BREASTFEEDING AND CHILDREN'S EARLY COGNITIVE OUTCOMES

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Abstract—This paper investigates whether breastfeeding affects 5- to 6-year old children's cognitive development using three U.S. longitudinal data sets. The results for the full samples roughly point to a dose-response effect of breastfeeding on children's cognitive outcomes, with breastfeeding six months or more associated with about one-tenth of a standard deviation increase in cognitive test scores. The breastfeeding effects do not appear to be due to differences in maternal employment, cognitive ability, or parenting skills. In contrast, within-sibling results show no statistically significant breastfeeding effect.

I. Introduction

THE American Academy of Pediatrics (2005) recommends exclusive breastfeeding for the first six months of a child's life and then continued breastfeeding through at least the first year. Data show increasing rates of breastfeeding from the mid-1990s to the mid-2000s in the United States (McDowell, Wang, & Kennedy-Stephenson, 2008). In the mid-1990s, about 60% of infants were ever breast-fed, and by the mid-2000s the number had increased to over 75%. The rate of breastfeeding at six months remained steady over this period, at a little over 30%. Breastfeeding rates are spread unevenly across demographic groups, with children in poor families, born to young mothers or non-Hispanic black less likely to be breast-fed. Any benefits of breastfeeding are thus spread unequally across children from different demographic backgrounds.

The medical literature points to a plethora of health benefits for breastfeeding mothers and their children. For mothers, breastfeeding has been linked to decreased postpartum bleeding, earlier return to prepregnancy weight, and a reduced risk of breast cancer, among other benefits. The list of potential health benefits for breast-fed children is extensive and includes a lower incidence of bacterial meningitis, diarrhea, respiratory tract infections, otitis media, and urinary tract infections. (See American Academy of Pediatrics, 2005, for a research summary.) In addition, medical researchers have found a dose-response relationship between breastfeeding and health benefits to infants (Chantry et al., 2006).

Medical researchers have posited two key theories as to why breastfeeding may be linked to cognitive development. The first relates to the act of breastfeeding itself, which causes the release of the hormones prolactin and oxycontin in the mother. These hormones may enhance positive mothering behaviors and thus indirectly influence children's cognitive development (Feldman & Eidelman, 2003). The second relates to the content of breast milk. The long-chain polyunsaturated fatty acids docosahexaenoic acid (DHA) and arachidonic acid (ARA), which are found in breast milk, quickly build up in the brain during the third trimester and first months of life. Medical researchers have found that these fatty acids have a positive influence on neural development.[1] In general, however, the evidence in the medical literature on the association between breastfeeding and children's cognitive outcomes is mixed—sometimes positive and sometimes not different from 0 (Jain, Concato, & Leventhal, 2002, Slykerman et al., 2005; Ip et al., 2007).

Children's cognitive test scores are related to later educational and labor market attainment (Murnane, Willett, & Levy, 1995). Cunha and Heckman (2007) posit that early investments in children are particularly advantageous because they can have multiplier effects on investments in later childhood. They note that these effects help to explain why the return to early investments in disadvantaged children is so high. Thus, a breastfeeding effect on children's early cognitive development can have important implications for outcomes later in life.

Any study that attempts to evaluate a causal effect of breastfeeding on children's cognitive or health outcomes needs to worry about selection. That is, mothers who breast-feed and their children may be systematically different from those who do not. The differences may be related to observable characteristics, such as the child's birth weight or prematurity, or the mother's age or education, or to unobservable characteristics, such as the mother's ability or motivation. If these characteristics also affect children's cognitive outcomes, it may appear that breastfeeding itself has beneficial consequences, when in fact it is really due to the characteristics of the mothers and their children. Rich data sets that include a measure of maternal cognitive ability, prenatal health behaviors, and children's birth weight should help to mitigate this problem. Much of the medical literature on breastfeeding and children's cognitive and health outcomes does not take into account selection issues.

This paper studies the relationship between breastfeeding and children's early cognitive outcomes using three national U.S. longitudinal data sets that contain both breastfeeding information and young children's cognitive test scores. It examines whether maternal employment in the months after the child's birth affects breastfeeding estimates and whether supplementing breast milk with infant formula or food reduces any breastfeeding effect. Only a

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[1] See the discussion in Horta et al. (2007). Formula companies began to add DHA and ARA to infant formula in 2002. However, the evidence is mixed on whether the supplemented infant formula has additional beneficial effects on children's cognitive development compared to nonsupplemented formula (see the discussion in McCann & Ames, 2005).

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small literature in economics exists on this topic, and the findings vary across papers. The hope is that a consistent research method across a number of rich data sets will enable us to answer the question of whether breastfeeding has an impact on children's early cognitive development.

The paper proceeds as follows. Section II provides a brief overview of the background literature on breastfeeding and children's cognitive test scores. Section III describes a simple model of breastfeeding and children's human capital outcomes. Section IV provides the empirical approach, and section V presents the data, variables, and summary statistics. Section VI displays the results. Section VII discusses the results and section VIII concludes. An online data appendix provides information about the three data sets, variable definitions, descriptive statistics, sample construction, and additional tables and analysis.

II. Literature

Social scientists have employed four statistical approaches to try to estimate the causal effect of breastfeeding on children's cognitive test scores. The first is to find an instrumental variable for breastfeeding, such as whether the birth was by cesarean (Denny & Doyle, 2010) or whether the hospital where the child was born participated in a breastfeeding promotion program (Del Bono & Rabe, 2011). The second is to control for selection on observables with propensity score matching techniques (Belfield & Kelly, 2010; Iacovou & Sevilla-Sanz, 2010; Jiang, Foster, & Gibson-Davis, 2011). The third approach is to include a mother fixed effect in sibling samples (Belfield & Kelly, 2010; Der, Batty, & Deary, 2006; Evenhouse & Reilly, 2005; Neidell, 2000). And, the fourth, used in most of the studies, is to include a vast array of potentially confounding variables in the child test score equations, including, when possible, a maternal cognitive test score (Gibson-Davis & Brooks-Gunn, 2006).

Online appendix table 1 provides a further description of these studies, including their data sets, sample sizes, control variables, and estimated effects. With a few exceptions, least squares, propensity score matching, and instrumental variable estimates point to positive effects of breastfeeding on children's cognitive test scores (Belfield & Kelly, 2010; Del Bono & Rabe, 2011; Denny & Doyle, 2010; Gibson-Davis & Brooks-Gunn, 2006; Iacovou & Sevilla-Sanz, 2010; Jiang et al., 2011; Neidell, 2000), and within-sibling analyses find no effect (Belfield & Kelly, 2010; Der et al., 2006; Neidell, 2000).

Note that there are additional strands of breastfeeding literature by social scientists, including papers that examine the relationship between breastfeeding and labor supply (Chatterji & Frick, 2005) and the effect of breastfeeding on health outcomes (Evenhouse & Reilly, 2005). This paper fits into the larger literature in economics on effects of childhood inputs on cognitive test scores (Todd & Wolpin, 2007) and effects of human capital investments before age 5 on later life outcomes (Almond & Currie, 2011, provide an excellent summary of this literature).

III. Conceptual Framework

The following is a simple static model of breastfeeding and child human capital outcomes based on a dynamic utility maximization model of child health and parental investments (including breastfeeding) presented in Blau, Guilkey, and Popkin (1996). Its purpose is to provide some guidance for the empirical analysis that follows by informing the types of control variables in the child outcome equation and illustrating the presence of unobservable mother and child characteristics. Cunha and Heckman (2007) present a much richer multiperiod model of child human capital development and parental investment.

First, assume that parental utility is a function of a child's human capital h, consumption C, and leisure L:

$$U = U(h, C, L; Z, m). \tag{1}$$

Z is an observed exogenous determinant of preferences, and m is an unobserved determinant of preferences.[2] The production function for young children's human capital, h is a function of parental time investments I, time breast-fed B, and other food and formula and purchased material inputs F:

$$h = h(I, B, F; X, a_0). \tag{2}$$

X is an observed exogenous determinant of preferences, and a_0 represents a child's unobserved initial endowments. The parental time constraint is

$$I + B + H + L = 1. \tag{3}$$

H is the mother's hours of work. The full income constraint is

$$Y + w \times H = C + p_f \times F. \tag{4}$$

Y is nonlabor income, w is the mother's wage, p_f is the price of food, and the consumption good is the numeraire. Substituting equation (2) into (1) and maximizing utility subject to time and budget constraints (3) and (4) and solving first-order conditions yield (Marshallian) demand and labor supply functions for B, H, I, F, and C of the following form, given interior solutions:

$$B = B\left(X, Z, Y, p_f, w, m, a_0\right). \tag{5}$$

Equations determining whether an interior solution is optimal for B, H, I, F, and C take the form

$$Pr\left(B\left(X, Z, Y, p_f, w, m, a_0\right) > 0\right). \tag{6}$$

Substituting equation (5) into (2) for inputs F and I yields

$$h = h\left(B, X, Z, Y, p_f, w, m, a_0\right). \tag{7}$$

[2] For simplicity, I assume a household consists of a mother with one child.

A child's human capital (cognitive ability here) is a function of observed child and parent characteristics, as well as price, wage, and nonlabor income. Time spent breastfeeding is also a function of these same characteristics (see equation [5]). Unobservable maternal preferences and a child's unobserved initial endowments (health and ability, for example) influence time spent breastfeeding as well as cognitive outcomes, which produces a simultaneity problem if breastfeeding enters directly into the cognitive outcome equation. If the correlation between breastfeeding and the unobservables is positive, one would expect the estimated breastfeeding effects to be biased upward.

IV. Empirical Approach

Ideally, a randomized trial would be performed with an experimental group of infants exclusively breast-fed and a control group of infants not breast-fed. While a randomized study is not ethical, a recent medical study by Kramer et al. (2008) is based on an experiment in which a random selection of maternity hospitals and their affiliated polyclinics in Belarus participated in a postbirth breastfeeding promotion program. The article's analysis is based on an intent-to-treat research design. The treatment was associated with increased breastfeeding duration and considerably higher child IQ at age 6.5. However, unobserved differences in parental background and Russian-language skills based on region and community of residence, as well as the fact that the pediatricians who performed the IQ tests knew the treatment status of their polyclinic, could bias the results. Thus, observational data over multiple data sets with a myriad of control variables may provide our best hope of determining whether breastfeeding affects children's cognitive development.

In this paper, I use three observational data sets and implement four statistical approaches to adjust for differences between breast-fed and non-breast-fed children. The first and simplest model is a linear specification,

$$T_i = X^p{}_i\theta + B_i\alpha + \varepsilon_i, \tag{8}$$

where $i =$ child, T is a cognitive test score, X^p is a vector of pretreatment (prebreastfeeding) mother and child characteristics, B is an indicator for whether the child was breast-fed or a series of mutually exclusive indicators reflecting breastfeeding duration, and ε is a disturbance term.

Estimation is done using weighted least squares to obtain the effect of breastfeeding on children's test scores. In this initial estimation, I rely on the rich pretreatment observable mother and child characteristics in the data sets to account for differences between breast-fed and non-breast-fed children; thus, selection issues may still remain. In addition, a key assumption is that the pretreatment characteristics (X^p) enter linearly, when their true functional form is unknown. Propensity score matching, the second statistical approach used, allows controls for selection on observables while not specifying a functional form for the outcome equation. Intuitively, the idea is to obtain the effect of breastfeeding by estimating the mean difference between cognitive test scores of children who were breast-fed and matched sets of non-breast-fed children. The matching is based on an estimated probability of having been breast-fed, known as the propensity score.[3]

In the empirical analysis, the propensity score matching strategy is implemented as follows. The first step is to estimate a propensity score for each child using a logit with controls for pretreatment mother and child characteristics X^p. The second step is to conduct a balancing test for misspecification of the propensity score function. That is, the observable characteristics should be independent of the breastfeeding indicator conditional on the estimated propensity score. I use the regression-based balancing test recommended by Smith and Todd (2005b) with a quartic polynomial. If any covariate fails the balancing test, I add the higher-order and interaction terms of the imbalanced variables to the propensity score specification and rerun the regressions. The third step involves nonparametrically matching each treated child to nontreated children with similar propensities to have been breast-fed using an Epanechnikov kernel estimator with a bandwidth of .05 to obtain a treatment effect on the treated. Common support is imposed by dropping 3% of the treated observations in which the propensity score density of the control observations is the lowest. The average treatment effect on the treated (that is, the average effect of being breast-fed versus not being breast-fed for children who were breast-fed) is then calculated over the area of common support.

The third statistical approach is to add a mother fixed effect to equation (8) using a sample of siblings who received cognitive tests at the same young age. This approach is used in much of the literature on effects of early childhood inputs (see Almond & Currie, 2011). The appeal of the approach is that it eliminates confounding from (fixed) unobserved shared background characteristics. However, as Almond and Currie (2011) noted, this method is not a panacea. It does not control for unobserved sibling-specific factors, which can be worrisome given prior research has found that mothers' breastfeeding decisions are related to children's characteristics at birth (Datar, Kilburn, & Loughran, 2006).[4]

The fourth strategy is to include additional observable potentially confounding factors such as maternal employment and parenting measures. These may be influenced by whether a mother breast-feeds her child, and thus could dampen any breastfeeding effect. Even so, it will be informative to see the sensitivity of breastfeeding estimates to the inclusion of more detailed controls. Much of the literature in the social sciences on breastfeeding and children's

[3] See Smith and Todd (2005a) for a more detailed description of propensity score matching estimation.

[4] This also applies to linear regression. However, in fixed effects, the breastfeeding effects are solely identified by siblings with different breastfeeding histories.

cognitive test scores controls for these types of post-breastfeeding measures.

Finally, I considered a number of instrumental variables, such as breastfeeding rates by state and state laws about breastfeeding in public and workplace accommodations.[5] These are indicative of a possible favorable climate for breastfeeding. However, I was unconvinced that the exclusion restriction was valid or that the instruments were powerful enough in the first stage. Therefore, issues of selection may remain.

V. Data, Variables, and Summary Statistics

I analyze three U.S. longitudinal data sets that contain breastfeeding information and young children's cognitive test scores in the empirical analysis: the National Longitudinal Survey of Youth 1979 Matched Mother and Child Data (NLSY79-C), the Early Childhood Longitudinal Study—Birth Cohort (ECLS-B), and the Panel Study of Income Dynamics Child Development Supplement (PSID-C). The data sets were chosen because they have multiple cognitive test scores for young children, contain a maternal cognitive test score (NLSY79-C and PSID-C only), and generally include a rich amount of information on maternal prenatal behaviors and background, child characteristics, maternal employment, and parenting behaviors. (See the online data appendix for a description of the three data sets.) Below, I discuss key variables, assess the representativeness of the subsamples of young children used in the empirical analysis, and provide summary statistics.

A. Variables

Table 1 summarizes the variables that will be used in the empirical analysis across the three data sets (the online data appendix provides variable definitions). Cognitive math and reading test scores are measured for children approximately ages 5 and 6 across all three data sets. Breastfeeding is measured in two ways: as an indicator for ever breast-fed and as a series of mutually exclusive intervals with not breast-fed as the omitted category. These measures do not connote exclusive breastfeeding, as information on supplementation is not consistently available in the NLSY79-C and not available at all in the PSID-C. However, the ECLS-B data set contains information on the age at which the child was first given formula or food, and I explore the effects of supplementation in section VI.

Table 1 also shows the sets of explanatory variables that will be included as controls in the empirical analyses. The pretreatment mother characteristics include measures of prenatal health behaviors, background information, and a cognitive test score (NLSY79-C and PSID-C only). The pretreatment child characteristics include variables that relate to the child's birth, as well as gender and birth order. Both sets of variables can affect the child's cognitive development and the likelihood of being breast-fed and have been used in prior research on breastfeeding effects on children's test scores.

In some specifications, I also include two sets of parenting inputs, although they are measured after the child's birth. The maternal employment postbirth variables shown in table 1 contain employment measures I construct from work history information in the NLSY79 and the limited early employment data available in ECLS-B.[6] The parenting score and household income postbirth variables include parenting scores typically used to measure early parental inputs into children, such as the Home Observation for Measurement of the Environment (HOME) score, as well as the log of family income at the child assessment interview.

B. Sample Sizes and Sample Representativeness

Table 2 shows weighted means of selected characteristics of children in the three survey subsamples used in this paper and for the population of children born in comparable calendar years from National Center for Health Statistics (NCHS) Natality Data files. By 2008, the NLSY79-C full sample, weighted, should be representative of the resident biological children of mothers born from 1957 to 1964 who were living in the United States when first interviewed in 1979. Large demographic changes have occurred since 1979, with immigration being the most obvious. Thus, it is not surprising that the subsample of 5- to 6-year-olds used in this paper, or even the full sample of all NLSY79-C children (shown in the second column for comparison), does not compare well to birth data from 1989, the average birth year in the NLSY79-C subsample. Most notably, the NLSY79-C sample has a much lower proportion of children with Hispanic mothers than the birth cohort data and underrepresents Western states and overrepresents North Central states. In contrast, characteristics of the weighted ECLS-B kindergarten subsample used in this paper compare quite favorably to 2001 Natality data. In addition, 5- to 6-year-olds in the PSID-C sample used here, as in the NLSY79-C, are less likely to have Hispanic mothers than children in the comparable birth cohort and also have mothers who are older and more likely to be married. I use survey weights in the empirical analysis that follows.

C. Summary Statistics

Online appendix tables 2 to 4 present weighted descriptive statistics for each survey by whether the child was breast-fed and breastfeeding duration. The NLSY79 and PSID-C samples show, respectively, about 57% and 61% of 5- and 6-year-olds were breast-fed, a much lower percentage than the 69% shown in the ECLS-B. This is likely due

[5] See Ross Products Division (2001, 2004) and La Leche League (2009).

[6] The PSID-C does not include specific questions about early maternal employment, and the PSID-C mothers' presence in the main PSID surveys that do collect employment is spotty.

TABLE 1.—SUMMARY OF VARIABLES ACROSS THE NLSY79-C, ECLS-B, AND PSID-C

	NLSY79-C	ECLS-B	PSID-C
Child test scores	PIAT-math, reading recognition tests, ages 5–6	ECLS-B math, reading tests, kindergarten age	WJ Letter-Word, Applied Problems tests, ages 5–6
Breastfeeding measures	Ever breast-fed; breast-fed ≤ 1 month, 2–3 months, 4–5 months, 6+ months	Ever breast-fed; breast-fed ≤ 1 month, 2–3 months, 4–5 months, 6+ months	Ever breast-fed; breast-fed ≤ 1 month, 2–3 months, 4–5 months, 6+ months
Pretreatment mother characteristics			
Cognitive test score	AFQT score	—	WJ Passage Comprehension score
Race/ethnicity	Black, Hispanic, poor white oversample	Black, Hispanic	Black, Hispanic
Religion	Baptist, Catholic	—	Baptist, Catholic
Foreign born	Foreign born	Foreign born	New immigrant sample
Employment prebirth	Part time, full time in 12 months prior to birth	Worked 1–6, 7–12 months in year prior to birth	—
Education at birth	Years of education	Years of education	Years of education
Marital status at birth	Married at birth	Married at birth	Married at birth
Father's education at birth	Spouse's years of education at birth	Child's biological father's years of education at birth	Child's biological father's years of education at birth
Age at birth	Age in years	Age in years	Age in years
Region at birth	North Central, West, South	North Central, West, South	North Central, West, South
Smoke during pregnancy	Smoke during pregnancy	Smoke during pregnancy	—
Prenatal care during first trimester	Prenatal care during first trimester	Prenatal care during first trimester	—
Receive WIC during pregnancy	—	Receive WIC during pregnancy	Receive WIC during pregnancy
Pretreatment child characteristics			
Sex	Female	Female	Female
Birth order	First born, second born	First born, second born	First born, second born
Low birth weight	≤5.5 pounds	<2500 and ≥1500 grams, <1500 grams	≤5.5 pounds
Gestational weeks	<35 weeks, 35–37 weeks	<35 weeks, 35–37 weeks	<35 weeks, 35–37 weeks
C-section delivery	C-section delivery	C-section delivery	—
Child-based oversample indicators	—	Twin, Asian/Pacific Islander, Native American, Chinese	—
Maternal employment postbirth	Part time/full time in first 3 months, next 3 months, next 6 months, and years 2–4	Return to work in first 3 months after birth, next 3 months, greater than 6 months (round 1)	—
Parenting score and household income postbirth			
Parenting score	Age 5–6 HOME score	Round 1 NCATs score, read 3–6 times per week, read every day to child kindergarten interview	HOME score 1997 interview
Household income	Log household income age 5–6 interview	Log household income kindergarten interview	Log household income 1997 interview

to the earlier time periods of the data. Overall, 11% of NLSY79-C 5- to 6-year-olds were breast-fed for one month or less and 19% were breast-fed for six months or more. The comparable numbers for ECLS-B kindergartners are 15% breast-fed for one month or less and 32% breast-fed for six months or more. In the PSID-C, about 7% of 5- to 6-year-olds were breast-fed for one month or less and 27% were breast-fed for six months or more.

All three surveys show cognitive assessment scores that favor breast-fed children over those not breast-fed.[7] In the NLSY79-C, breast-fed 5- to 6-year-olds have PIAT-reading recognition and math test scores that are, on average, over 36% of a standard deviation higher than scores for children not breast-fed. In ECLS-B, breast-fed kindergartners' reading and math test scores are about 30% of a standard deviation higher than their non-breast-fed peers. And in the PSID-C, the advantage is over 31% of a standard deviation. In the NLSY79-C and ECLS-B, children's average test score differentials tick up as average breastfeeding duration increases, with the largest differential for those breastfed six months or more compared to scores for non-breast-fed children.

The descriptive statistics also show differentials in pretreatment characteristics, favoring children who were breast-fed. Mothers of breast-fed children on average have higher years of education, are more likely to be married at the child's birth, are older, and are less likely to smoke dur-

[7] I rescale the scores to have a mean of 0 and a standard deviation of 1 (see the online data appendix for more information). The scores are normed on nationally representative samples, and thus I do not standardize the scores within my subsamples. Therefore, the means and standard deviations in the data will not be exactly 0 and 1. I do, however, interpret the results in terms of the national sample norms of a standard deviation of 1.

Table 2.—Comparison of Samples with National Averages

	NLSY79-C		All Births, 1989	ECLS-B, Kindergarten	All Births, 2001	PSID-C, Ages 5–6	All Births, 1993
	Ages 5–6	All Children					
Child characteristics							
Female	.487	.484	.488	.492	.489	.472	.488
First born	.378	.402	.410	.406	.398	.403	.407
Second born	.362	.343	.324	.329	.326	.350	.324
Year of birth	1988.687	1988.136	1989	2001	2001	1993.226	1993
	(5.745)	(6.580)				(2.667)	
Mother characteristics							
Nonblack, non-Hispanic	.769	.731	.702	.647	.640	.708	.672
Black, non-Hispanic	.152	.180	.159	.149	.147	.188	.162
Hispanic	.079	.089	.139	.204	.213	.104	.166
Years of education at birth	13.042	12.810	12.442	12.886	12.846	13.100	12.534
	(2.418)	(2.544)	(2.657)	(2.849)	(2.833)	(2.380)	(2.743)
Married at birth	.825	.796	.729	.678	.665	.771	.690
Age at birth	27.522	27.117	26.318	27.342	27.253	27.798	26.659
	(5.529)	(6.117)	(5.685)	(6.209)	(6.194)	(5.678)	(5.972)
Region at birth							
New England	.183	.188	.193	.171	.170	.183	.186
North Central	.301	.286	.229	.224	.220	.263	.225
South	.337	.344	.341	.365	.367	.313	.343
West	.179	.182	.236	.240	.243	.241	.245
Sample size	6,142	11,495	4,040,958	6,550	4,025,933	573	4,000,240

Means, standard deviations in parentheses. NLSY79-C, ECLS-B, and PSID-C data weighted. Data for all U.S. births in 1989, 1993, and 2001 are from the National Center for Health Statistics Natality Data files. About 5% of 1989 births do not have a reported ethnicity on their birth certificate, mostly due to states not requiring the information (Louisiana, New Hampshire, and Oregon). Race, however, is required on birth certificates in 1989, and the proportion black is .167 for all births. Mother's years of education is missing for about 9% of 1989 births.

ing pregnancy than mothers of children not breast-fed. They also have higher test scores (NLSY79-C and PSID-C). Mothers of breast-fed 5- and 6-year-olds have AFQT scores that average about 75% of a standard deviation higher than those of non-breast-fed children (NLSY79-C). Posttreatment measures favor breast-fed children as well. As breastfeeding duration increases, average maternal and paternal education, the likelihood of being married at the child's birth, and average AFQT scores also increase in the NLSY79-C and ECLS-B. In contrast, the PSID-C does not show a consistent pattern of more positive characteristics associated with higher breastfeeding duration.

VI. Results

Tables 3 to 6 show the relationship between breastfeeding and young children's cognitive test scores using the NLSY79-C, ECLS-B, and PSID-C data sets. The top panel of each table (labeled A) displays results for a 0/1 indicator for whether breast-fed, and the next panel (labeled B) shows results from a series of mutually exclusive indicators for breastfeeding duration with not breast-fed as the omitted category. The columns show weighted least squares, maternal fixed effects (table 4 only), and propensity score matching estimates. The majority of the specifications use pretreatment mother/father and child characteristics as controls.

I include two additional sets of controls in some weighted least squares specifications, although they were measured after the child's birth. The first measures maternal employment postbirth. As shown in section III, the decision to breast-feed, the duration of breastfeeding, and maternal employment are likely linked.[8] Researchers have found that maternal employment during children's early years negatively affects their cognitive outcomes (Ruhm, 2004, for example). Thus, one could worry that the breastfeeding variables are picking up something about the effects of maternal employment on children's cognitive development rather than the effects of breastfeeding per se. If the added postbirth employment measures, though potentially endogenous, do not affect the breastfeeding estimates, this should be less of a concern.

The second set of postbirth controls I add to the weighted least squares estimation are parenting measures and household income, as included in much of the breastfeeding literature. On the positive side, these variables, while potentially endogenous, may help control for some of the selection that occurs in the choice to breast-feed. However, measures such as parenting skills may also be influenced by whether the mother breast-fed her child, and thus cause an underestimation of any breastfeeding effect.

A. *NLSY79-C*

We first focus on the NLSY79-C results shown in table 3. Column 1 adjusts for pretreatment mother and child characteristics, excluding mother's AFQT score. Weighted least squares estimates show breastfeeding associated with about .10 to .12 of a standard deviation increase in 5- and 6-year-olds' PIAT-math and reading recognition test scores. Panel B shows a dose-response effect of breastfeeding, with

[8] Chatterji and Frick (2005) find that returning to work within three months of the child's birth is associated with a significant reduction in the probability that the mother will initiate breastfeeding.

TABLE 3.—ESTIMATES OF THE EFFECT OF BREASTFEEDING ON 5- AND 6-YEAR-OLDS' PIAT-READING RECOGNITION AND MATH TEST SCORES IN THE NLSY79-C

	(1)	(2)	(3)	(4)	(5)
PIAT-Reading Test					
A. Breast-fed (yes/no)					
Breast-fed	.104	.066	.067	.056	.080
	(.032)	(.032)	(.032)	(.031)	(.030)
B. Breastfeeding duration categories					
Breast-fed ≤ 1 month	.049	.027	.026	.016	—
	(.051)	(.050)	(.050)	(.049)	
Breast-fed 2–3 months	.055	.025	.026	.014	—
	(.043)	(.043)	(.043)	(.042)	
Breast-fed 4–5 months	.138	.089	.091	.088	—
	(.049)	(.049)	(.049)	(.049)	
Breast-fed 6+ months	.180	.133	.134	.121	—
	(.048)	(.047)	(.047)	(.047)	
PIAT-Math Test					
A. Breast-fed (yes/no)					
Breast-fed	.116	.083	.085	.071	.087
	(.031)	(.031)	(.031)	(.030)	(.030)
B. Breastfeeding duration categories					
Breast-fed ≤ 1 month	.089	.070	.074	.063	—
	(.047)	(.047)	(.047)	(.047)	
Breast-fed 2–3 months	.121	.093	.096	.078	—
	(.041)	(.042)	(.042)	(.041)	
Breast-fed 4–5 months	.116	.071	.068	.063	—
	(.048)	(.048)	(.048)	(.048)	
Breast-fed 6+ months	.136	.094	.094	.076	—
	(.049)	(.048)	(.048)	(.048)	

The entries in columns 1 to 4 are weighted least squares estimates with robust standard errors clustered by mother in parentheses. Column 1 adjusts for pretreatment mother and child characteristics excluding AFQT score, column 2 adds mother's AFQT score (also pretreatment), column 3 adds maternal employment measures postbirth, and column 4 adds a parenting score and household income postbirth. Entries in column 5 are unweighted propensity score matching estimates (the average treatment effect on the treated) with bootstrapped standard errors in parentheses (500 replications). The propensity score is estimated using a logit with all pretreatment mother and child characteristics, including mother's AFQT score as explanatory variables; the matching method uses an Epanechnikov kernel with a bandwidth of .05 and 3% trimming. In panel B, not breast-fed is the omitted category.

TABLE 4.—ESTIMATES OF THE EFFECT OF BREASTFEEDING ON 5- AND 6-YEAR-OLDS' PIAT-READING RECOGNITION AND MATH TEST SCORES IN THE NLSY79-C: SIBLING SUBSAMPLE

	Weighted Least Squares (1)	Weighted Fixed Effects (2)
PIAT-Reading Test		
A. Breast-fed (yes/no)		
Breast-fed	.029	.003
	(.037)	(.084)
B. Breastfeeding duration categories		
Breast-fed ≤ 1 month	.003	−.040
	(.057)	(.099)
Breast-fed 2–3 months	−.029	−.014
	(.050)	(.104)
Breast-fed 4–5 months	.042	.141
	(.055)	(.121)
Breast-fed 6+ months	.105	.031
	(.053)	(.122)
PIAT-Math Test		
A. Breast-fed (yes/no)		
Breast-fed	.069	.134
	(.036)	(.085)
B. Breastfeeding duration categories		
Breast-fed ≤ 1 month	.101	.149
	(.053)	(.099)
Breast-fed 2–3 months	.057	.143
	(.049)	(.103)
Breast-fed 4–5 months	.033	.159
	(.055)	(.126)
Breast-fed 6+ months	.085	.050
	(.055)	(.118)

Robust standard errors clustered by mother in parentheses. Column 1 adjusts for pretreatment mother and child characteristics, including mother's AFQT score. Column 2 adjusts for the same set of variables as column 1, with the exception of any fixed mother characteristics. Sample size is 4,624 siblings from 1,890 families: 383 families contain at least one sibling who was breast-fed and at least one who was not; 787 families contain siblings who differ in their more detailed breastfeeding history. In panel B., not breast-fed is the omitted category.

TABLE 5.—ESTIMATES OF THE EFFECT OF BREASTFEEDING ON KINDERGARTNERS' READING AND MATH TEST SCORES IN ECLS-B

	(1)	(2)	(3)	(4)
Reading Test				
A. Breast-fed (yes/no)				
Breast-fed	.101	.100	.075	.101
	(.037)	(.037)	(.037)	(.033)
B. Breastfeeding duration categories				
Breast-fed ≤ 1 month	.061	.061	.043	—
	(.050)	(.050)	(.049)	
Breast-fed 2–3 months	.070	.068	.054	—
	(.051)	(.051)	(.050)	
Breast-fed 4–5 months	.107	.105	.072	—
	(.068)	(.068)	(.068)	
Breast-fed 6+ months	.147	.148	.113	—
	(.045)	(.045)	(.045)	
Math Test				
A. Breast-fed (yes/no)				
Breast-fed	.094	.093	.068	.085
	(.035)	(.036)	(.035)	(.032)
B. Breastfeeding duration categories				
Breast-fed ≤ 1 month	.080	.080	.062	—
	(.050)	(.050)	(.049)	
Breast-fed 2–3 months	.086	.085	.069	—
	(.049)	(.050)	(.049)	
Breast-fed 4–5 months	.070	.067	.034	—
	(.069)	(.069)	(.069)	
Breast-fed 6+ months	.116	.116	.084	—
	(.042)	(.043)	(.043)	

The entries in columns 1 to 3 are weighted least squares estimates with robust standard errors in parentheses. Column 1 adjusts for pretreatment mother and child characteristics, column 2 adds maternal employment measures postbirth, and column 3 adds a maternal parenting score, indicators for frequency the mother reads to the child, and household income postbirth. Entries in column 4 are unweighted propensity score matching estimates (the average treatment effect on the treated) with bootstrapped standard errors in parentheses (500 replications). The propensity score is estimated using a logit with all pretreatment mother and child characteristics as explanatory variables; the matching method uses an Epanechnikov kernel with a bandwidth of .05 and 3% trimming. In panel B, not breast-fed is the omitted category.

TABLE 6.—ESTIMATES OF THE EFFECT OF BREASTFEEDING ON 5- TO 6-YEAR-OLDS' WOODCOCK-JOHNSON (WJ) LETTER WORD AND APPLIED PROBLEMS TEST SCORES IN THE PSID-C

	(1)	(2)	(3)	(4)
WJ Letter Word Test				
A. Breast-fed (yes/no)				
Breast-fed	.069	.047	.048	.030
	(.126)	(.125)	(.125)	(.132)
B. Breastfeeding duration categories				
Breast-fed ≤ 1 month	.526	.546	.544	—
	(.232)	(.233)	(.232)	
Breast-fed 2–3 months	−.211	−.226	−.226	—
	(.170)	(.164)	(.165)	
Breast-fed 4–5 months	.218	.219	.215	—
	(.194)	(.195)	(.196)	
Breast-fed 6+ months	.053	.007	.009	—
	(.152)	(.152)	(.152)	
WJ Applied Problems Test				
A. Breast-fed (yes/no)				
Breast-fed	.215	.182	.150	.128
	(.126)	(.127)	(.121)	(.130)
B. Breastfeeding duration categories				
Breast-fed ≤ 1 month	.173	.183	.177	—
	(.176)	(.186)	(.178)	
Breast-fed 2–3 months	.197	.175	.140	—
	(.194)	(.193)	(.192)	
Breast-fed 4–5 months	.463	.447	.402	—
	(.170)	(.179)	(.174)	
Breast-fed 6+ months	.167	.109	.073	—
	(.147)	(.147)	(.141)	

The entries in columns 1 to 3 are weighted least squares estimates with robust standard errors clustered by mother in parentheses. Column 1 adjusts for pretreatment mother and child characteristics excluding mother's cognitive test score, column 2 adds a maternal cognitive test score (also pretreatment), and column 3 adds a maternal parenting score and household income postbirth. Entries in column 4 are unweighted propensity score matching estimates (the average treatment effect on the treated) with bootstrapped standard errors in parentheses (500 replications). The propensity score is estimated using a logit with all pretreatment mother and child characteristics as explanatory variables; the matching method uses an Epanechnikov kernel with a bandwidth of .15 and 3% trimming. In panel B, not breast-fed is the omitted category.

breastfeeding six months or more having large effects of .14 to .18 of a standard deviation in test scores. The addition of mother's AFQT score to the specification in column 2 results in a substantial drop in the breastfeeding estimates. The coefficient on the breastfeeding dummy variable for the PIAT-reading recognition test declines by 37% to .066, and the coefficient for the PIAT-math test declines by 28% to .083. Similarly, the coefficient on the indicator for whether the child was breast-fed for six months or more declines by 26% (reading) and 31% (math), which leaves the coefficients at .133 (reading) and .094 (math).

Column 3 adds maternal employment postbirth, which barely changes the results. I also tried alternative measures of maternal employment, and the breastfeeding coefficients barely changed. Next, column 4 adds a HOME score and log of household income measured at the interview at age 5 or 6. Here, we see a small decline in the breastfeeding coefficients, with the coefficient falling to .056 for the PIAT-reading test and no longer statistically significant and the coefficient falling to .071 for the PIAT-math test. All breastfeeding duration dummy variables are no longer statistically significant for the PIAT-math test, but the top two, four to five months and six or more months, remain at least marginally significant for the PIAT-reading recognition test.

I also used the same set of pretreatment characteristics as column 2 in column 5, which shows propensity score matching estimates for the effect of being breast-fed on cognitive test scores. The propensity score estimates were obtained using an Epanechnikov kernel with a bandwidth of .05 and 3% trimming.[9] They are not weighted with the sample weights. The propensity score estimates are fairly similar to those from the linear regression in column 2, suggesting that functional form issues are not important here.

Table 4 displays weighted least squares and maternal fixed effects estimates of breastfeeding on children's cognitive outcomes using the sibling subsample of 5- and 6-year olds in the NLSY79-C. Some have posited (Evenhouse & Reilly, 2005, for example) that within-sibling analyses can control for the selection problem associated with the decision to breast-feed. Within-sibling breastfeeding effects are solely identified from sibling sets in which at least one was breast-fed and at least one was not, or the durations differ. The sibling sample used here is fairly large: 4,624 siblings from 1,890 families. Only 383 families (20% of the 1,890 families) contain at least one sibling who was breast-fed and at least one who was not, and 787 families (42%) contain siblings who differ in their more detailed breastfeeding history.

The specifications in table 4 adjust for all pretreatment mother and child characteristics as in column 2 of table 3. The weighted least squares estimates for the sibling subsample are generally diminished from those of the full sample. The differences are likely related to sample selection introduced by excluding singletons; when I run the regressions for the singleton subsample, the breastfeeding effects are much higher than for the full sample. As found in the prior literature that uses the NLSY79-C, once maternal fixed effects, which eliminate any fixed mother (but not child) characteristics, are incorporated, all breastfeeding effects are no longer statistically significant. Indeed, only a few pretreatment background characteristics are statistically significant in the fixed-effects analysis, likely due to the small amount of variation in these measures within sibling sets. Moving from least squares in column 1 to fixed effects in column 2, the coefficient estimates increase for the PIAT-math test, except for six months (although they are all not statistically different from 0). It is difficult to come up with a concrete explanation as to why this occurs, although perhaps it is due to child-based selection introduced by identifying the effects only from siblings with different breastfeeding durations.

B. *ECLS-B*

We next turn to the ECLS-B results shown in table 5. Column 1 adjusts for pretreatment mother and child background characteristics. Panel A shows breastfeeding effects

[9] All variables pass the regression-based balancing test at the .05 level after five interaction and higher-order terms were added to the matching specification.

of .094 and .101 on math and reading test scores of kindergartners, a similar magnitude to that found in the NLSY79-C. In panel B, only breastfeeding for six months or more has a statistically significant effect, ranging from .116 (math) to .147 (reading). Unfortunately, ECLS-B does not contain a maternal cognitive test score. The next column controls for the month the mother returned to work, available in the round 1 interview. Similar to the NLSY79-C, the maternal employment measures do not have an impact on the breastfeeding estimates. Column 3 adds a maternal parenting score available in the first round, whether the mother reads frequently to the child in a typical week (kindergarten interview), and log of household income (kindergarten interview). The breastfeeding effects fall to .068 (math) and .075 (reading), and the effects of breastfeeding six months or more fall to .084 (math) and .113 (reading). The last column contains propensity score matching estimates using the same pretreatment mother and child characteristics as in column 1. The matching estimates are obtained using an Epanechnikov kernel with a bandwidth of .05 and 3% trimming.[10] The results are similar to the least squares estimates in panel A of column 1.

ECLS-B oversamples twins, which enables the inclusion of a maternal fixed effect. However, in the sample of about 550 twin pairs, only a tiny fraction have different breastfeeding statuses, and about 50 pairs have different breastfeeding histories. All breastfeeding effects were not statistically different from 0 in the within-twin estimation.

Finally, the ECLS-B data set contains information on whether and when the mother supplemented her breastfeeding with formula or food. If the fatty acids in breast milk promote cognitive development, breastfeeding effects could be diluted with supplementation. Including indicators for timing of supplementation in a specification that controls for the same pre-treatment characteristics in column 1 of table 5 reveals mostly negative but not statistically significant supplementation effects (see the online appendix, table 5). However, the breastfeeding effects for those who do not supplement at four to five months or six or more months are very large for the reading test, at over two-tenths of a standard deviation, and yet fairly similar to those in column 1, panel B of table 5 for the math test. It is thus difficult to make any strong conclusions on supplementation effects based on the findings.

C. *PSID-C*

Table 6 displays weighted least squares and propensity score matching estimates of breastfeeding effects on cognitive test scores for the PSID-C sample of 5- to 6-year olds. The least squares effects shown in column 1 for the Applied Problems math test are much larger than those found for the ECLS-B and NLSY79-C samples—at .215 of a standard deviation. In contrast, the estimate for the Letter-Word verbal test is small (.069) and not statistically significant. With the inclusion of a maternal cognitive test score in column 2, the breastfeeding effect for the Applied Problems test also becomes statistically insignificant, which is also found for the propensity score matching estimates in column 4. The results for the duration categories are very different from that found in the other surveys, although one can see from the means why this might have occurred. Breastfeeding for one month or less has a huge effect, of over half of a standard deviation, on the Letter-Word test score for all specifications, and the other breastfeeding duration categories essentially have no effect. The same is true for the breastfed four- to five-month category for the Applied Problems test, which is over 40% of a standard deviation. Note that each of these two categories contains fewer than 45 observations.[11]

The large magnitude of the standard errors in all of the PSID-C results in table 6 deserves some attention. For example, the standard errors for breastfeeding for six months or more in column 3 are .141 (Applied Problems) and .152 (Letter-Word). It would be impossible to detect an effect of having been breast-fed for six months or more at conventional statistical levels unless it was larger than .28 to .30 of a standard deviation, about three times the size of similar estimates from the NLSY79-C and ECLS-B in tables 3 and 5.

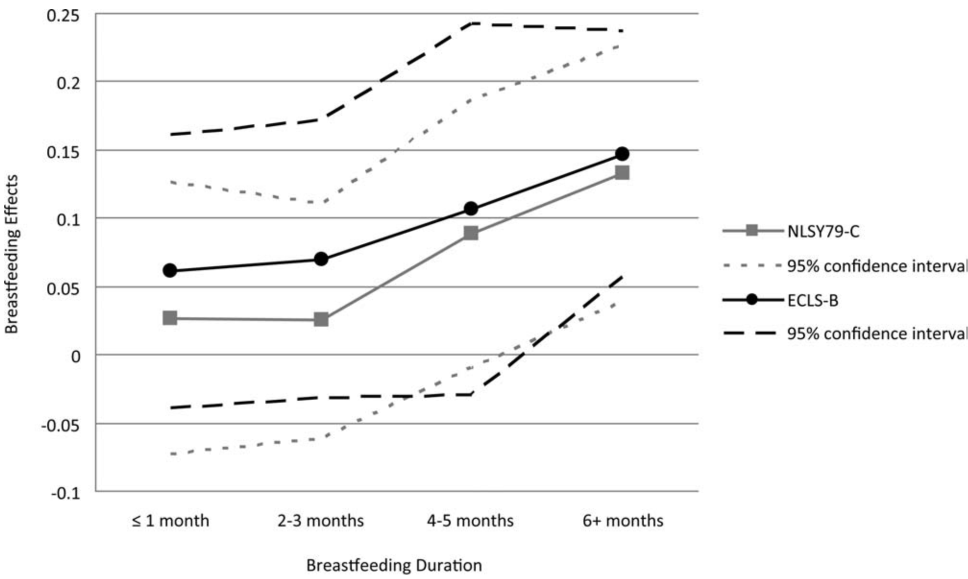
D. *Stratification by Maternal Characteristics*

I also stratify the NLSY79-C and ECLS-B samples (the PSID-C sample is too small) by mother's race and ethnicity, age at the child's birth, years of education, and cognitive test score to investigate whether there is heterogeneity in the effects of breastfeeding. Table 6 in the online appendix reports the results, which adjust for all pretreatment mother and child characteristics. Note that the standard errors in this table are much larger than those in tables 3 and 5, suggesting that subdividing the samples may be too demanding of the data. In general, the breastfeeding effects in the subsamples tend not to be consistently large or small within a particular subsample, relative to the other groups. An exception is that breastfeeding appears to have a larger effect for children of black, non-Hispanic mothers, although not for the PIAT-reading recognition test in the NLSY79-C. Gibson-Davis and Brooks-Gunn (2006) find positive breastfeeding effects only for mothers with at least some post-

[10] Almost all variables pass the balancing test at the .05 level after fourteen higher-order and interaction terms are added. The exceptions are two dummy variables for missing WIC participation and missing prebirth employment, which affect only a small number of observations. I could not get the variable North Central region to balance, even after including various interactions, and thus deleted it from the propensity score matching specification.

[11] If I increase the sample size by including 3- to 4-year-olds, the results are very similar. In contrast, when I add 7- to 8-year-olds, the breastfeeding effects increase.

FIGURE 1.—EFFECT OF BREASTFEEDING ON YOUNG CHILDREN'S READING TEST SCORES



secondary education. This is not the case in the NLSY79-C and ECLS-B data.

VII. Discussion

This section first synthesizes the results and points out caveats and then compares the results to those in prior literature.

A. *Finding and Caveats*

The NLSY79-C and ECLS-B results suggest that breastfeeding has a small, positive effect on cognitive test scores of young children. Using only pretreatment mother and child characteristics and excluding maternal cognitive test score in the NLSY79-C, the effects are about one-tenth of a standard deviation across the NLSY79-C and ECLS-B data sets. The addition of the mother's AFQT score causes the NLSY79-C results to fall to .066 (reading) and .083 (math) of a standard deviation. If, conservatively, one reduces the ECLS-B effects by one-third to account for a missing maternal test score, the effects would be of similar magnitude to the NLSY79-C: .067 (reading) and .063 (math). The propensity score matching estimates are very similar to the weighted least squares estimates that control for pretreatment mother and child characteristics, suggesting that functional form issues are not a worry here.

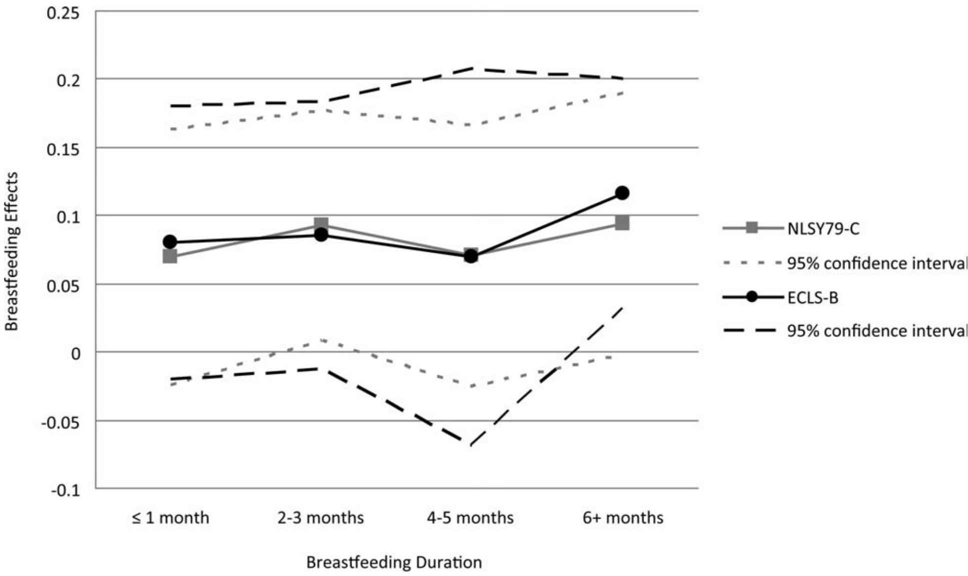
The NLSY79-C and ECLS-B results for the reading tests point roughly to a dose-response effect of breastfeeding as illustrated in figure 1, although the 95% confidence intervals are quite large and overlapping. These estimates are adjusted for all pretreatment mother and child characteristics, including mother's AFQT score in the NLSY79-C. Having been breast-fed for six months or more has the largest effect, of .133 of a standard deviation in the NLSY79-C and .147 in ECLS-B. As shown in figure 2, the math tests do not consistently show the same step up in effects at the higher breastfeeding durations across the data sets, and the six-month effects are .094 (NLSY79-C) and .116 (ECLS-B) of a standard deviation.[12]

Breastfeeding effects in the PSID-C are extremely variable depending on which child cognitive test score is used. In addition, the breastfeeding coefficients are extremely large for some of the shorter breastfeeding durations yet very small for the longer durations. Given the smaller sample size, long recall of breastfeeding duration, and lack of prenatal health behavior data in the PSID-C, I think these large effects are much less credible than the smaller effects found in the NLSY79-C and ECLS-B.

The paper further investigates both whether breastfeeding effects on children's cognitive test scores are the result of maternal employment differences or maternal parenting skills correlated with breastfeeding status. With detailed postbirth employment measures in the NLSY79-C and a less detailed measure in ECLS-B, the answer to the first appears to be no. Differences in maternal parenting skills based on the choice to breast-feed may be due to selection or to the release of hormones during breastfeeding that enhances positive mothering behaviors (Feldman & Eidelman, 2003). The inclusion of maternal parenting measures postbirth does decrease the breastfeeding effects, although not to the same degree as the inclusion of a maternal cognitive test score. Still, the six-month breastfeeding effect

[12] Using the NLSY79-C, Cunha, Heckman, and Schennach (2010) find that the percentage of total variance in measurement due to signal is very high for the PIAT-reading recognition test for 5- and 6-year-olds (about 96) and fairly low for the PIAT-math test for 5- and 6-year-olds (about 31).

FIGURE 2.—EFFECT OF BREASTFEEDING ON YOUNG CHILDREN'S MATH TEST SCORES



points to over one-tenth of a standard deviation increase in reading test scores for NLSY79-C and ECLS-B children. The six-month breastfeeding effects on math test scores are .076, and not statistically significant, in the NLSY79-C and .084 in ECLS-B. If breastfeeding and positive maternal parenting practices create a synergy, one might expect the interaction of the maternal parenting score and breastfeeding to have a positive and significant impact on children's cognitive test scores. However, the interaction term is not statistically significant in the NLSY79-C or ECLS-B. These sets of results suggest that the breastfeeding effects on children's cognitive outcomes are likely not solely due to maternal parenting skills, at least as measured here.

Many medical researchers have posited that polyunsaturated long-chain fatty acids in breast milk promote cognitive development (Horta et al., 2007). Thus, one would expect any breastfeeding effects to be diluted the earlier the introduction of infant formula or food. I do not find significant supplementation effects on cognitive outcomes. The magnitude of the supplementation in ECLS-B is not measured, however, so this is likely not a strong test.

Breastfeeding effects on children's cognitive outcomes are not statistically significant in within-sibling (NLSY79-C) and twin (ECLS-B) specifications. One could argue that these estimates show that any breastfeeding effect on children's cognitive outcomes is due to unobserved maternal characteristics. However, the answer is not so clear-cut. First, fixed effects may exacerbate measurement error issues in breastfeeding and its duration, causing attenuation bias, which is also consistent with some of the results. And second, the identification of breastfeeding effects solely from siblings with different breastfeeding histories potentially introduces other significant selection issues. For example, parents may engage in compensatory behavior and invest in their non-breast-fed child in other unobserved ways that increase his or her cognitive outcomes (see, for example, Behrman, Pollack, & Taubman, 1982). Sibling fixed-effect estimates that rely on the small amount of sibling variation left after the compensatory behavior would likely result in nonsignificant breastfeeding effects.

Finally, I would stop short of saying the significant least squares and propensity score matching estimates show that breastfeeding truly has a causal effect on children's cognitive test scores. A causal interpretation would imply that the contents of the breast milk or the release of hormones during breastfeeding that may enhance positive mothering behaviors stimulate children's cognitive development. While this may be true, it is also possible that even with the rich set of explanatory variables used here, additional parent or child (potentially) observable or unobservable characteristics are driving the results. The inclusion of a maternal cognitive test score in the children's outcome equations significantly reduces the breastfeeding coefficients, and ideally we would have a test score for the child's father in addition to his level of education, which is included in the pretreatment characteristics.[13] Posttreatment controls may be affected by whether the child was breast-fed and thus cause an underestimation of any breastfeeding effects. As an experiment, I added to the fullest NLSY79-C specifications a number of additional posttreatment variables: child ever participated in Head Start, child ever enrolled in preschool, and mother's detailed marital status, spouse or partner in the household, whether spouse or partner worked in the prior calendar year, and spouse or partner years of education—all measured at the child's interview at age 5 or 6. The breastfeeding coefficients barely changed.

[13] I included father's occupational status in some ECLS-B specifications, but the variable was not statistically significant; thus, I omitted it in the final paper.

B. *Comparison to Prior Literature*

The breastfeeding estimates found in this paper are generally similar, or on the low side, when compared to the prior research on the topic (see table 1 in the online appendix). For example, the weighted least squares point estimates of the effect of having ever been breast-fed in this paper range from .056 to .085 of a standard deviation (NLSY79-C) and .068 to .101 (ECLS-B). The higher estimates are from specifications that condition on pretreatment characteristics, and the lower are from specifications with posttreatment measures as well. The estimates are similar in magnitude to the least squares results found by Belfield and Kelly (2010) with ECLS-B for 54-month olds but lower than their IV or propensity score matching estimates. They are also similar to least squares results in Denny and Doyle (2010) for 7- and 11-year-olds, and to least squares (but not IV) estimates of having ever been breast-fed in Del Bono and Rabe (2011) for 5- and 7-year-olds. The estimates are generally lower than the over one-tenth of a standard deviation effect found by Gibson-Davis and Brooks-Gunn (2006) and Iacovou and Sevilla-Sanz (2010), although their papers restrict the breastfeeding measure to at least one month.

The weighted least squares point estimates for having been breast-fed for six months or more range from .076 to .134 of a standard deviation (NLSY79-C) and .084 to .148 (ECLS-B). These estimates are similar to the magnitudes found in Belfield and Kelly (2010) for 54-month-olds in ECLS-B (least squares only) and Der et al. (2006) using the NLSY79-C. In addition, as found in Neidell (2000) with the NLSY79-C and Belfield and Kelly (2010) with twins in ECLS-B, I find no statistically significant breastfeeding effects in the NLSY79-C and ECLS-B in maternal fixed-effects models. In contrast, Evenhouse and Reilly (2005) find positive breastfeeding effects in maternal fixed effects models on a school-based sample of older youths.

VIII. Conclusion

This paper examines whether breastfeeding has an impact on young children's cognitive test scores using three very rich, national longitudinal data sets from the United States. The results generally point to a small, positive, and statistically significant effect of breastfeeding on young children's cognitive test scores. In addition, there appears to be a dose-response effect of breastfeeding, with breastfeeding six months or more generally having the largest effect. Propensity score matching estimates, which are based on the assumption of selection on observables, are very similar to the least squares estimates. And while controlling for maternal employment postbirth does not have an impact on the breastfeeding effects, controlling for posttreatment maternal parenting skills and household income does diminish the breastfeeding effects, although they are generally still statistically significant. However, within-sibling models using NLSY79-C and ECLS-B data result in nonsignificant breastfeeding effects.

To gauge the monetary benefits of breastfeeding, I calculate a rough estimate of the present discounted value of the increase in lifetime earnings to a child from having ever been breast-fed and from having been breast-fed for six months or more. Krueger (1999) does a similar exercise to calculate benefits from a kindergarten intervention. To obtain the wage returns to test scores, I estimate wage regressions for 2008 using 24- to 26-year-olds in the National Longitudinal Survey of Youth 1997 (NLSY97) who took the PIAT-math test in 1997.[14]

Median annual earnings of full-time, full-year workers age 15 and over were \$46,367 for men and \$35,745 for women in 2008 (DeNavas-Walt, Proctor, & Smith, 2009). Following Krueger (1999), I assume any cognitive test score gains from breastfeeding persist over the child's lifetime and that individuals work from ages 20 to 65. I use a real discount rate of 7%, the historical average annual return to equities (see, for example, chapter 1 of Bogle, 2010). I also discount the benefits back to the point of intervention, when the child is age 0.[15] The present value calculation provides a rough estimate for the following thought experiment. If a mother does not breast-feed her child, on average, how much money would she have had to put in a mutual fund at the child's birth so that by his retirement at age 65, he was as well off as he would have been if he had been breast-fed? Using the above assumptions, I find gains in the present discounted value of lifetime earnings from having ever been breast-fed of \$1,162 to \$1,778 for males and \$780 to \$1,193 for females (2008 dollars). Having been breast-fed for six months or more is associated with gains of \$1,655 to \$2,588 for males and \$1,110 to \$1,737 for females. Of course, many assumptions underlying this calculation could be incorrect, and there may be unobservables driving the positive breastfeeding results, but it does suggest potential economic gains for children who are breast-fed.

Breastfeeding is likely more time intensive than using infant formula, although formula feeding involves more direct costs.[16] Although beyond the scope of this paper, a calculation of the net benefit of breastfeeding would need to take into account the monetary, utility, and time costs and

[14] See section IV of the online data appendix and online appendix tables 7 and 8 for more details. The wage regressions are similar to those in Murnane et al. (1995).

[15] I also use the following information to calculate the present value estimates. Test score coefficients from the NLSY97 log hourly wage equations that include early background and job characteristics, but exclude highest grade completed (which may be influenced by test scores), are .103 of a standard deviation for men and .090 for women. When I condition on pretreatment mother and child characteristics, including AFQT score (NLSY79-C), the weighted least squares estimates of the effect of breastfeeding range from .066 to .083 of a standard deviation in young children's test scores (NLSY79-C) and .094 to .101 (ECLS-B). Breastfeeding for six months or more is associated with .094 to .133 of a standard deviation (NLSY79-C) and .116 to .147 (ECLS-B).

[16] Breast milk is easily digested, and thus breast-fed babies often eat more frequently than formula-fed babies do.

benefits of both breastfeeding and formula feeding. For example, costs and benefits of formula feeding include the direct cost of infant formula and bottles, parental time costs and utility or disutility of feeding, and bottle preparation and bottle clean-up. Costs and benefits of breastfeeding include maternal time costs and utility or disutility of feeding (and possibly pumping) and the direct cost of a pump if the mother pumps. To complicate things even further, one could factor in the value of any health benefits to the mother and the child associated with each type of feeding, as was done above for child cognitive outcomes.

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