5 pediatric conditions and sudden infant death syndrome. 3) Cost of formula</td>
<td>respiratory track illness 4) NEC 5) Otitis media 6) SIDS Maternal Outcomes None Other Outcomes 1) Formula</td>
<td>where infant formula accounts for 11-38% of total costs (2012 dollars). 1) The marginal cost of NEC on the hospital stay was US$43,818 after controlling for patient factors, NEC risk, and dose of human milk received during days 1-14. 2) Each of published estimates. Breastfeeding is often poorly defined in the literature (e.g., any, exclusive, total duration). Incidence and mortality data in Mexico is not reported by month of age which led to authors having to create two age categories and estimate for those categories.</td>
<td>This was a single center study and thus may not be generalizable to other centers. The presence of other morbidities was not controlled for which may inflate the...</td>
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<td>Pokhrel et al., 2015</td>
<td>UK</td>
<td><strong>Disciplinary Approach</strong>&lt;br&gt;Primary: Epidemiological&lt;br&gt;Secondary: Health Economics&lt;br&gt;<strong>Methodological Approach</strong>&lt;br&gt;Static and dynamic modelling</td>
<td>a) Exclusive breastfeeding at 4 months&lt;br&gt;b) Any breast milk at discharge from the NICU&lt;br&gt;c) Lifetime months of any breastfeeding</td>
<td>1) Excess cases and direct treatment costs for 4 pediatrics illnesses. 2) Excess cases and direct treatment costs for 1 maternal illness. 3) QALY gained, and it associated monetary value using</td>
<td>Pediatrics Outcomes&lt;br&gt;1) Gastroenteritis&lt;br&gt;2) Respiratory disease&lt;br&gt;3) Otitis media&lt;br&gt;4) NEC&lt;br&gt;Maternal Outcomes&lt;br&gt;1) Breast cancer&lt;br&gt;Other Outcomes&lt;br&gt;None</td>
<td>ml/kg/day of human milk on days 1-14 of life decreased non-NEC related NICU costs by US$534.</td>
<td>marginal cost impact of NEC. The institution's feeding protocols may have led to the underestimate of the impact of human milk fortifier and formula on both NEC and cost because very few infants in this setting receive either during the first 14 days of life.</td>
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<td>Colaizy et al., 2016</td>
<td>United States</td>
<td><strong>Disciplinary Approach</strong> Primary: Epidemiological Secondary: Health Economics <strong>Methodological Approach</strong> Dynamic Modelling <strong>Perspective</strong> Societal</td>
<td>Current breast milk intake as a proportion of all enteral feeds during the NICU stay and followed until 36 weeks post menstrual age compared to a simulated cohort where 90% of ELBW infants received optimal breast milk intake</td>
<td>willingness to pay per QALY for Breast cancer</td>
<td><strong>Outcomes</strong>&lt;br&gt;1) Hospital direct and indirect medical costs for the NICU stay&lt;br&gt;2) Medicare physician reimbursement for neonatology&lt;br&gt;3) Parental non-medical expenditure for NICU infants&lt;br&gt;4) Death</td>
<td>2) If the number of first time mothers who currently breastfeed for 7-18 months in their lifetime was doubled, over £31 million pounds could be saved from reductions in breast cancer cases and increases in quantity and quality of maternal life.</td>
<td>underestimate the impact of breastfeeding on disease risk.</td>
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<td>defined as 98% or more of enteral feeds being breast milk from the infant's mother.</td>
<td>cost using value of a statistical life cost methodology</td>
<td>current human milk feeding among ELBW infants results in 928 excess cases of NEC and 121 deaths. 3) The cost of NEC for suboptimal compared to optimal human milk feeding for ELBW infants is an additional US$27.1 million in medical costs, US$563,655 in indirect costs, and US$1.5 billion in premature death.</td>
<td>center estimate for breastfeeding rates during the NICU stay which may not reflect the population average. The cost estimates used were significantly lower than other published studies because they were marginal estimates for the cost of NEC after controlling for other factors and morbidities that impact total NICU costs. The estimates for NEC incidence did not include all possible variables and thus may be subject to some residual confounding. Last, the analysis did not</td>
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<td>Mahon et al., 2016</td>
<td>UK</td>
<td><strong>Disciplinary Approach</strong>&lt;br&gt;Primary: Epidemiological&lt;br&gt;Secondary: Health Economics&lt;br&gt;<strong>Methodological Approach</strong>&lt;br&gt;Static Modelling&lt;br&gt;<strong>Perspective</strong>&lt;br&gt;Societal</td>
<td>Current rate of 35% to 100% breastfeeding during the NICU stay and continued exclusive breastfeeding to 6 months</td>
<td>1) Cases averted, cost savings, and QALY gained from 2 pediatric conditions and death that occurs during the NICU stay 2) Cases averted, cost savings, and QALY gained for 4 pediatrics conditions that occur after the NICU stay and 2 illnesses developed later in adulthood 1) NEC during the NICU stay 2) Sepsis during the NICU stay 3) Death during the NICU stay 3) SIDS after the NICU stay 4) Acute otitis media after the NICU stay 5) Leukemia after the NICU stay 6) Neurodevelopmental impairment and disability after the NICU stay 7) Childhood Obesity and its resulting impact on Type 2 diabetes later in life 8) Childhood Obesity and its resulting impact on Coronary Heart Disease later in life</td>
<td>1) The NHS would save £30.1 million and would avert 190 deaths annually if all NICU infants received 100% human milk due to reductions in cases of NEC and sepsis. 2) Total lifetime savings to the NHS if all NICU infants received 100% human milk would be £904 per infant and would gain an average of 0.2 QALY per infant. 3) Per cohort of preterm infants,</td>
<td>(Year of pounds adjusted for inflation not stated)</td>
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<td>Rollins et al., 2016</td>
<td>Brazil, China for medical costs; 96 countries for cognitive loss costs</td>
<td>Disciplinary Approach: Nutritional Economics Secondary: Epidemiological and Health Economics Methodological Approach: Static Modelling Perspective: Societal</td>
<td>Varied by analysis which included exclusive breastfeeding to 6 months and continued breastfeeding for 1-2 years. 1) Cost of lost earnings in billions and as % of GNI 2) Costs of medical treatment for up to 8 pediatric illnesses 3) Pediatric and maternal deaths 4) Environmental resources used to produce formula</td>
<td>premature death for sudden infant death syndrome after the NICU stay.</td>
<td>Other Outcomes None</td>
<td>there would be 238 averted deaths per year which is associated with a reduction in lifetime productivity of £153.4 million.</td>
<td>The analysis is limited by the use of existing literature and the limitations within each of those studies.</td>
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<td>g for 1-2 years would yield health expenditure savings of US$312 million in the US, US$7.8 million in the UK, US$30 million in Urban China, and US$1.8 million in Brazil.</td>
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<td>4) Improving breastfeeding from present levels to 90% meeting medical recommendations would reduce health expenditure by US$2.45 billion in the US, US$22.6 million in urban China, and US$6 million in Brazil.</td>
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<td>5) Improving breastfeeding to 45% meeting medical recommendations would reduce health expenditure by</td>
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<td>Walters et al., 2016</td>
<td>Cambodia, Indonesia, Laos, Myanmar, Timor-Leste, Viet Nam, Thailand</td>
<td>Disciplinary Approach: Primary: Epidemiological Secondary: Health Economics</td>
<td>Simulated exposures to breast milk including 100% receive some up to 6 months, 100% are exclusively breastfeed to 6 months with continued breastfeeding to 2 years, and 90% of women have 2 years of cumulative lactation.</td>
<td>1) Cases, direct treatment costs and indirect family costs for 2 pediatrics illnesses 2) Cases of mortality for 2 pediatric illnesses and 1 maternal illness 3) Potential earnings lost due to lost IQ points 4) Cost of formula 5) Cost of national breastfeeding program</td>
<td>Pediatrics Outcomes 1) Gastroenteritis 2) Acute respiratory track illness (as proxy for pneumonia) 3) IQ</td>
<td>1) Lost potential earnings from cognitive losses in IQ total $1.6 billion per year across all countries. 2) Inadequate breastfeedin generates annual health care treatment costs for diarrhea and acute respiratory illness of $0.3 billion. 3) Inadequate breastfeedin generates 1,749 maternal deaths from breast cancer per year. 4) Implementin g a national breastfeedin program in Viet Nam would avert 200 child deaths and has a 139% return on investment.</td>
<td>Model simulations use many assumptio ns and relies on precision of published estimates and many of those estimates came from high income countries. Breastfeed ing is often poorly defined in the literature (e.g., any, exclusive, total duration). Data was not available in all countries, so they extrapolate d from one country to the others. Cost data was not available on a national level and this they used local cost data and...</td>
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<td>Bartick et al., 2017</td>
<td>United States</td>
<td><strong>Disciplinary Approach</strong>&lt;br&gt;Primary: Epidemiological&lt;br&gt;Secondary: Health Economics</td>
<td>Current rates of any and exclusive breastfeeding and a hypothetical 90% of women breast fed to medical recommendation were modeled for up to 24 months of age for each infant. Lifetime lactation was measured up to 4 years for each mother across all of her births.</td>
<td>1) Excesses case and deaths for 8 pediatric illnesses, 6 maternal illnesses, and sudden infant death syndrome 2) Direct and indirect medical costs for 8 pediatric illnesses and 5 maternal illnesses 3) Indirect non-medical costs for 8 pediatric illnesses and 5 maternal illnesses 4) Costs of premature death (VSL) for 3 pediatric illnesses, and 5 maternal illnesses, and sudden</td>
<td><strong>Pediatrics Outcomes</strong>&lt;br&gt;1) Acute Lymphoblastic Leukemia 2) Acute otitis media 3) Chon’s Disease 4) Ulcerative Colitis 5) Gastroenteritis 6) Lower respiratory tract illness 7) Obesity among non-Hispanic white infants 8) NEC 9) SIDS</td>
<td><strong>Maternal Outcomes</strong>&lt;br&gt;1) Breast cancer 2) Premenopausal ovarian cancer 3) Type 2 diabetes 4) Hypertension 5) Myocardial infarction 6) Premature death</td>
<td><strong>Other Outcomes</strong>&lt;br&gt;None</td>
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</table>

- Disciplinary Approach: **Primary** - Epidemiological, **Secondary** - Health Economics
- Methodological Approach: Dynamic Modelling
- Perspective: Societal

- Costs for premature death (VSL) for 3 pediatric illnesses, and 5 maternal illnesses, and sudden infant death syndrome.
- Outcomes measured include pediatric and maternal illnesses, as well as costs associated with specific health outcomes.
- Main findings highlight the costs associated with suboptimal breastfeeding, including excess cases and deaths for various illnesses, and the economic impact on society.
- The model assumes a causal relationship between breastfeeding and risk reduction, with limitations noted regarding the precision of published estimates and the inability to measure complete costs from all perspectives.
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<tr>
<th>Author and Date</th>
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<th>Breastfeeding or Formula Milk Exposure Measured</th>
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<tbody>
<tr>
<td>Stuebe et al., 2017</td>
<td>United States</td>
<td><strong>Disciplinary Approach</strong>&lt;br&gt;Primary: Epidemiological&lt;br&gt;Secondary: Health Economics&lt;br&gt;<strong>Methodological Approach</strong>&lt;br&gt;Dynamic Modelling&lt;br&gt;<strong>Perspective</strong>&lt;br&gt;Societal</td>
<td>Changes in 10% increments to exclusive breastfeeding from 0 to 6 months and any breastfeeding from 0 to 12 months</td>
<td>infant death syndrome</td>
<td>premature death due to suboptimal breastfeeding was attributable to maternal costs.</td>
<td>though it is possible that some of the relationship may be confounded. The analysis also assumed a steady state of breastfeeding rates even though breastfeeding rates have increased year over year.</td>
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<p>| 1) Excesses case and deaths for 8 pediatric illnesses, 6 maternal illnesses, and sudden infant death syndrome&lt;br&gt;2) Direct and indirect medical costs for 8 pediatric illnesses and 6 maternal illnesses&lt;br&gt;3) Indirect non-medical&lt;br&gt;&lt;br&gt;<strong>Pediatrics Outcomes</strong>&lt;br&gt;1) Acute Lymphoblastic leukemia&lt;br&gt;2) Acute otitis media&lt;br&gt;3) Chron's Disease&lt;br&gt;4) Ulcerative Colitis&lt;br&gt;5) Gastroenteritis&lt;br&gt;6) Lower respiratory track illness&lt;br&gt;7) Obesity among non-Hispanic white infants&lt;br&gt;8) NEC&lt;br&gt;9) SIDS | <strong>Maternal Outcomes</strong>&lt;br&gt;1) Breast cancer&lt;br&gt;2) Premenopausal&lt;br&gt;3) Premature death due to suboptimal breastfeeding was attributable to maternal costs. | Model simulations use many assumptions and relies on precision of published estimates. Breastfeeding in the published literature is often poorly defined (e.g., any, exclusive, total duration). Complete cost from all perspectives, particularly... |</p>
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<td>Unar-Munguia et al., 2017</td>
<td>Mexico</td>
<td><strong>Disciplinary Approach</strong>&lt;br&gt;Primary: Health Economics &lt;br&gt;Secondary: Epidemiological and Health Economics</td>
<td>Current exclusive breastfeeding rates at 6 months and continued breastfeeding between 12 and 36 months was compared to 95% of parous women breastfeeding exclusively for 6 months and</td>
<td>Costs for 8 pediatric illnesses and 6 maternal illnesses 4) Costs of premature death (VSL) for 3 pediatric illnesses, and 6 maternal illnesses, and sudden infant death syndrome</td>
<td><strong>Ovarian cancer</strong>&lt;br&gt;3) Type 2 diabetes&lt;br&gt;4) Hypertension&lt;br&gt;5) Myocardial infarction&lt;br&gt;6) Premature death</td>
<td><strong>Breastfeeding with the degree of difference related to size difference between the current rate of breastfeeding and the proposed optimal rate.</strong></td>
<td><strong>Maternal time and the cost of breast milk replacement, was not able to be measured. In this analysis, fewer simulations were purposefully run to be more conservative to reflect the uncertainty of state level data for the model inputs, especially for premature infant breastfeeding.</strong></td>
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**Pediatrics Outcomes**<br>None

**Maternal Outcomes**<br>1) Breast Cancer

**Other Outcomes**<br>None

1) Suboptimal exclusive breastfeeding at 6 months results in statistically significant excess per 100,000 women of 537 cases of breast cancer, 126 premature deaths, 2,629 DALYs, and Conservatice estimates were used at each decision point which may have resulted in an underestimate of the economic burden of breast cancer due to suboptimal breastfeeding.
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<td></td>
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<td>continued breastfeeding between 12 and 36 months</td>
<td>3) Cost of productivity, defined as foregone wages and short and long term subsidies for women eligible for social security benefits, for the breast cancer patients for morbidity and mortality</td>
<td></td>
<td>US$13.97 million. 2) The total economic cost of suboptimal breastfeeding was US$245 million, 80% of which were attributable to medical costs. 3) Sensitivity analyses demonstrated that increasing the discount rate to 5% would reduce the total economic burden estimates by 50% while using per Capita GDP instead of foregone wage would increase the total economic burden estimates by double.</td>
<td>Further, not all costs could be measured which might also contribute to an underestimate. Third, the model used literature estimates which may not perfectly capture breast cancer incidence and mortality as well as the impact of breastfeeding on breast cancer. Last, the model had some overlap because there was not information available that would delineate the number of women who breastfeed exclusively for the first</td>
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<td>Siregar, Pitiyan, Walters, 2018</td>
<td>Indonesia</td>
<td><strong>Disciplinary Approach</strong>&lt;br&gt;Primary: Health Economics&lt;br&gt;Secondary: Epidemiological&lt;br&gt;<strong>Methodological Approach</strong>&lt;br&gt;Static Modelling&lt;br&gt;<strong>Perspective</strong>&lt;br&gt;Societal</td>
<td>Current breastfeeding rates was compared to breastfeeding to medical recommendation.</td>
<td>1) Excess cases and costs incurred to providers for 2 pediatric health conditions&lt;br&gt;2) Excess cases and costs incurred to patients for 2 pediatric health conditions&lt;br&gt;3) Excess cases and costs incurred to health care system for 2 pediatric health conditions&lt;br&gt;4) Change in health care costs</td>
<td><strong>Pediatrics Outcomes</strong>&lt;br&gt;1) GII (diarrhea)&lt;br&gt;2) Pneumonia/respiratory disease</td>
<td><strong>Maternal Outcomes</strong> None&lt;br&gt;<strong>Other Outcomes</strong> None</td>
<td>1) The cost to treat diarrhea and respiratory illness was US$ 11.37 per case.&lt;br&gt;2) The total annual cost for not breastfeeding according to medical recommendations was US$118 million which includes US$88 million in medical costs to the healthcare system costs and US$30 million for patient costs, such as transport and missed time.</td>
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<tr>
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<td>Oliveira, et al, 2019</td>
<td>United States</td>
<td><strong>Disciplinary Approach</strong> Primary: Health Economics Secondary: Epidemiological Methodological Approach Static Modelling Perspective Institutional (Governmental agency and payer)</td>
<td>Breastfeeding rates in 2016 compared to a hypothetical optimal breastfeeding of 90% to medical recommendation for the first year of life (exclusive for 6 months with continued breastfeeding through 12 months)</td>
<td>per newborn</td>
<td><strong>Breastfeeding or Formula Milk Exposure Measured</strong></td>
<td>Pediatrics Outcomes 1) Acute Lymphoblastic leukemia 2) Acute otitis media 3) Crohn’s Disease 4) Ulcerative Colitis 5) Gastritis 6) Lower respiratory track illness 7) Obesity among non-Hispanic white infants 8) NEC 9) SIDS 10) Infant food package utilization</td>
<td><strong>Outcomes</strong> 1) If 90% of WIC met medical recommendations to breastfeed exclusively for 6 months with continued breastfeeding for 12 months, there would be an 8% increase in WIC participants per month and a US$252.4 million dollar increase in WIC program costs. 2) Under optimal conditions, federal Medicaid expenditure would decrease by at least US$111.6 million and WIC households (or their healthcare payer) would see savings of</td>
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**Main Findings**

1) If 90% of WIC met medical recommendations to breastfeed exclusively for 6 months with continued breastfeeding for 12 months, there would be an 8% increase in WIC participants per month and a US$252.4 million dollar increase in WIC program costs. 2) Under optimal conditions, federal Medicaid expenditure would decrease by at least US$111.6 million and WIC households (or their healthcare payer) would see savings of

**Author stated limitation**

Conservative estimates were used at each modeling choice which may have resulted in an underestimation of the impact improving breastfeeding rates. Further, the USBC calculator which was used to estimate costs has model parameters that are based on literature estimates. These may be subject to underestimation and confounding. The economic costs were not exhaustive. The model did not
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</table>
| Santacruz-Salas et al., 2019 | Spain | Disciplinary Approach  
Primary: Health Economics  
Secondary: None | Breastfeeding, Mixed Feeding, and Formula feeding for the first 6 months of life | sudden infant death syndrome  
5) Cost of food packages  
6) Cost of WIC administrative services | Packages  
2) WIC administrative costs | US$9 billion. | account for any potential downstream cost impact such as price elasticity for decreased formula demand and increased demand for lactation support, equipment, and supplies. The model also did not account for additional investments that might be needed to achieve optimal breastfeeding rates. |

1) Payments made for hospitalization for the infant  
2) Payments made for primary care visits for the infant  
3) Payments

**Pediatrics Outcomes**
1) Claims to the public health system for all medical reasons  
2) Claims to the public health system for infant illnesses

**Maternal Outcomes**
None

**Other Outcomes**
None

1) Infants exclusively breastfed for 6 months had lower cost for hospital admission (p=0.08), primary care visits (p<0.01), specialty visits (p=0.14), The analysis was limited to the payer perspective for infants alone. Caregiving costs and lost familial income for illnesses were not accounted for. |
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<td>Walters Over</td>
<td>Disciplinary Current 1) Cases Pediatrics 1) Not Model</td>
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1) Cases measured. They were not able to measure maternal behaviors that might lead to early breastfeeding cessation such as mastitis. They used medical records which does not capture all sources of costs, particularly maternal time costs for feeding and any privately secured care that was not indicated in the public care system.

2) Controlling for maternal and infant sociodemographic variables, the mean cost for health care expenses for infants exclusively breastfed for 6 months was €454.40-€503.50 lower compared to those who were not exclusively breastfed for 6 months (mixed fed or formula fed).

3) Payment made for pharmacy use for the infant (p=0.02), medical tests (p=0.63), emergency visits (p<0.01) and total healthcare payments (p<0.01) compared to those who were not exclusively breastfed for 6 months (mixed fed or formula fed).

4) Payment made for specialty care visits for the infant.

5) Payment made for emergency room visits for the infant.

6) Payments made for medical tests for the infant.
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<td>et al., 2019</td>
<td>130 mostly low-middle income countries plus United States</td>
<td><strong>Approach</strong> Primary: Nutritional Economics Secondary: Epidemiological and Health Economics</td>
<td>rates per country compared to medical recommendations from WHO and UNICEF</td>
<td>of morbidity and mortality for 3 pediatric illnesses and 3 maternal illnesses 2) Health care system treatment costs for 2 pediatrics illnesses and 1 maternal illness 3) Potential earnings lost due to lost IQ points for children 4) Potential earnings lost due to premature mortality for children and mothers 5) Cost of formula</td>
<td><strong>Outcomes</strong> 1) Gastroenteritis 2) Acute respiratory track illness (as proxy for pneumonia) 3) Obesity 4) IQ</td>
<td>breastfeeding to medical recommendation can be attributed globally to over 175 million excess cases of pediatric illness and over 996 million excesses cases of maternal disease annually. 2) Not breastfeeding to medical recommendation can be attributed globally to 595,379 excess pediatric deaths and 98,943 excess maternal deaths annually. 3) The cost of avoidable healthcare treatment globally due to not breastfeeding is US$ 1146.81 million annually. 4) The cost of cognitive loses globally due</td>
<td>simulations use many assumptions and relies on precision of published estimates and many of those estimates came from high income countries. Breastfeeding is often poorly defined in the literature (e.g., any, exclusive, total duration). Cost data similarly relied on precision of previously published estimates and governmen reports.</td>
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| Quesada, Méndez, Martín-Gil, 2020 | Spain | Disciplinary Approach: Primary: Epidemiological Secondary: Health Economics Methodological Approach: Static Modelling Perspective: Payer | Exclusive breastfeeding at hospital discharge and 6 months postpartum | 1) Costs savings for 4 pediatric illnesses resulting from increased breastfeeding rates | Pediatrics Outcomes 1) Gastroenteritis (diarrhea) 2) Respiratory infection (bronchitis and asthma) 3) Otitis media 4) NEC  
Maternal Outcomes None  
Other Outcomes None | 1) Increasing exclusive breastfeeding rates at hospital discharge and 6 months from their 2014 levels (85% and 15% respectively) to 2020 WHA recommendations (95% and 50% respectively) would save Spanish healthcare system €197 million/year or €464/child born from analysis was limited to cases only in the first two years of life for the 4 illnesses studied. All other potential impact were not measured. | to not breastfeeding is US$ 285.39 billion annually.  
5) The cost for premature death globally due to not breastfeeding is US$53.7 billion for pediatric deaths and US$1.26 billion annually for maternal deaths. |
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| Lechosa-Muñiz et al., 2020 | Spain | **Disciplinary Approach**<br>Primary: Health Economics<br>Secondary: None  
**Methodological Approach**<br>Micro-costing  
**Perspective**<br>Payer | Exclusive breastfeeding, exclusive formula feeding, and mixed feeding at hospital discharge and 2, 4, 6, 9, and 12 months postpartum | 1) Cost of hospitalization for infectious diseases at hospital discharge, 2, 4, 6, 9, and 12 months  
2) Cost of primary care office visits for infectious diseases at hospital discharge, 2, 4, 6, 9, and 12 months  
3) Cost of drug treatment for infectious diseases at hospital discharge, 2, 4, 6, 9, and 12 months  
4) Cost of emergency room visits for infectious diseases at hospital discharge, 2, 4, 6, 9, and 12 months | **Pediatrics Outcomes**<br>1) Infectious diseases defined by All Patients Refined—Diagnosis Related Groups including non-bacterial Gastroenteritis (diarrhea), Respiratory infections (bronchitis and asthma, upper respiratory tract, RSV pneumonia, pneumonia, other respiratory signs, symptoms and minor diagnoses), Kidney and Urinary Tract infections, Infectious & parasitic diseases including HIV, Fever, Viral Illness, Other infectious and parasitic diseases, and Other skin, subcutaneous tissue and breast disorders. | just 4 pediatric illnesses.  
1) Children who were exclusively formula fed had higher costs during the 1st year of life compared to exclusively breast fed children for infectious diseases for hospitalizations (791.6€ exclusive formula v. 86.9€ exclusive breastmilk), pediatrician visits (295.7€ v. 97.9€), emergency room visits(260.1€ v. 196.2€), and total costs in the first year of life (1339.5€ v. 443.5€).  
2) Children who were fed a mixed diet of breast milk and formula had costs in between exclusive formula fed and exclusive breastfed | The analysis is limited by the use of cost data from a single area in Spain and relies on existing health records. The study is observational and thus cannot confer causality. |

1) Children who were exclusively formula fed had higher costs during the 1st year of life compared to exclusively breast fed children for infectious diseases for hospitalizations (791.6€ exclusive formula v. 86.9€ exclusive breastmilk), pediatrician visits (295.7€ v. 97.9€), emergency room visits(260.1€ v. 196.2€), and total costs in the first year of life (1339.5€ v. 443.5€).  
2) Children who were fed a mixed diet of breast milk and formula had costs in between exclusive formula fed and exclusive breastfed.
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<td>infants for all measured costs.</td>
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Supplementary File

Supplementary Appendix Tables

Appendix Table A. Summary of Reviewed Articles Categorization of Author Characteristics, Location, Approaches, and Perspectives

Appendix Table B. Summary of Reviewed Articles Measures and Outcomes

Appendix Table C. Summary of Reviewed Articles Key Assumptions, Methodological Choices, Findings, Limitations, and Editorial Comments