E. J. Ourso College of Business
Department of Economics

DEPARTMENT OF ECONOMICS WORKING PAPER SERIES

Breastfeeding and Early Childhood Outcomes: Is There a Causal Relationship?

Masayuki Onda
Louisiana State University

Working Paper 2016-09
http://faculty.bus.lsu.edu/papers/pap16_09.pdf

Department of Economics
Louisiana State University
Baton Rouge, LA 70803-6306
http://www.bus.lsu.edu/economics/

Breastfeeding and Early Childhood Outcomes: Is There a Causal Relationship?

Masayuki Onda *†

September 13, 2016

Abstract

This paper examines the impact of breastfeeding on early childhood outcomes. Using Birth Cohort of Early Childhood Longitudinal Survey data and employing a recently developed econometric technique, we estimate the upper and lower bounds of the effect of breastfeeding on early childhood health and cognitive ability. We find that even a small fraction of selection on unobservables explains the entire effect of breastfeeding on early childhood outcomes.

JEL Classification: I12, I14, L21

Keywords: Breastfeeding, Health, Overweight, Cognitive Skills, Selection on Unobservables.

*Department of Economics, Louisiana State University, Baton Rouge, LA 70803. Tel:+1-225-578-5211. Fax:+1-225-578-3807. E-mail address: monda1@lsu.edu.

†I thank Ozkan Eren for helpful comments and advice.

1 Introduction

Breastfeeding is a prime source of nutrients. The observational research suggests that breastfeeding reduces the risk of infection and obesity and advances cognitive development.[1] Referring to studies reporting benefits of breastfeeding on a wide range of child outcomes, the World Health Organization (WHO) and United Nations Children's Emergency Fund (UNICEF) recommend breastfeeding babies for the first six months of life exclusively. Breastfeeding has also been promoted in the United States.[2] Figure 1 presents time-series of the incidence of breastfeeding for the period of 2002-2012: the number of U.S. children who were *ever breastfed* and *breastfed at least 6 months* has been increasing to 80.0 and 51.4 percent from 71.4 and 37.9 percent over a decade (Department of Health and Human Service 2015). Healthy People 2020 (2010) aims to achieve an even higher incidence of breastfeeding, 81.9 percent and 60.6 percent for *ever breastfed* and *at least 6 month breastfed* respectively.

The common perception that breastfeeding benefits child outcomes has also been greatly reinforced by the supporting research (e.g., Morrow-Tlucak, Haude, and Ernhart 1988; Lucas et al. 1992; Dewey, Heinig, and Nommsen-Rivers 1995; Raisler, Alexander, and O'Campo 1999; Miralles et al. 2006). However, caution must be warranted. Most studies depend on observed variations in breastfeeding which are arguably endogeneous to the specifications. The lack of evidence supported by valid instrumental variables and randomized control trials raises concerns on the causal effect of breastfeeding on various outcomes. Potential violation of the zero conditional mean assumption - independence of the decision to breastfeed from child outcomes - may lead to misleading inference about the benefits of breastfeeding.

[1] A plethora of correlation studies investigate the impact of breastfeeding on infection in the United States (Dewey, Heinig, and Nommsen-Rivers 1995; Raisler, Alexander, and O'Campo 1999), developing countries (Jason, Nieburg, and Marks 1984; Habicht, DaVanzo, and Butz1986; Victora et al. 1987) and developed countries (Kovar et al. 1984; Rubin et al. 1990; Howie et al. 1990; Beaudry, Dufour, and Marcoux 1995); on obesity (Lyle et al. 2001; Miralles et al. 2006; Shehadeh et al. (2003)); and on cognitive development in the United States (Jacobson, Chiodo, and Jacobson 1999; Der, Batty, and Deary 2006) and developed countries (Lucas et al. 1992; Angelsen et al. 2001; Mortensen et al. 2002; Oddy et al. 2003; Gómez-Sanchiz et al. 2003)). Meta analysis and literature review of the effect of breastfeeding were conducted for health (Feachem and Koblinsky 1984; Cunningham, Jelliffe, and Jellife 1991) and cognitive development (Anderson, Johnstone, and Remley 1999; Drane and Logemann 2000; Jain, Concato, and Leventhal 2002).

[2] Government agencies (e.g. the U.S. department of Health and Human Services), professional associations (e.g. the American Academy of Pediatrics), and non profit organizations (e.g. La Leche League International and United States Breastfeeding Committee) promote breastfeeding.

Of all the existing studies in breastfeeding literature, a countable number of research papers investigating the causal impact of breastfeeding on early childhood outcomes report mixed findings at best. Baker and Milligan (2008) find that an increase in mandatory maternity leave in Canada increases a mother's time away from work and breastfeeding duration but has no effect on a child's health outcomes. Implementing a randomized Promotion of Breastfeeding Intervention Trial (PROBIT) in Belarus, Kramer et al. (2001, 2007, 2008, 2009) find that prolonged and exclusive breastfeeding has a limited positive effect on a child's health, no discernible effect on nonverbal-IQ, and a positive effect on verbal-IQ.[3] Using the Birth Cohort of Early Childhood Longitudinal Survey (ECLS-B) data, Belfield and Kelly (2012) estimate several econometric models to conclude that breastfeeding improves health and cognitive ability. Jenkins and Foster (2013), in contrast, report that breastfeeding has little benefit on early childhood test scores. Utilizing random variation in breastfeeding support service on weekdays and weekends, Fitzsimons and Vera-Hernández (2015) identify a positive effect of breastfeeding on a child's cognitive development but no statistically significant effect on health outcomes in U.K.

This paper has two objectives. First, we revisit the associations between breastfeeding and outcomes pertaining to early childhood health and cognitive ability using the restricted ECLS-B data. The rich collection of the prenatal information and the reliable records regarding the incidence and duration of breastfeeding allow us to explore this association in more detail. Second, we examine whether the associations between breastfeeding and these outcome variables are causal or not. Employing the econometric strategy developed by Altonji, Elder, and Taber (2005), we analyze the sensitivity of the effect of breastfeeding to nonrandom selection. Specifically, this technique allows us to estimate both the lower and upper bounds of the effect of breastfeeding under various assumptions (e.g., selection on unobservables is equal to selection on observables and selection is random). Furthermore we calculate how large the amount of selection on unobservables relative to selection on observables has to be to explain the entire treatment effect of breastfeeding under the

[3]Kramer et al (2001, 2008) find that prolonged and exclusive breastfeeding significantly reduces the risk of gastrointestinal infection and atopic eczema and improves similarity, vocabulary, and verbal IQ on Wechsler Abbreviated Scales of Intelligence. Kramer et al. (2001, 2009) however find no significant reduction on respiratory infection and overweight status. Note that Kramer et al.'s PROBIT includes only breastfed babies and captures the intention-to-treatment of breastfeeding promotion program, Baby Friendly Hospital Initiative (BFHI). See Kramer et al. (2001) for detail of their research design.

assumption of exogeneity.

Our findings using the ECLS-B data is mostly consistent with those of the observational studies: the estimated effects of breastfeeding are positive and significant on early childhood health and cognitive development. Controlling for child and family characteristics rarely alters the result, although the effects of breastfeeding on 48-month outcomes are imprecisely estimated. Including prenatal attributes continues to produce the relatively large effect of breastfeeding. Our sensitivity checks, however, raise concerns regarding the causal effect of breastfeeding on these outcomes. The lower bound of the effect of breastfeeding is not different from zero at the five percent level of significance on a child's health outcomes and are even negative on the cognitive ability. Our further examination indicates that even 10 percent of selection on unobservables is sufficient to explain the entire positive effect of breastfeeding on early childhood outcomes.

The remainder of this paper is organized as follows. Section 2 describes empirical strategy and section 3 explains data. Section 4 reports the estimation results and section 5 concludes.

2 Empirical Methodology

2.1 Baseline Model

To begin, we estimate the following outcome equation:

$$Y_i = X_i\gamma + \alpha BF_i + \epsilon_i. \tag{1}$$

where Y_i is the various outcomes for child i, BF_i is an indicator variable taking the value of one if the child was breastfed and zero otherwise, X_i' is the vector of control variables, and ϵ_i is the error term. Ordinary least square (OLS) and probit estimation yield unbiased estimator of α as long as the mean of the error term conditional on observed characteristics is independent of parents' decision to breastfeed, $E[\epsilon_i|BF_i, X_i] = 0$.

2.2 Nonrandom Selection and Assessment of Selection Bias

The causal interpretation of the effect of breastfeeding hinges on the zero conditional mean assumption.[4] Ethical issues to implement a randomized control trial for the decision to breastfeed and difficulties in coming up with a valid instrument prevent one from making a firm inference about causality. To address this problem, we apply the technique used in Altonji et al. (2005).[5] The basic idea of this procedure is to evaluate how much the selection on unobservables relative to the selection on observables would have to be to explain the entire association between treatment and outcome variables.

Consider the bivariate probit model:

$$BF_i = 1(X_i'\beta + \upsilon_i > 0), \tag{2}$$

$$Y_i = 1(X_i'\gamma + \alpha BF_i + \epsilon_i > 0), \tag{3}$$

$$\begin{bmatrix} \upsilon_i \\ \epsilon_i \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix}\right). \tag{4}$$

where BF_i, Y_i, X_i', and ϵ_i are as previously defined, and υ_i is the usual error term for breastfeeding equation. Altonji et al. (2005) prove that one can identify an upper bound on α that occurs when we assume

$$\frac{Cov(BF_i, \epsilon_i)}{Var(\epsilon_i)} = 0. \tag{5}$$

and a lower bound that occurs when we assume that

$$\frac{Cov(BF_i, \epsilon_i)}{Var(\epsilon_i)} = \frac{Cov(BF_i, X_i'\gamma)}{Var(X_i'\gamma)}. \tag{6}$$

An intuitive interpretation of these conditions is as follows: condition (5) says that the part of Y_i

[4]Parents' decision to breastfeed is possibly endogenous to the OLS specification. For example, a mother who invests more household resources in her child's education may be inclined to breastfeed as she knew benefits of breastfeeding reported by observational studies. Her enthusiasm for her child's success, which is unobserved to researchers, may be positively associated with decision to breastfeed and early childhood outcomes. Selection on unobservables of this kind consequently bias the estimated coefficient on decision to breastfeed upward.

[5]Oster (2014) develops the econometric technique to identify the omitted variable bias under the proportional selection assumption.

related to the unobservables has no relationship with breastfeeding BF_i; in contrast, condition (6) says that the part of Y_i that is related to the observables and part related to the unobservables are equal in magnitude. As such, denoting ρ to be the correlation between decision to breastfeed and the error term, the conditions (5) and (6) simplify an interval of ρ with an upper and a lower bounds as

$$0 \leq \rho \leq \frac{Cov(BF_i, X_i'\gamma)}{Var(X_i'\gamma)}. \tag{7}$$

In our subsequent empirical work, we estimate the bivariate probit model using equations (2), (3), and (4), and maximize the likelihood by imposing $\rho = Cov(BF_i, X_i'\gamma)/Var(X_i'\gamma)$. If the lower-bound estimates yield substantial positive effects of breastfeeding, we interpret them as evidence of a causal positive impact of breastfeeding.

As discussed in detail in Altonji et al.(2005), the key assumption leading to equal selection on observables and unobservables is that the set of covariates are randomly drawn from all factors that determine the outcome variables. While this assumption may not hold exactly, it is more likely to be applicable to the nature of a large-scale survey than an OLS assumption. Large data sets such as ECLS-B are designed to serve multiple purposes rather than to address a specific question. Additionally, due to limitations in the number of factors that we know to matter and that we know to collect and can afford to collect, the variables that are available are likely to be more or less a random subset of those relevant to a particular question (e.g. the effect of breastfeeding).[6] Other necessary assumptions are a relatively large number of observables are available and none of the observables and unobservables play a dominant role on determining outcome variables.

2.3 The Degree of Selection on Unobservables

In addition to bounding the treatment effect under various assumptions, given the binary nature of our variable of interest, one can also compute the (normalized) amount of selection on unobservables by the ratio $\{E[\epsilon_i|BF_i = 1] - E[\epsilon_i|BF_i = 0]\}/Var(\epsilon_i)$.[7] Similarly, the (normalized) extent of

[6] The assumption of equal selection on observables and unobservables should not be taken literally. Researchers do not often choose their explanatory variables randomly and there will be less selection on observables than selection on unobserables. This assumption represents one extreme. The other extreme is the assumption that there is no selection on unobservables such as OLS.

[7] Note that ϵ_i is the error term from equation (1) and denotes the unobservables in the outcome equation (3).

selection on observables can be written as the ratio $\{E[X_i'\gamma|BF_i=1]-E[X_i'\gamma|BF_i=0]\}/Var(X_i'\gamma)$. [8] Equating these ratios, one can ask how large the selection on unobservables has to be, relative to the selection on observables, to explain the entire effect of breastfeeding α.

We now return to the breastfeeding equation (2). Estimation of the participation equation via OLS yields the predicted value of $X_i'\hat{\beta}$ and the residuals $\hat{v}_i$ ($BF_i = X_i'\hat{\beta} + \hat{v}_i$). Replacing BF_i with the predicted values and the residuals from the participation equation, we can express equation (1) as $BF_i = X_i'(\gamma + \alpha\hat{\beta}) + \alpha\hat{v}_i + \epsilon_i$. The probability limit of the OLS estimator of α is given by

$$\text{plim}\,\hat{\alpha} = \alpha + \frac{Var(BF_i)}{Var(\hat{v}_i)}\{E[\epsilon_i|BF_i=1] - E[\epsilon_i|BF_i=0]\}. \tag{8}$$

where the second term is the bias. Setting the amount of selection on observables to be equal to the amount of selection on unobservables, the bias term in (8) can be written as

$$\frac{Var(BF_i)}{Var(\hat{v}_i)}\left\{\frac{E[X_i'\gamma|BF_i=1] - E[X_i'\gamma|BF_i=0]}{Var(X_i'\gamma)}Var(\epsilon_i)\right\}. \tag{9}$$

Under the null hypothesis of no effect of breastfeeding, one can consistently estimate γ, and hence $E[X_i'\gamma|BF_i]$ via OLS from a separate model imposing $\alpha = 0$. The estimated value of γ and the variance of the residuals, along with the sample value of $Var(BF_i)$, provide an estimate of selection on observables and unobservables.

Dividing the OLS estimate of α from equation (1) by the bias (9) yields the *implied ratio* described by Altonji et al. (2005). The implied ratio gauges how large the selection on unobservables relative to selection on observables would need to be to account for the entire effect of breastfeeding. Small values of the implied ratio indicate that the treatment effect is sensitive to selection on unobservables. Although there is no clear cutoff of large and small values in an implied ratio, it may be reasonable to consider a value in the neighborhood of one to conclude in favor of a causal relationship (Altonji et al. 2005).

[8] Note that X_i' is the set of control variables from equation (1) and γ is the corresponding parameter vector.

3 Data

The ECLS-B is a longitudinal study of children during the first six years, conducted by the National Center for Education Statistics in 2001. The ECLS-B follows a sample of approximately 14,000 children and oversamples for racial minority, twins, and low-birth weight children. Information about these children were collected in 2001-02 (roughly nine months old), 2003-04 (roughly 24 months old), and 2005-06 (roughly 48 months old).

The ECLS-B contains information on a wide variety of outcomes, including cognitive ability, physical development, and a record of health problems. Parent and child surveys in the nine-month wave provide a rich set of information on child characteristics, family background, geological location, a mother's prenatal attributes, and most importantly the decision to breastfeed and duration of breastfeeding. Each child was also administered a series of shorter and full versions of the Bayley Short Form (BSF) to measure mental development at nine and 24 months old and tests used on Kindergarten Cohort of Early Childhood Longitudinal Survey (ECLS-K) at 48 months old. The parent responded whether her baby had suffered from asthma, respiratory illness, gastrointestinal illness, and ear infection. Moreover, the body mass index (BMI) measures for the children were collected at the 24- and 48-month wave.

Our outcomes of interest are as follows: (i) an indicator variable for *no health problem* taking the value of one if a child did not suffer from respiratory illness, asthma, gastrointestinal illness, or ear infection by the date of the nine-, 24-, and 48-month survey, and zero otherwise, (ii) an indicator for *normal weight* that takes the value of one if a child was categorized as neither overweight nor obese at the time of the 24- and 48-month survey, and (iii) *cognitive score* which is standardized to have a mean zero and a standard deviation one.

We define two indicator variables for variables of interest. The *ever breastfed* indicator takes the value of one if a child was ever breastfed, and zero if *never*. To capture intensity, we also define an indicator variable that takes the value of one if a child was breastfed for more than six months, and zero if *never*. Table 1 shows the summary statistics for breastfeeding variables. About 67 percent of children were ever breastfed and 27 percent were at-least-6-month breastfed relative to those who were never breastfed.[9] Although these frequencies of breastfeeding on the ECLS-B data are slightly lower than the corresponding numbers reported in the National Immunization Survey (70.3 and 34.5 percent respectively) owing to an oversample for racial minority and low-birth weight children, it is reassuring that our measures are not far off from those of the national representative survey.

Table 2 reports the means of a set of nine-, 24-, and 48-month outcomes for children who were *ever breastfed* and were *breastfed for more than 6 months* relative to those who were *never breastfed*. Contrasting these unconditional means shows a stark difference. Breastfed children are far less likely to have health problems than the never-breastfed children and are less likely to be overweight. The difference in cognitive scores is large - for example, about 0.27 standard deviation units higher on the 24-month *cognitive score* for the breastfed children.

Table 2 also reports the means of various child characteristics, family background, geographical information, and mother's prenatal attributes. White, married parents with higher education are more likely to breastfeed their babies. A wealthier household with few children is also more likely to select into breastfeeding. It is noteworthy that mothers who have higher BMI measures during pregnancy are less likely to breastfeed their babies, although lighter babies at birth are less likely to be breastfed. There are few noticeable differences between the sample of children who were *ever breastfed* and were *breastfed for more than 6 month*. We thus only report the estimates using the sample of the children who were breasted for more than six months and were never breastfed in the text and relegate findings on those who were *ever breastfed and never* to Appendix A.

4 Results

4.1 Probit and OLS estimates of the Effect of Breastfeeding

Panel A of Table 3 reports the coefficient estimates on breastfeeding from probit and OLS models for *no health problem*, and *cognitive score* at nine months. The difference in means for *no health problem* is 0.063 when no controls are included, as shown by the average marginal effect in the

[9] Our incidence of *ever breast-fed* is similar to that of Belfield and Kelly (2012).

square brackets with no control (col 1). When we add the first set of controls, the marginal effect slightly increases in magnitude, which is indicative that observable child characteristics explain a small fraction of the variation in the *no health problem*. The size of this estimated effect is somewhat large - 8.4 percent reduction in probability that a child suffers from illness. The point estimate of the marginal effect on breastfeeding declines slightly to 0.059 when we add family background and region controls in column (3) and decline further to 0.052 when we add a set of prenatal measures including mother's BMI and indicators for whether a mother smoked, drank, was employed, and received WIC. The estimated effect of breastfeeding is stable and marginally significant.

Cognitive scores, however, provide a different pattern. The difference in mean for *cognitive score* is 0.108 and significant at the five percent level. The estimated effect of breastfeeding on *cognitive score* is moderate - 0.108 standard deviation units increase in cognitive score. When we add a set of a child's age in month, birth weight, gender, and race, statistical significance has however disappeared. The estimated effects of breastfeeding remain insignificant once additional sets of controls are included.

In panel B of Table 3 we report estimates of the effect of breastfeeding on 24-month outcome variables. The first row of the panel presents the estimated effect of breastfeeding on the probability that a child is neither overweight nor obese. Inclusion of control variables leaves the estimated coefficient on breastfeeding almost intact: the raw difference of 0.107 declines to 0.102 when child characteristics, family background, and region are included in the probit model and to 0.088 when we add prenatal attributes. The estimated effect is about a nine percent increase in the probability that a child is a normal weight. The third row presents the estimates of the effect of breastfeeding on cognitive score. The raw difference of 0.385 declines to 0.183 once all the detailed controls have been included. The estimated effect of breastfeeding is positive and is significant - 0.183 standard deviation units increase in cognitive score. We further examine the effect of breastfeeding on 48-month outcomes in panel C of Table 3. None of the estimates are precisely estimated when we have added a full set of control variables.[10]

[10] Gelbach (2016) suggests that one abandon sequentially including control variables to a base model in order to check the stability of the estimates of interest. We hence employed Gelbach's conditional decomposition to complement our sensitivity analysis and examined how much the explained portion of the effect of breastfeeding is associated with child characteristics, family background, and prenatal attributes. Our findings are twofold. First

Of all eight outcome variables, the estimated effects on *no health problem* at nine months old as well as on *normal weight* and *cognitive score* at 24 months old are positive and precisely estimated in our most extensive specification. These estimates can be assumed to be unbiased under the zero conditional mean assumption. Although we control for a rich set of observables, it is still possible that our point estimates are confounded by selection on unobservables. We now further explore this possibility.

4.2 Sensitivity Analysis

In Table 4 we report estimates of the impact of breastfeeding that correspond to various values of ρ, the correlation in the error terms between breastfeeding equation (2) and outcome equation (3). We report results for nine-month *no health problem* in panel A and 24-month *normal weight* and *cognitive score* in panel B, and present probit estimates and average marginal effects in brackets. We set ρ equal to zero (univariate probit case) and increase the value of ρ up to 0.2 by estimating bivariate probit models simultaneously constraining ρ to the specific value. We use a 24-month *cognitive score* indicator as a substitute for the continuous *cognitive score*. The raw difference in the probability that a child had no health problem is 0.063. When $\rho = 0$, the estimated effect is 0.052, and the figure declines to 0.019 when $\rho = 0.05$ and to -0.013 when $\rho = 0.1$. The former estimate is insignificant and the latter even has a negative sign. Given that a small value of selection to breastfeeding can wipe out the entire positive association, the evidence for a strong effect of breastfeeding is considerably weaker than indicated by the estimates that treat breastfeeding as exogenous.

In the panel B of Table 4 we present the results for the 24-month *normal weight* and *cognitive score*. The results are quite similar to the nine-month *no health problem*. The effect of breastfeeding on the probability that a child weighs normal is 0.088 when $\rho = 0$, and declines to 0.030 and is

variations in child characteristics and prenatal attributes offset each other for early childhood health whereas those in child characteristics and family background account for a majority of the explained portion on cognitive scores. Second, the variation in family background dominates the explained component of the positive effect on cognitive scores as a child ages 24 months old or older: family background accounts for three quarters of the explained portion on cognitive score at nine months old, while it explains 85 percent on cognitive score at 24 months old. Our findings support that family background has an immense influence on parents' decision to breastfeed and a child's academic performance. The results are available upon request.

insignificant when $\rho = 0.1$. The sign of the estimate even becomes negative when we impose stronger correlation $\rho = 0.2$. The effect of breastfeeding on the probability that a child earns a cognitive score greater than the median of its score distribution shows a similar pattern. The effect is 0.072 when $\rho = 0$, which points to a positive, significant effect similar to the OLS estimate on *cognitive score*. It declines to 0.011 when $\rho = 0.1$, and becomes negative when $\rho = 0.2$.

Having shown some preliminary evidence on the sensitivity of the results, we now proceed to formally testing the sensitivity of the positive association reported in Table 4 using the strategy developed in Altonji et al. (2005).

4.3 The Degree of Selection on Unobservables Relative to Selection on Observables

The last column of Table 4 presents the estimates of the effect of breastfeeding in the bivariate probit model by imposing $\rho = Cov(BF_i, X_i'\gamma)/Var(X_i'\gamma)$ as discussed on equation (7). For nine-month *no health problem*, the estimate of ρ is 0.11. The estimate of the effect of breastfeeding is -0.058 (0.071), which is insignificant with the negative sign. Under the assumption of equality of selection on observables and unobservables, the estimate suggests that there be no evidence of the causal effect of breastfeeding on health at nine months old.

The result for 24-month *normal weight* follows a similar pattern, although the assumption of equality of selection on observables and unobservables leads to a positive estimated effect of breastfeeding 0.105 (0.086) along with $\rho = 0.09$. The average marginal effect is moderate 0.036 and imprecisely estimated. Moreover, the result for 24-month *cognitive score* shows how sensitive the relationship is between parents' decision to breastfeed and a child's cognitive development. The entire positive effect of breastfeeding has disappeared when $\rho = 0.47$, indicating strong nonrandom selection to breastfeeding. Given the result of our sensitivity analysis and evaluation on selection on unobservables relative to selection on observables, there is little evidence that breastfeeding advances a child's health and cognitive ability at the age of nine, 24, and 48 months.

4.4 Nonrandom Selection

As a final check, we report the implied ratios in Table 5. Each column corresponds to nine-month *no health problem* and 24-month *normal weight* and *cognitive score*. The first row of Table 5 presents the unconstrained estimate of the effect of breastfeeding α on these three outcome variables. The bias $Cov(BF,\epsilon)/Var(\hat{v})$, which is estimated by equation (9), is given in row 2. The third row displays the estimated implied ratio by dividing the unconstrained estimate by the bias. Recall that one can use the value of one and above as indicator of a potential causal relationship. For nine-month *no health problem*, the implied ratio is only 0.12; that is, if the normalized degree of selection on unobservables is 12 percent as large as the degree of selection on observables, the effect of breastfeeding on a child's health is fully explained. This evidence along with the results from sensitivity analysis may allow us to rule out the possibility that the positive effect is causal.

Similarly, the estimated ratios for 24-month *normal weight* and *cognitive score* are well below one: the implied ratio is 0.07 for *normal weight* and 0.11 for *cognitive score*. It indicates that if the selection on unobservables is only 7 and 11 percent of the selection on observables, the impact of breastfeeding would be minimal. Overall, the effect of breastfeeding appears to be very sensitive to nonrandom selection.

4.5 Findings from other studies

With these results in hand, we contrast our findings to those of the observational research in the U.S. Dewey, Heinig, and Nommsen-Rivers (1995) document that breastfeeding is significantly associated with a reduction in the incidence of diarrhea and ear infection in the first year of life but does not in the later years. Using the National Maternal and Infant Health Survey data, Raisler, Alexander, and O'Campo (1999) report a dose-response relationship of breastfeeding to early childhood health outcomes: exclusive breastfeeding is significantly associated with fewer incidences of diarrhea and colds than non-exclusive breastfeeding. Utilizing the matched Michigan Alcoholism Screening Test data, Morrow-Tlucak, Haude, and Ernhart (1988) find that breastfeeding is significantly correlated with the higher scores on the Mental Development Index of the Bayley Scales at the ages of one and two years old. Estimating several econometric models under the several assumptions, Belfield and Kelly (2012) report that breastfeeding advances early childhood health and cognitive ability.[11]

Our findings from Altonji et al.'s (2005) technique is mostly consistent with those of existing research that take potential endogeneity into account. The more exclusive and prolonged breastfeeding has limited effect on health and full-scale IQ at the age of one and six-and-a-half years old in Belarus (Kramer et al, 2001, 2007, 2008).[12] Breastfeeding has no statistically significant effect on early childhood health in the U.K. (Fitzsimons and Vera-Hernádez, 2015).[13] The expansion of the maternity leave mandate in Canada causes a large increase in breastfeeding duration but does not affect early childhood health (Baker and Milligan 2008). In contrast, our finding that breastfeeding has no discernible effect on cognitive scores differs from the positive effect of breastfeeding on verbal-IQ scores in Belarus (Kramer et al. 2008) and on cognitive scores in the U.K. (Fitzsimons and Vera-Hernández 2015).

A potential explanation may be related to the shorter duration of mothers' stay with their children at home following delivery. The Family and Medical Leave Act guarantees 12-week unpaid maternity leave to mothers in the United States whereas Statutory Maternity Leave in U.K. grants mothers 52-week leaves at maximum. In Belarus mothers were at home with their children for an average of three years with little use of daycare (Martens 2012). Neuroscience studies showing the epigenetic behavioral effect of postnatal maternal care by rats to their offspring suggest that physical interactions inherent to breastfeeding might cause a positive behavioral change that promotes cognitive development (Weaver et al. 2004). The increased duration and frequency of mother-child contact through breastfeeding could increase verbal interaction between mothers and children, which may advance the cognitive ability in verbal domain. Exploring this issue is an important task, but is beyond the scope of this paper.

[11] Belfield and Kelly (2012) does not provide sufficient causal evidence. First their instrumental variables (e.g. county-level measures of the unemployment rate and the percentage of working women, and state indicators of maternity leave eligibility) are weak. Second it is unclear what their treatment and control groups are in their Lewbel instrumental estimation models. Finally their propensity matching estimates still rely on the zero conditional mean assumption.

[12] Kramer et al.(2001) does not compare breastfed children to non-breastfed children. Their PROBIT compares future outcomes of the more exclusive and prolonged breastfed children to those of the less exclusive and prolonged breastfed children.

[13] Fitzsimons and Vera-Hernández (2015) identify the local average treatment effect of breastfeeding due to variation in breastfeeding support on weekdays and weekends.

5 Conclusion

In the last decade or so, factors advancing early childhood health and cognitive development have received considerable attention among researchers and policy makers. This paper examines one of the potential factors, breastfeeding. Using the ECLS-B data and employing the econometric technique developed by Altonji et al. (2005), we evaluate the associations between breastfeeding - the prime source of nutrients at the earliest stage of human lives - and health as well as cognitive development. Viewing the complete set of results, we have the following findings. Breastfeeding is positively associated with the probabilities that a child has no health problem, is at a normal weight, and acquires better cognitive ability. Our further findings, however, suggest that the positive breastfeeding effect is very sensitive to nonrandom selection to breastfeeding and only a small amount of selection on unobservables is sufficient to explain the whole positive effect of breastfeeding.

Before we conclude, there are two caveats to keep in mind. First we explore the impact of breastfeeding on the population of children born in 2001 in the United States. Given the high degree of economic inequality and constrained maternity leaves, our findings might not be generalized to other countries. Second, it is crucial to note that breastfeeding may affect outcomes other than the early childhood outcomes examined in our study. There may be effects on child health and academic performance in later stages of life (Rees and Sabia 2009; Fletcher 2011). The increase in mother-child interaction owing to breastfeeding may foster development of a bond between mothers and children in early infancy (Fergusson and Woodward 1999; Britton, Britton, and Gronwaldt 2006). The aggregate effect of breastfeeding would have to be examined by accounting for all beneficial effects in these dimensions. Future research may address these issues in greater detail.

References

Altonji, Joseph G., Todd E. Elder, and Christopher R. Taber, "Selection on Observed and Unobserved Variables: Assessing the Effectiveness of Catholic Schools," *Journal of Political Economy*, 2005, *113* (1), 151–184.

Anderson, James W, Bryan M Johnstone, and Daniel T Remley, "Breast-feeding and cognitive development: a meta-analysis," *The American Journal of Clinical Nutrition*, 1999, *70* (4), 525–535.

Angelsen, NK, T Vik, G Jacobsen, and LS Bakketeig, "Breast feeding and cognitive development at age 1 and 5 years," *Archives of Disease in Childhood*, 2001, *85* (3), 183–188.

Baker, Michael and Kevin Milligan, "Maternal employment, breastfeeding, and health: Evidence from maternity leave mandates," *Journal of Health Economics*, 2008, *27* (4), 871–887.

Beaudry, Micheline, Rene Dufour, and Sylvie Marcoux, "Relation between infant feeding and infections during the first six months of life," *The Journal of Pediatrics*, 1995, *126* (2), 191–197.

Belfield, Clive R. and Inas Rashad Kelly, "The Benefits of Breast Feeding across the Early Years of Childhood," *Journal of Human Capital*, 2012, *6* (3), 251–277.

Britton, John R., Helen L. Britton, and Virginia Gronwaldt, "Breastfeeding, Sensitivity, and Attachment," *Pediatrics*, 2006, *118* (5), e1436–e1443.

Centers for Disease Control and Prevention, "Nutrition, physical activity and obesity data, trends and maps web site," 2015.

Cunningham, Allan S, Derrick B Jelliffe, and EF Patrice Jelliffe, "Breast-feeding and health in the 1980s: a global epidemiologic review," *The Journal of Pediatrics*, 1991, *118* (5), 659–666.

Der, Geoff, G. David Batty, and Ian J. Deary, "Effect of breast feeding on intelligence in children: prospective study, sibling pairs analysis, and meta-analysis," *BMJ : British Medical Journal*, 2006, *333* (7575), 945–945.

Dewey, Kathryn G, M Jane Heinig, and Laurie A Nommsen-Rivers, "Differences in morbidity between breast-fed and formula-fed infants," *The Journal of Pediatrics*, 1995, *126* (5), 696–702.

Drane, Daniel L and Jeri A Logemann, "A critical evaluation of the evidence on the association between type of infant feeding and cognitive development," *Paediatric and Perinatal Epidemiology*, 2000, *14* (4), 349–356.

Feachem, Richard G and Marge A Koblinsky, "Interventions for the control of diarrhoeal diseases among young children: promotion of breast-feeding," *Bulletin of the World Health Organization*, 1984, *62* (2), 271.

Fergusson, David M and Lianne J Woodward, "Breast feeding and later psychosocial adjustment," *Paediatric and Perinatal Epidemiology*, 1999, *13* (2), 144–157.

Fitzsimons, Emla and Marcos Vera-Hernández, "Breastfeeding and Child Development," *mimeo.*, 2015.

Fletcher, Jason M., "Long-term effects of health investments and parental favoritism: the case of breastfeeding," *Health Economics*, 2011, *20* (11), 1349–1361.

Gelbach, Jonah B., "When Do Covariates Matter? And Which Ones, and How Much?," *Journal of Labor Economics*, 2016, *34* (2), 509–543.

Gómez-Sanchiz, Manuela, Ramón Cañete, Inmaculada Rodero, J Enrique Baeza, and Octavio Ávila, "Influence of breast-feeding on mental and psychomotor development," *Clinical Pediatrics*, 2003, *42* (1), 35–42.

Habicht, Jean-Pierre, Julie DaVanzo, and William P Butz, "Does breastfeeding really save lives, or are apparent benefits due to biases?," *American Journal of Epidemiology*, 1986, *123* (2), 279–290.

Howie, Peter W, J Stewart Forsyth, Simon A Ogston, Ann Clark, and CD Florey, "Protective effect of breast feeding against infection," *Bmj*, 1990, *300* (6716), 11–16.

Jacobson, Sandra W, Lisa M Chiodo, and Joseph L Jacobson, "Breastfeeding effects on intelligence quotient in 4-and 11-year-old children," *Pediatrics*, 1999, *103* (5), e71–e71.

Jain, Anjali, John Concato, and John M Leventhal, "How good is the evidence linking breastfeeding and intelligence?," *Pediatrics*, 2002, *109* (6), 1044–1053.

Jason, Janine M, Phillip Nieburg, and James S Marks, "Mortality and infectious disease associated with infant-feeding practices in developing countries," *Pediatrics*, 1984, *74* (4), 702–727.

Jenkins, Jade Marcus and E. Michael Foster, "The Effects of Breastfeeding Exclusivity on Early Childhood Outcomes," *American Journal of Public Health*, 2013, *104* (S1), S128–S135.

Kovar, Mary Grace, Mary K Serdula, James S Marks, and David W Fraser, "Review of the epidemiologic evidence for an association between infant feeding and infant health," *Pediatrics*, 1984, *74* (4), 615–638.

Kramer, Michael S, Beverley Chalmers, Ellen D Hodnett, Zinaida Sevkovskaya, Irina Dzikovich, Stanley Shapiro, Jean-Paul Collet, Irina Vanilovich, Irina Mezen, and Thierry Ducruet, "Promotion of Breastfeeding Intervention Trial (PROBIT): a randomized trial in the Republic of Belarus," *Jama*, 2001, *285* (4), 413–420.

_ , Frances Aboud, Elena Mironova, Irina Vanilovich, Robert W Platt, Lidia Matush, Sergei Igumnov, Eric Fombonne, Natalia Bogdanovich, and Thierry Ducruet, "Breastfeeding and child cognitive development: new evidence from a large randomized trial," *Archives of general psychiatry*, 2008, *65* (5), 578–584.

_ , Lidia Matush, Irina Vanilovich, Robert W Platt, Natalia Bogdanovich, Zinaida Sevkovskaya, Irina Dzikovich, Gyorgy Shishko, Jean-Paul Collet, and Richard M Martin, "A randomized breast-feeding promotion intervention did not reduce child obesity in Belarus," *The Journal of Nutrition*, 2009, *139* (2), 417S–421S.

_ , _ , _ , _ , _ , _ , _ , _ , _ , _ , George Davey Smith, Matthew W Gillman, Beverley Chalmers, Ellen Hodnett, Stanley Shapiro, and for the Promotion of Breastfeeding Intervention Trial Study Group, "Effects of prolonged and exclusive breastfeeding on child height, weight, adiposity, and blood pressure at age 6.5 y: evidence from a large randomized trial," *The American Journal of Clinical Nutrition*, 2007, *86* (6), 1717–1721.

Lucas, Alan, Ruth Morley, TJ Cole, G Lister, and C Leeson-Payne, "Breast milk and subsequent intelligence quotient in children born preterm," *The Lancet*, 1992, *339* (8788), 261–264.

Lyle, Robert E, Stephen C Kincaid, Janet C Bryant, Audra M Prince, and Robert E McGehee Jr, "Human milk contains detectable levels of immunoreactive leptin," in "Bioactive Components of Human Milk," Springer, 2001, pp. 87–92.

Martens, Patricia J, "What do Kramers baby-friendly hospital initiative PROBIT studies tell us? A review of a decade of research," *Journal of Human Lactation*, 2012, *28* (3), 335–342.

Miralles, Olga, Juana Sánchez, Andreu Palou, and Catalina Picó, "A physiological role of breast milk leptin in body weight control in developing infants," *Obesity*, 2006, *14* (8), 1371–1377.

Morrow-Tlucak, Mary, Richard H Haude, and Claire B Ernhart, "Breastfeeding and cognitive development in the first 2 years of life," *Social Science & Medicine*, 1988, *26* (6), 635–639.

Mortensen, Erik Lykke, Kim Fleischer Michaelsen, Stephanie A Sanders, and June Machover Reinisch, "The association between duration of breastfeeding and adult intelligence," *Jama*, 2002, *287* (18), 2365–2371.

Oddy, Wendy H, Garth E Kendall, Eve Blair, Nicholas H De Klerk, Fiona J Stanley, Louis I Landau, Sven Silburn, and Stephen Zubrick, "Breast feeding and cognitive development in childhood: a prospective birth cohort study," *Paediatric and Perinatal Epidemiology*, 2003, *17* (1), 81–90.

Oster, Emily, "Unobservable selection and coefficient stability: Theory and evidence," *University of Chicago Booth School of Business Working Paper*, 2014.

Raisler, Jeanne, Cheiyl Alexander, and Patricia O'Campo, "Breast-feeding and infant illness: a dose-response relationship?," *American Journal of Public Health*, 1999, *89* (1), 25–30.

Rees, Daniel I and Joseph J Sabia, "The effect of breast feeding on educational attainment: Evidence from sibling data," *Journal of Human Capital*, 2009, *3* (1), 43–72.

Rubin, David H, John M Leventhal, Peter A Krasilnikoff, HS Kuo, James F Jekel, Birgitte Weile, Alice Levee, Matthew Kurzon, and Arne Berget, "Relationship between infant feeding and infectious illness: a prospective study of infants during the first year of life," *Pediatrics*, 1990, *85* (4), 464–471.

Shehadeh, N, E Khaesh-Goldberg, R Shamir, R Perlman, P Sujov, A Tamir, and IR Makhoul, "Insulin in human milk: postpartum changes and effect of gestational age," *Archives of Disease in Childhood-Fetal and Neonatal Edition*, 2003, *88* (3), F214–F216.

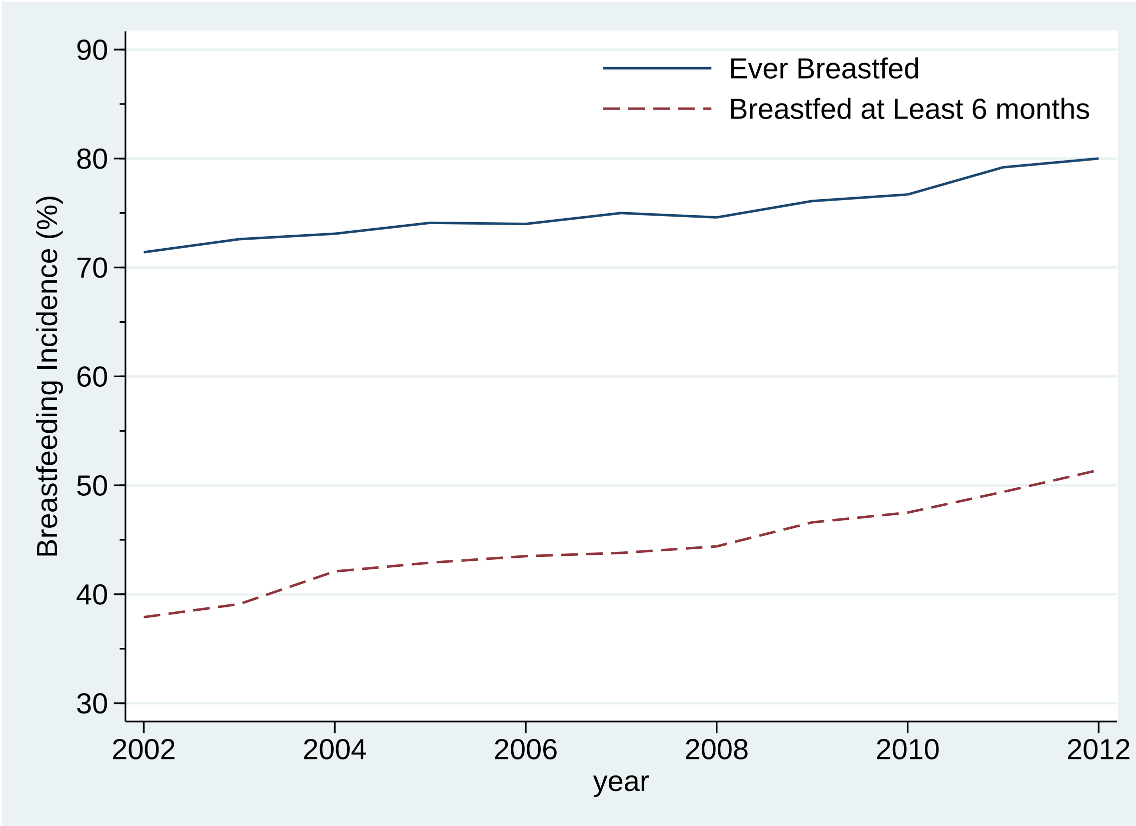
US Department of Health and Human Services, Office of Disease Prevention and Health Promotion, US Department of Health and Human Services, and Office of Disease Prevention and Health Promotion, "Healthy people 2020," 2010.

Victora, Cesar G, J Patrick Vaughan, Cintia Lombardi, Sandra M C Fuchs, Luciana P Gigante, Peter G Smith, Leticia C Nobre, AnaMaria B Teixeira, Leila B Moreira,

and Fernando C Barros, "Evidence for protection by breast-feeding against infant deaths from infectious diseases in Brazil," *The Lancet*, 1987, *330* (8554), 319–322.

Weaver, Ian C. G., Nadia Cervoni, Frances A. Champagne, Ana C. D'Alessio, Shakti Sharma, Jonathan R. Seckl, Sergiy Dymov, Moshe Szyf, and Michael J. Meaney, "Epigenetic programming by maternal behavior," *Nature Neuroscience*, 2004, *7* (8), 847–854.

Figure 1: Breastfeeding among U.S. Children Born 2002-2012



Notes: National Immunization Survey, Department of Health and Human Service (2015).

Table 1: SUMMARY STATISTICS FOR BREAST-FEEDING VARIABLES ECLS-B

	Frequency %	Observations
Ever breast-fed	0.67	10,550
Breast-fed for 6+ months	0.27	4,700

Source: ECLS-B nine month wave.

Note: *Not ascertained*, *don't know*, *refused*, and *Not applicable* are assigned to missing values. All variables are measured at nine months from the response by the mother.

Table 2: SUMMARY STATISTICS FOR OUTCOME AND EXPLANATORY VARIABLES

	Ever BF vs Never			6m+ bf vs never		
	No bf	Bf		No bf	6+ bf	
	Mean	Mean	Diff	Mean	Mean	Diff
9 month outcome variables[a]						
No health problem	0.47	0.54	-0.06***	0.47	0.55	-0.08***
Cognitive score	-0.09	0.05	-0.14***	-0.09	0.11	-0.20***
24 month outcome variables[a]						
Normal weight	0.71	0.75	-0.04***	0.71	0.76	-0.05**
No health problem	0.51	0.51	-0.00	0.51	0.51	-0.00
Cognitive score	-0.18	0.09	-0.27***	-0.18	0.21	-0.40***
48 month outcome variables[a]						
Normal weight	0.66	0.70	-0.03**	0.66	0.72	-0.06***
No health problem	0.59	0.58	0.01	0.59	0.56	0.03
Cognitive score	-0.10	0.05	-0.15***	-0.10	0.06	-0.16***
Child information						
Age (month)	10.51	10.46	0.05	10.51	10.86	-0.35***
Birth weight (kg)	2.79	2.98	-0.19***	2.79	3.04	-0.25***
Male	0.51	0.51	0.00	0.51	0.50	0.02
White	0.39	0.42	-0.03**	0.39	0.45	-0.06***
Family information						
Married	0.51	0.73	-0.22***	0.51	0.81	-0.30***
Mother's years of schooling	12.34	13.76	-1.42***	12.34	14.32	-1.98***
Father's years of schooling	12.97	13.97	-1.00***	12.97	14.44	-1.47***
Number of siblings	1.20	1.03	0.16***	1.20	1.08	0.11**
Log income	10.05	10.55	-0.49***	10.05	10.73	-0.68***
Socioeconomic Scale	-0.41	0.12	-0.54***	-0.41	0.32	-0.73***
Geographical information						
Urban	0.80	0.88	-0.08***	0.80	0.89	-0.09***
Prenatal information						
BMI	31.29	30.56	0.73***	31.29	29.87	1.42***
Smoked	0.20	0.09	0.12***	0.20	0.04	0.16***
Drinking	0.01	0.01	0.00*	0.01	0.00	0.01
Working	0.70	0.71	-0.01	0.70	0.70	-0.00
WIC	0.56	0.35	0.21***	0.56	0.28	0.27***
N	3450	7100	10550	3450	1300	4700

Source: ECLS-B nine-, 24-, and 48-month wave.

Note: *Not ascertained*, *don't know*, *refused*, and *not applicable* are assigned to missing values. Birth weight, parents' years of schooling, and log household income are converted to contenuous variables from categorical variables by assigning the mean of the upper/lower bounds of each interval. Missing values on age, parents' education, log household income, and variables used for mother's BMI are imputed with mean of variables. *, **, and *** difference are statistically significant at the .1, .05, and .01 level.

[a] *Normal weight* takes one if BMI of a child is categorized in neither overweight nor obese and zero otherwise. *No health problem* takes one if a child did not suffer from asthma, respiratory illness, gastrointestinal illness, or ear infection, and zero otherwise. *Cognitive scores* are standardized to mean zero and standard deviation one.

Table 3: PROBIT AND OLS ESTIMATES OF BREASTFEEDING EFFECTS

6m+ BF vs Never	None	Child characteristics	Col.2 plus family background and region	Col.3 plus prenatal attributes
	(1)	(2)	(3)	(4)
Panel A: 9 months	No health problem (N=3,850)			
:Breastfeeding	0.158**	0.217***	0.154**	0.135*
	(0.063)	(0.065)	(0.071)	(0.072)
	[0.063]	[0.084]	[0.059]	[0.052]
Pseudo R^2	0.00	0.02	0.03	0.03
	Cognitive score (N=3,800)			
Breastfeeding	0.108**	0.048	-0.006	-0.000
	(0.049)	(0.048)	(0.050)	(0.051)
R^2	0.00	0.04	0.07	0.07
Panel B: 24 months	Normal weight (N=3,300)			
:Breastfeeding	0.302***	0.338***	0.296***	0.257***
	(0.072)	(0.073)	(0.080)	(0.081)
	[0.107]	[0.117]	[0.102]	[0.088]
Pseudo R^2	0.01	0.03	0.03	0.04
	No health problem (N=3,300)			
:Breastfeeding	-0.049	-0.048	-0.063	-0.095
	(0.068)	(0.069)	(0.076)	(0.076)
	[-0.019]	[-0.018]	[-0.024]	[-0.036]
Pseudo R^2	0.00	0.02	0.02	0.03
	Cognitive score (N=3,300)			
Breastfeeding	0.385***	0.320***	0.180***	0.183***
	(0.051)	(0.049)	(0.050)	(0.051)
R^2	0.03	0.11	0.15	0.15
Panel C: 48 months	Normal weight (N=2,950)			
:Breastfeeding	0.186**	0.239***	0.123	0.045
	(0.074)	(0.075)	(0.083)	(0.084)
	[0.069]	[0.086]	[0.044]	[0.016]
Pseudo R^2	0.00	0.03	0.03	0.06
	No health problem (N=2,950)			
:Breastfeeding	-0.007	0.018	0.037	0.024
	(0.071)	(0.073)	(0.080)	(0.081)
	[-0.003]	[0.007]	[0.015]	[0.009]
Pseudo R^2	0.00	0.01	0.02	0.02
	Cognitive score (N=2,850)			
Breastfeeding	0.101*	0.084	0.008	0.008
	(0.061)	(0.062)	(0.069)	(0.070)
R^2	0.00	0.01	0.02	0.02

Note. ECLS-B panel weights are used with clustering at student level. Control variables in column (2)-(4) include age, birth weight, gender, and race (white/nonwhite). Family background variables used as controls include marital status, mother's and father's education, number of siblings, log income, and socioeconomic scale. Region controls for urban/rual. Prenatal attributes are a mother's BMI and indicators for whether she smoked, drank, was employed, and received WIC during pregnancy. Huber-White standard errors are in parentheses. Average marginal effects are in brackets. * 0.10, ** 0.05 and ***0.01 denote significance levels.

Table 4: SENSITIVITY OF ESTIMATES OF BREASTFEEDING EFFECTS ON HEALTH OUTCOMES AND COGNITIVE SCORE TO ASSUMPTIONS ABOUT SELECTION BIAS IN ECLS-B

6m+ BF vs Never	CORRELATION OF DISTURBANCES[a]				
	$\rho = 0$	$\rho = 0.05$	$\rho = 0.1$	$\rho = 0.2$	$\rho =$ Cov(X'β,X'γ) / Var(X'γ)[b]
Panel A: 9 months	No health problem				
:Breastfeeding	0.135	0.050	-0.034	-0.201	-0.058
	(0.072)	(0.072)	(0.072)	(0.071)	(0.071)
	[0.052]	[0.019]	[-0.013]	[-0.077]	[-0.022]
Constraint on ρ					0.11
Panel B: 24 months	Normal weight				
:Breastfeeding	0.256	0.171	0.085	-0.084	0.105
	(0.086)	(0.086)	(0.086)	(0.085)	(0.086)
	[0.088]	[0.059]	[0.030]	[-0.029]	[0.036]
Constraint on ρ					0.09
	Cognitive score				
:Breastfeeding	0.202	0.117	0.032	-0.135	-0.596
	(0.082)	(0.081)	(0.081)	(0.080)	(0.075)
	[0.072]	[0.042]	[0.011]	[-0.048]	[-0.210]
Constraint on ρ					0.47

Note.- The ECLS-B sampling weights are used in the computations. The control variables are identical to those described in note a, b, and c of Table 3. Average marginal effects are in brackets. Huber-White standard errors are in parentheses. Cognitive score takes one if a child earns BSF-R mental score greater than the medians of its distribution, and zero otherwise.

[a] Models estimated as bivariate probits with the correlation ρ between u and ϵ set to the values in column headings.

[b] The model is $BF = 1(X'\beta + u > 0)$ and $Y = 1(X'\gamma + \alpha BF + \epsilon > 0)$; β, γ, and α are estimated simultaneously as a constrained bivariate probit model.

Table 5: AMOUNT OF SELECTION ON UNOBSERVABLES RELATIVE TO SELECTION ON OBSERVABLES REQUIRED TO ATTRIBUTE THE ENTIRE BREASTFEEDING EFFECT TO SELECTION BIAS

6m+ BF vs Never	9 months	24 months	
	No health problem	Normal weight	Cognitive score[c]
$\hat{\alpha}$	0.05	0.09	0.18
$Cov(BF,\epsilon)/Var(\hat{\upsilon})^a$	0.45	1.28	1.65
Implied ratio[b]	0.12	0.07	0.11

Note. The model is Y = 1(X'$\gamma + \alpha BF + \epsilon > 0$) for *no health problem* and *normal weight*, and Y = X'$\gamma + \alpha BF + \epsilon$ for cognitive scores, estimated by OLS. The $\hat{\gamma}$ used to evaluate

$$\frac{\hat{E}(X'\hat{\gamma}|BF=1) - \hat{E}(X'\hat{\gamma}|BF=0)}{\hat{Var}(X'\hat{\gamma})}$$

is estimated under the restriction $\alpha = 0$, using the sample of the more than 6 month breastfed and never breastfedd infants. The ECLS-B panel weights are used with clustering at student level. See notes a, b, and c of Table 3 for a description of the controls.

[a] If the condition that the standardized selection on unobservables is equal to the standardized selection on observables holds: that is,

$$\frac{E(\epsilon|BF=1) - E(\epsilon|BF=0)}{Var(\epsilon)} = \frac{E(X'\gamma|BF=1) - E(X'\gamma|BF=0)}{Var(X'\gamma)}$$

[b] The implied ratio in row 3 on each panel is the ratio of standardized selection on unobservables to observables under the hypothesis that there is no breastfeeding effect.

[c] Cognitive score is a standardized continous variable.

Appendix A. TABLES

Table A1: PROBIT AND OLS ESTIMATES OF BREASTFEEDING EFFECTS

Ever BF vs Never	None	Child characteristics	Col.2 plus family background and region	Col.3 plus prenatal attributes
	(1)	(2)	(3)	(4)
Panel A: 9 months	No health problem (N=8,350)			
:Breastfeeding	0.172***	0.187***	0.132***	0.118***
	(0.039)	(0.040)	(0.042)	(0.043)
	[0.068]	[0.073]	[0.051]	[0.046]
Pseudo R^2	0.00	0.02	0.02	0.03
	Cognitive score (N=8,350)			
Breastfeeding	0.070**	0.036	-0.002	-0.007
	(0.028)	(0.028)	(0.029)	(0.029)
R^2	0.00	0.04	0.05	0.06
Panel B: 24 months	Normal weight (N=7,350)			
:Breastfeeding	0.229***	0.247***	0.210***	0.192***
	(0.045)	(0.045)	(0.048)	(0.048)
	[0.078]	[0.083]	[0.070]	[0.064]
Pseudo R^2	0.01	0.02	0.02	0.03
	No health problem (N=7,350)			
:Breastfeeding	0.008	0.022	0.012	-0.004
	(0.042)	(0.043)	(0.045)	(0.046)
	[0.003]	[0.009]	[0.005]	[-0.001]
Pseudo R^2	0.00	0.01	0.02	0.02
	Cognitive score (N=7,350)			
Breastfeeding	0.262***	0.218***	0.087***	0.087***
	(0.033)	(0.031)	(0.032)	(0.032)
R^2	0.02	0.12	0.17	0.18
Panel C: 48 months	Normal weight (N=6,650)			
:Breastfeeding	0.081*	0.106**	0.037	0.003
	(0.046)	(0.047)	(0.050)	(0.050)
	[0.030]	[0.038]	[0.013]	[0.001]
Pseudo R^2	0.00	0.02	0.03	0.04
	No health problem (N=6,600)			
:Breastfeeding	0.023	0.033	0.054	0.040
	(0.045)	(0.045)	(0.048)	(0.049)
	[0.009]	[0.013]	[0.021]	[0.016]
Pseudo R^2	0.00	0.01	0.01	0.01
	Cognitive score (N=6,400)			
Breastfeeding	0.149***	0.143***	0.097***	0.099***
	(0.034)	(0.034)	(0.036)	(0.036)
R^2	0.01	0.02	0.02	0.02

Note. ECLS-B panel weights are used with clustering at student level. The control variables are identical to those in Table 3. Huber-White standard errors are in parentheses. Average marginal effects are in brackets. * 0.10, ** 0.05 and ***0.01 denote significance levels.

Table A2: SENSITIVITY OF ESTIMATES OF BREASTFEEDING EFFECTS ON HEALTH OUTCOMES AND COGNITIVE SCORE TO ASSUMPTIONS ABOUT SELECTION BIAS IN ECLS-B

Ever BF vs Never	CORRELATION OF DISTURBANCES[a]				
	$\rho = 0$	$\rho = 0.05$	$\rho = 0.1$	$\rho = 0.2$	$\rho =$ Cov($X'\beta$,$X'\gamma$) / Var($X'\gamma$)[b]
Panel A: 9 months	No health problem				
:Breastfeeding	0.118	0.035	-0.048	-0.212	-0.246
	(0.043)	(0.043)	(0.042)	(0.042)	(0.042)
	[0.046]	[0.014]	[-0.019]	[-0.081]	[-0.094]
Constraint on ρ					0.22
Panel B: 24 months	Normal weight				
:Breastfeeding	0.188	0.104	0.021	-0.142	-0.008
	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)
	[0.063]	[0.035]	[0.007]	[-0.048]	[-0.003]
Constraint on ρ					0.12
	Cognitive score				
:Breastfeeding	0.087	0.004	-0.079	-0.242	-0.912
	(0.051)	(0.050)	(0.050)	(0.050)	(0.044)
	[0.030]	[0.001]	[-0.028]	[-0.084]	[-0.305]
Constraint on ρ					0.61
Panel C: 48 months	Cognitive score				
:Breastfeeding	0.154	0.070	-0.013	-0.176	-0.379
	(0.050)	(0.050)	(0.050)	(0.049)	(0.048)
	[0.054]	[0.025]	[-0.004]	[-0.062]	[-0.134]
Constraint on ρ					0.32

Note.- The ECLS-B sampling weights are used in the computations. The control variables are identical to those described in note a, b, and c of Table 3. Average marginal effects are in brackets. Huber-White standard errors are in parentheses. Cognitive and motor scores take one if a child earns BSF-R mental and Bruininks-Oseretsky test scores greater than the medians of its distribution, and zero otherwise.

[a] Models estimated as bivariate probits with the correlation ρ between u and ϵ set to the values in column headings.

[b] The model is $BF = 1(X'\beta + u > 0)$ and $Y = 1(X'\gamma + \alpha BF + \epsilon > 0)$; β, γ, and α are estimated simultaneously as a constrained bivariate probit model.

Table A3: AMOUNT OF SELECTION ON UNOBSERVABLES RELATIVE TO SELECTION ON OBSERVABLES REQUIRED TO ATTRIBUTE THE ENTIRE BREASTFEEDING EFFECT TO SELECTION BIAS

Ever BF vs Never	9 months	24 months		48 months
	No health problem	Normal weight	Cognitive score[c]	Cognitive score[c]
$\hat{\alpha}$	0.05	0.07	0.09	0.10
$Cov(BF, \epsilon)/Var(\hat{\upsilon})^a$	0.76	0.79	1.01	3.32
Implied ratio[b]	0.06	0.08	0.09	0.03

Note. The model is Y = $1(X'\gamma + \alpha BF + \epsilon > 0)$ for *no health problem* and *normal weight*, and Y = $X'\gamma + \alpha BF + \epsilon$ for cognitive scores, estimated by OLS. The $\hat{\gamma}$ used to evaluate

$$\frac{\hat{E}(X'\hat{\gamma}|BF=1) - \hat{E}(X'\hat{\gamma}|BF=0)}{\hat{Var}(X'\hat{\gamma})}$$

is estimated under the restriction $\alpha = 0$, using the full sample. The ECLS-B panel weights are used with clustering at student level. See notes a, b, and c of Table 3 for a description of the controls.

[a] If the condition that the standardized selection on unobservables is equal to the standardized selection on observables holds: that is,

$$\frac{E(\epsilon|BF=1) - E(\epsilon|BF=0)}{Var(\epsilon)} = \frac{E(X'\gamma|BF=1) - E(X'\gamma|BF=0)}{Var(X'\gamma)}$$

[b] The implied ratio in row 3 on each panel is the ratio of standardized selection on unobservables to observables under the hypothesis that there is no breastfeeding effect.

[c] Cognitive score is a standardized continous variable.