Any Casual Link between Breastfeeding and Scholastic Achievement?[1]

Bhavneet Walia and Dong Li
Department of Economics
Kansas State University
Manhattan, KS 66506-4001

This Version: October 2007

Abstract

It has long been debated whether breastfeeding leads to higher intelligence quotient (IQ) and more successful scholastic achievement. This study empirically examines the issue. Many past studies fail to take into account the possible endogeneity of the breastfeeding decision and thus falsely identify the correlation between breastfeeding and IQ as a causal relationship. We attempt to distinguish the causation and correlation between the two variables. Our results show that, after controlling for possible endogeneity, breastfeeding has no significant impact on IQ or scholastic achievement.

JEL classification: J13; I10
Keywords: Breastfeeding; Endogeneity; Scholastic achievement; Matching estimator; Generalized method of moments

[1] We thank Professor John Horwood for providing the data used in this study.

I. Introduction

The impact of breastfeeding on health and academic outcomes of children has been an issue of debate for a long time. In recent years, a large amount of literature has emerged showing the association between breastfeeding and cognitive development. A number of papers claim that breastfeeding has a positive effect on child's cognitive development. At issue is whether such papers have properly distinguished between causation and correlation with respect to these two variables. In this study, we try to distinguish causation and correlation between duration of breastfeeding and cognitive development such as scholastic achievement and intelligence quotient (IQ).

Horwood and Fergusson (1998) examined whether breastfeeding caused cognitive benefits into "young adulthood". Controlling for factors such as mother's age, mother's education, family socio-economic status, average income of the family, average standard of living of the family, mother's smoking habits, number of siblings and birth weight, the authors found breastfeeding to have a lasting positive effect on IQ and other academic outcomes. This study was highly publicized by the CNN Headline News among other news outlets in January 1998 when the study was published in *Pediatrics*. Children in the sample were tested on various standard testing scales such as the Wechsler Intelligence Scale for children (WISC-R) and the Progressive Achievement Test of Reading Comprehension (PAT). Out of ten different measures of academic achievement, the authors found breastfeeding to be positive and significant in 9 cases. The only measure without a significant effect of breastfeeding is teacher's rating of reading ability at age 8 years. We are able to replicate their results using the same data set and the same linear regression models.

Mortensen et al. (2002) examined the relationship between duration of breastfeeding and adult intelligence using two different samples. They found a strong and positive association between duration of breastfeeding and adult intelligence. The authors controlled for family characteristics such as marital status, education, age, height, smoking habits of the mother, social status of the family, number of prior pregnancies for the mother, gestation age, birth weight, birth length and delivery conditions. They found positive association between duration of breastfeeding with both parental social status and education. The authors provide three reasons that breastfeeding and cognitive development may be positively correlated. First, the composition of human milk and that of infant formula may be different. Second, it may reflect the differences in the surroundings of the child, the mother-child interaction, and the mother's attitude towards the child. Third, some unidentified factors are correlated with both the infant feeding methods and the outcome variables.

Michaelson et al. (2003) found positive effects of breastfeeding on cognitive and visual acuity of brain development. The authors suggested that this positive association maybe due to the three reasons similar to those outlined in Mortensen et al. (2002). There have been some past studies questioning the relationship between breastfeeding and cognitive growth of children. Jacobson et al. (1999) challenged the past literature associating breastfeeding directly with a higher intelligence quotient. They found that, after taking into consideration mother's IQ and other parental factors, the effect of breastfeeding on child's IQ disappears. Their results showed that the positive association between breastfeeding and IQ is due to genetic and socio-environmental factors. Angelsen et al. (2001) examined the effects of breastfeeding on cognitive development at

age 1 and 5 years. They compared children who were breastfed for 3-6 months with those who were breastfed less than 3 months. They found a positive effect of breastfeeding on mental development and a comparatively smaller but positive effect on motor development for children age 13 months to 5 years. The importance of controlling for parental education and maternal IQ can be seen in the papers such as Malloy and Berendes (1998) and Jacobson et al. (1999). Malloy and Berendes (1998) examined the effect of breastfeeding on intellectual development using a sample from a relatively homogeneous population to see if the past results had been contaminated by differences in background. Their study compared children who were fed on formula milk to children who were breastfed. While failing to include information on maternal and paternal education, they found breastfeeding to be significant in a linear regression. However, after controlling for maternal and paternal education, breastfeeding became insignificant. Assuming the decision of breastfeeding to be exogenous, these studies have used linear models to estimate the effect of breastfeeding on cognitive development of the child.

The goal of this study is to examine whether treating breastfeeding as exogenous leads to upward biased result. Past studies have used ordinary linear squares (OLS) estimation or its equivalent such as analysis of variance (ANOVA) to measure the effect of breastfeeding on IQ. Treating the decision to breastfeed as exogenous is questionable, as suggested by Mortensen et al. (2002) and Michaelson et al. (2003). In this paper we take into account the possible endogeneity of breastfeeding in our model. We will examine whether breastfeeding is causing better academic achievement or whether breastfeeding is merely correlated with better academic achievement. Using generalized methods of moment estimation and matching estimator we look at the impact of

breastfeeding on scholastic achievement. Some previous studies examined the health benefits of breastfeeding on child outcome while treating breastfeeding as endogenous. Senauer and Kassouf (2000) used a sample of Brazilian children to look at the health benefits of breastfeeding and the demand for medical assistance by children. Even after controlling for possible endogeneity of breastfeeding, they still found breastfeeding to have a significantly positive effect on the health outcome of the children. Barrera (1991) and the Cebu Study Team (1992) also estimated the child health production function while allowing breastfeeding to be endogenous. Barrera (1991) looked at the relationship between duration of unsupplemented breastfeeding and height. In the same study the author showed how the use of OLS estimation by treating breastfeeding as exogenous can lead to biased results. Correcting for heterogeneity and endogeneity in previous models, the Cebu Study Team (1992) found how surroundings of the child such as household and community impact child's health production function.

Section II describes the data set used for this project. Section III presents the model and the estimation techniques. Section IV shows the results from generalized method of moments estimation and the matching estimator. Concluding remarks are presented in Section V.

II. Data Set

The data set was provided to us by L. John Horwood, who used the same data in Horwood and Fergusson (1998). The data set was collected as a part of the Christchurch Health and Development Study (CHDS). It studied 1265 children over a period of 18 years. All children born between April 15, 1977 and August 5, 1977 in the urban region

of Christchurch, New Zealand were included in the study. The children were studied at birth, at age 1 year old, and then yearly until age 16. The final survey interview was conducted at age 18. Parents were concurrently surveyed to get information on family characteristics such as family income, standard of living, maternal and paternal characteristics, family size, and birth weight of child. See Horwood and Fergusson (1998) for more information on the data.

Some of the main covariates used in similar studies in the past include mother's age, maternal education, socio-economic status, family income, number of children in the family, standard of living, gender, birth weight, and mother's smoking habits. CHDS include years of maternal education, ranging from no formal education to college graduate. Molly and Berendes (1998) considered mother's education in their study. Another potentially relevant variable, if measured correctly, is maternal IQ. CHDS does provide information on maternal IQ, but the variable suffers from an abundance of missing observations. Furthermore, these omitted observations may suffer from severe selection bias. Therefore, we do not control for this factor in our study. Family socio-economic status is based on the Elley/Irving scale. Father's occupation is a variable with information on whether the father is an unskilled, skilled, or professional worker. Average family income is calculated using gross income of the family. Studies in past have shown that children from high income families tend to do better in academics due to the stability in their environment. Positive and healthy environment has a significant positive impact on child's future outcomes as shown by the past literature. Other variables used in this study include the maternal employment hours when the baby was 1 year old and the baby's age when the mother returned to work, the number of hours the

baby received care from extended family members (such as grandparents) and non-family members (such as daycares) at age 1 year. Summary statistics for all the variables used in the study are presented in Table 1.

Ten standardized tests are used to calculated academic outcome of the child. The revised Wechsler Intelligence Scale for children is used to test child's IQ level. This test reports child's IQ at age 8 years and 9 years. Progressive Achievement Test (PAT) at age 10 years and 12 years is used to measure the reading comprehension abilities of the child. Teacher ratings are used to measure ability in reading and math at age 8 and 12 years. A scholastic test between 0 and 69 is used to measure the aptitude for high school success. Figure 1 presents the graphs showing the relationship between the unadjusted test scores and duration of breastfeeding using cubic splines (Hastie and Tibshirani, 1990, and Schimek, 2000).

III. Model

The basic model used in this study is the same as the one used by Horwood and Fergusson (1998):

$AA = \alpha + X\,\beta + BF\,\gamma + e$

where AA stands for academic achievement (one of the ten standardized test scores), X includes family and child characteristics such as mother's age, mother's education, family's socio-economic status, average family income, average standard of living of the family, mother's smoking habits, family size, and birth weight of the baby, and BF stands for duration of breastfeeding. We were able to replicate the OLS results in Horwood and

Fergusson (1998). However, we argue that the OLS results are biased because the possible endogeneity is not properly accounted for.

We run generalized method of moments (GMM) regressions using maternal employment status and time cared by extended family members and non-family members as instruments. Our first two instruments are age of child when the mother returned to work and the number of hours mother worked when the baby was 1 year old. Longer hours of work would reduce the amount of time mother spends with the baby. Using a sample of 668 black and 511 white women, Kurinu et al. (1989) found a negative relationship between time at which mother returned to workforce and duration of breastfeeding while the results differed in magnitude for white and back women, full time and part time workers, and between skilled and unskilled workers. Two other instruments are the number of hours per week the baby is under care by extended family members such as grandparents and relatives, and the number of hours per week that the child was being cared for by non-relatives (such as daycares). This second set of instruments follows from the past literature that has shows the importance of family circumstances on the decision of breastfeeding. A study by Sullivan et al. (2004) showed how the load of household tasks could lead to an early cessation of breastfeeding. Duration of breastfeeding can be longer if the mother receives some direct or indirect help from other family members for taking care of the baby. By allowing the decision to breastfeed to be endogenous, we found that the significance of breastfeeding on academic outcome of the child reduced and in some cases disappears.

To further validate our findings from the generalized method of moments we test our sample for treatment effect of breastfeeding by using the matching estimator by

Abadie et al. (2004), Abadie and Imbens (2006), and Heckman and Ichimura (1998). In the matching estimator we compare the impact of the treatment (breastfeeding) on the subjects. Matching estimator measure the average effect of breastfeeding on the academic outcomes.

Average treatment effect can also be calculated for subpopulations of the whole population or the sample for the treated (ATT) and for the controls (ATC). Given two outcomes ($AA_i(0)$,$AA_i(1)$), average treatment effect is used when only one outcome is observed. It matches the unobserved outcome to the closest (similar characteristics) opposite observed outcome. To get unbiased estimate of treatment effect, the individuals to receive treatment are chosen randomly, given their characteristics. The probability that individual receives the treatment (breastfeeding) in between 0 and 1. Randomness in the participation decision and identification are assumed to ensure unbiased estimation of the treatment effect.

Let $AA_i=AA_i(BF_i)$ = $AA_i(0)$ if BF = 0

$AA_i(1)$ if BF = 1

where BF_i takes values of 0 and 1, $AA_i(BF)$ represent academic achievement as a function of breastfeeding. $AA_i(0)$ is academic achievement when there is no breastfeeding received, and $AA_i(1)$ is academic achievement when the child receives breastfeeding. For each individual, the treatment effect is given by $\beta = \sum_{i=1}^{N} \{AA_i(1) - AA_i(0)\}$, which is the difference between academic achievements if the baby was breastfed minus that if the baby was not breastfed. Simple matching estimator calculates the treatment

effect as:

$$\beta^{sm} = \frac{1}{N}\sum_{i=1}^{N}\left\{A\hat{A}_i(1) - A\hat{A}_i(0)\right\} = \frac{1}{N}\sum_{i}^{N}(2BF_i - 1)\{1 + M_m(i)\}AA_i$$

where BF_i represents breastfeeding and $M_m(i)$ represents the number of times one observation is used as a match.

The average treatment effect for the treated and controls is calculated as follows:

$$\beta^{sm,t} = \frac{1}{N_1}\sum_{i:BF=1_i}\left\{A\hat{A}_i - A\hat{A}_i(0)\right\} = \frac{1}{N_i}\sum_{i=1}^{N}\{BF_i - (1 - BF_i)M_m(i)\}AA_i$$

$$\beta^{sm,c} = \frac{1}{N_0}\sum_{i:BF=0_i}\left\{A\hat{A}_i(1) - A\hat{A}_i\right\} = \frac{1}{N_0}\sum_{i=1}^{N}\{BF_iM_m(i) - (1 - BF_i)\}AA_i$$

A bias can arise in finite samples. Bias corrected matching estimator is used to ensure unbiased estimates as shown by Abadie et al. (2004).

IV. Results

Tables 2 (a) to (d) presents the results from OLS and GMM. We are able to replicate the results in Horwood and Fergusson (1998) based on OLS. For 9 out of the 10 dependent variables breastfeeding is significant and positive in the OLS regressions. This lends support to the claim that breastfeeding is beneficial to academic achievement. However, when we use the GMM with the instruments discussed in the previous section, the breastfeeding effect largely disappears. Breastfeeding is insignificant at 5% level for 9 out of the 10 models in the GMM regressions. Breastfeeding becomes insignificant for most of the tests when instruments such as mother's work hours and family environment are taken into account. We argue that the positive relationship between breastfeeding and academic achievement is merely an association. Once we control for the possible endogeneity of breastfeeding decision, breastfeeding is no longer significant. The tables also report Sargan statistic and p-values from overidentification tests for the validity of the instruments used. The Sargan statistics support the validity of the instruments used in this paper. Other variables, including family income, birth order, and birth weight, have significant effects on academic achievement, which is consistent with past literature.

Table 2(a) presents the results from the IQ tests and the reading test. The major change is in the coefficient of breastfeeding, which becomes insignificant after we control for endogenity in the Horwood and Fergusson model. As we can see, mother's age has a significantly positive impact on IQ, as measured by the Revised Wechsler Intelligence scale. Using a sample of 11, 742 siblings from Netherlands, Kalmijn and Kraaykamp (2004) showed a positive association between maternal age and child's

schooling after controlling for child surroundings. Angrist et al. (1996) found that children born to younger mothers have more difficulties in school. They are more likely to repeat classes during their academic career compared to children from older mothers. As shown in Table 2(a) to (d) maternal education has a positive effect on the academic outcome of the child. Educated mother tend to be more stable and careful about the surroundings of their children. The environment in which a child grows has a significant impact of his or her future outcome. This is consistent with the past literature. Positive home environment plays a significant positive role in the successful outcome of the children.

Average family income is a significant variable in OLS and GMM. The coefficients for this variable in the linear regression and GMM regression are very close to each other and significant at 5%. This positive coefficient is supported by Blanden et al. (2006). They showed that income has a positive impact on non-cognitive activities, which indirectly affect the academic outcome of the children. Plug and Wim (2005) examined adopted children to correct for the possible selection bias for high income parents having a genetic effect on their children, which would lead to better academic achievement. Their results support the significantly positive relationship between family income and better academic outcomes. Similar studies have shown a significant long-term impact of family income level on cognitive and non-cognitive achievement of the child. The socio-economic status of the family has a positive impact on the academic outcome of the child. The information on this variable is collected using the Elley/Irving scale of socio-economic status, which looks at father's occupation type, whether it is managerial, skilled, or unskilled.

Significant effect of birth order can be seen in the results. Being born later among siblings has a negative impact on academic outcome of the children. Booth and Hiau (2006) found that the birth order effects are persistent even after controlling for other family characteristics. Families who choose quantity sacrifice quality in terms of child academic achievement. Birth weight has a positive impact on academic outcome of the child. The small significant effect of birth weight in our results is in line with the study by Miller et al. (2005).

Our results show that breastfeeding is not a significant factor in child's academic outcomes once we properly take into account other factors which indirectly affect the decision to breastfeed in the first place. We find that the significance of breastfeeding in OLS is merely a correlation.

After controlling for possible endogenity of breastfeeding, we find that breastfeeding has no significant impact on IQ or scholastic achievement. Mothers who cannot breastfeed their children due to certain reasons such as health problems or work constraints need not feel guilty. Our study does not question or look into the significance of breastfeeding on health outcomes of the child, as established by past research. One main limitation of our study is that due to severe and non-random missing data we are unable to control for maternal IQ, which may have a significant impact on the academic outcome of the child. Our results show that the main confounding factors for the academic outcome of the child are maternal age, maternal education, family income, family size, gender and birth weight. Results from matching estimator for average treatment effect (ATE), average treatment effect for the treated (ATE) and average treatment effect for the controls (ATC) are presented in Table 3. Most of the coefficients

show insignificant effect of breastfeeding on academic achievement of the child. For average treatment effect except IQ at 8 and mathematics at 12 all other tests show insignificant effect of breastfeeding. For average treatment effect on the treated again only IQ at 8 and mathematics at 12 show significant effect of breastfeeding, rest all the tests show insignificance of breastfeeding. Lastly for average treatment effect on the controls only test for reading ability at age 12 and mathematics at age 12 show significant effect of breastfeeding.

V. Conclusion

Some of the past research suggests a significantly positive association between breastfeeding and the child's academic outcomes. In this paper we argue that this result is based on the improper assumption that breastfeeding decision is exogenous. We find that after controlling for the endogeneity of breastfeeding, the significance of breastfeeding found in past literature disappears. We speculate that it may be the amount of time a mother spends with her baby that causes higher IQ or better academic success for the child. Though we are unable to directly control for the amount of time a mother spends with the baby given the data set, its proxy, maternal employment, is supported by past literature. The results of this study have an important implication for mothers who are unable to breastfeed their babies due to health or employment reasons. They should not feel guilty about such constraints. They can spend a good amount of time with their children and ensure the children's future academic outcomes regardless of their breastfeeding status. As established by past research the environment in which the child grows up is very significant for successful outcome of the child. Our study adds to the

past literature by showing the importance of mother-child interactions. The main contribution of this paper is that breastfeeding should be considered an endogenous variable in the academic outcome regressions and OLS estimation can produce biased results when measuring the effect of breastfeeding on academic achievement of the child. Once the possible endogeneity of breastfeeding is properly taken into account, the significantly positive impact of breastfeeding on academic outcomes disappears.

Table 1
Summary statistics: CHDS data set

Variable Description	Mean	Std. Dev.	Min	Max
Family & child characteristics				
Mothers age(in years)	25.809	4.898	15	47
Maternal education				
No education	.511	.500	0	1
High School	.303	.459	0	1
College	.186	.389	0	1
Average standard of living	2.893	.462	1	5
Family socio-economic status	2.068	.683	1	3
Paternal education				
No education	.483	.499	0	1
High School	.334	.472	0	1
College	.183	.387	0	1
Birth Order	1.975	1.000	1	5
Birth Weight (grams)	3356.536	528.753	1100	5140
Average family income	5.682	2.482	1	10
Mothers smoking habits(per day)	4.105	7.820	0	50
Maternal employment at age 1 year	3.262	8.666	0	98
Childs age at mothers return to work	76.132	40.402	0	99
Under care of family member	1.550	5.997	0	98
Under care of non family member	1.159	5.125	1	98
Male	1.498	.500	1	2
Duration of breastfeeding	3.974	4.198	0	12

Notes: Maternal education, family socio-economic status, paternal education, is coded on a 3-point scale. Childs birth weight is measures in grams. Maternal employment is measured in hours worked per week.

Table 1 (continued)
Summary statistics

Variable Description Satndardized tests	Number of observations	Mean	Std. Dev.	Min	Max
Revised Wechsler Intelligence Scale for IQ at age 8 years	881	101.877	15.604	30	143
Revised Wechsler Intelligence Scale for IQ at age 9 years	811	104.053	16.816	40	150
Teacher rating of reading ability at 8 years	1081	2.450	1.089	1	5
Teacher rating of reading ability at 12 years	1006	2.335	1.081	1	5
Teacher rating mathematics at 8 years	1081	2.578	1.009	1	5
Teacher rating mathematics at 12 years	999	2.488	1.077	1	5
Progressive Achievement test of reading comprehension at age 10 years	847	10.384	7.064	0	31
Progressive Achievement test of mathematics at age 11 years	831	24.910	7.418	0	40
Progressive Achievement test of reading comprehension at age 12 years	804	12.922	4.795	0	22
Test of Scholastic achievement at age 13 years	784	34.693	15.107	0	69

Note: Test of scholastic achievement is designed to measure the high school success of the child

Table 2 (a)

Independent Variables		Revised Wechsler Intelligence Scale for IQ at age 8 years		Revised Wechsler Intelligence Scale for IQ at age 9 years		Teacher rating of reading ability at 8 years	
		OLS	IV	OLS	IV	OLS	IV
Duration of breastfeeding		0.243***	0.554	0.195**	0.104	0.010	0.226*
		(2.878)	(0.548)	(2.239)	(0.090)	(1.360)	(1.837)
Maternal age at the child's birth		0.227***	0.231***	0.235***	0.240**	0.026***	0.028***
		(2.828)	(2.669)	(2.832)	(2.558)	(3.566)	(2.911)
Maternal education at the child's birth; High School		1.287	0.837	1.660**	1.846	0.156**	-0.130
		(1.626)	(0.558)	(2.054)	(1.170)	(2.182)	(0.680)
	College	3.451***	2.325	4.364***	4.656	0.284***	-0.442
		(3.450)	(0.672)	(4.289)	(1.263)	(3.176)	(1.034)
Family socio-economic status;	Professional	1.945*	1.556	2.818**	2.868	0.095	-0.133
		(1.689)	(0.898)	(2.421)	(1.524)	(0.923)	(0.708)
	Clerical	1.061	0.684	0.784	0.616	0.087	-0.046
		(1.319)	(0.634)	(0.957)	(0.542)	(1.183)	(0.386)
Rating of standard of living		1.346	-1.342	-1.843*	-1.834*	-0.041	-0.091
		(-1.387)	(1.273)	(1.855)	(1.737)	(0.462)	(0.767)
Average family income		0.387**	0.389**	0.423**	0.415**	0.050***	0.056***
		(2.282)	(2.265)	(2.397)	(2.087)	(3.244)	(2.840)
Maternal smoking during pregnancy		0.003	0.017	0.019	0.012	0.001	0.018*
		(0.066)	(0.187)	(0.384)	(0.108)	(0.2050	(1.680)
Gender		0.342	0.324	0.966	0.938	-0.418***	-0.352***
		(0.532)	(0.502)	(1.468)	(1.456)	(7.209)	(4.108)
Birth order	Second	-2.298***	-2.143**	-2.189***	-2.227***	-0.265***	-0.185*
		(2.978)	(2.446)	(2.798)	(2.641)	(3.813)	(1.905)
	Third	-1.861*	-1.914*	-1.666*	-1.677	-0.329***	-0.381***
		(1.941)	(1.965)	(1.670)	(-1.276)	(3.753)	(3.192)
	Fourth	-3.770**	-3.418**	-3.420**	-3.346*	-0.324**	-0.253
		(2.310)	(2.121)	(2.059)	(1.930)	(2.221)	(1.284)
	Fifth	3.235	3.797	-3.818*	-4.093	-0.762***	-1.056***
		(1.558)	(1.602)	(1.706)	(1.363)	(3.757)	(3.274)
Child's birth weight		0.002***	0.002**	0.001**	0.001*	0.000***	0.000
		(3.442)	(2.117)	(2.171)	(1.674)	(4.125)	(0.801)
Sargan statistic		4.811		3.382		0.596	
P-value		0.307		0.496		0.963	

Note: * indicates p<0.10, ** indicates p<0.05, *** indicates p<0.01

Table 2 (b)

Independent Variables		Teacher rating of reading ability at 12 years		Teacher rating mathematics at 8 years		Teacher rating mathematics at 12 years	
		OLS	IV	OLS	IV	OLS	IV
Duration of breastfeeding		0.020**	0.131	0.017**	0.083	0.024***	0.111
		(2.561)	(1.287)	(2.140)	(0.784)	(3.033)	(1.018)
Maternal age at the child's birth		0.015**	0.019**	0.019**	0.020**	0.020***	0.022**
		(2.025)	(2.220)	(2.478)	(2.519)	(2.588)	(2.742)
Maternal education at the child's birth; High School		0.159**	0.021	0.140*	0.058	0.197***	0.097
		(2.159)	(0.132)	(1.887)	(0.353)	(2.616)	(0.573)
	College	0.434***	0.094	0.220**	-0.001	0.303***	0.057
		(4.768)	(0.277)	(2.366)	(0.003)	(3.267)	(0.163)
Family socio-economic status;	Professional	0.266**	0.150	0.029	-0.040	0.122	0.031
		(2.533)	(1.970)	(0.272)	(0.249)	(1.137)	(0.192)
	Clerical	0.119	0.043	0.047	0.005	0.006	-0.060
		(1.575)	(0.392)	(0.618)	(0.049)	(0.080)	(0.538)
Rating of standard of living		-0.034	-0.023	-0.106	-0.105	0.021	0.038
		(0.370)	(0.218)	(1.160)	(1.055)	(0.225)	(0.360)
Average family income		0.047***	0.051***	0.050***	0.052***	0.067***	0.070***
		(2.997)	(2.935)	(3.142)	(3.219)	(4.129)	(3.964)
Maternal smoking during pregnancy		-0.002	0.007	-0.001	0.005	-0.002	0.005
		(0.357)	(0.812)	(0.142)	(0.559)	(0.529)	(0.570)
Gender		-0.308***	-0.278***	-0.156***	-0.137*	-0.188***	-0.160**
		(5.179)	(3.791)	(2.585)	(1.898)	(3.090)	(2.141)
Birth order	Second	-0.201***	-0.165**	-0.091	-0.063	-0.159**	-0.121
		(2.818)	(2.099)	(1.265)	(0.753)	(2.182)	(1.447)
	Third	-0.264***	-0.311***	-0.131	-0.147	-0.211**	-0.233**
		(2.914)	(2.938)	(1.445)	(1.458)	(2.272)	(2.104)
	Fourth	-0.541***	-0.487***	-0.198	-0.175	-0.365**	-0.305*
		(3.569)	(2.749)	(1.306)	(1.112)	(2.364)	(1.627)
	Fifth	-0.256	-0.406*	-0.356*	-0.460*	-0.403*	-0.489*
		(1.210)	(1.798)	(1.692)	(1.891)	(1.874)	(1.840)
Child's birth weight		0.000**	0.000	0.000***	0.000	0.000**	0.000
		(2.162)	(0.489)	(3.107)	(1.532)	(2.174)	(0.603)
Sargan statistic		4.925		1.343		3.062	
P-value		0.295		0.854		0.547	

Note: * indicates p<0.10, ** indicates p<0.05, *** indicates p<0.01

Table 2 (c)

Independent Variables		Progressive Achievement test of reading comprehension at age 10 years		Progressive Achievement test of mathematics at age 11 years	
		OLS	IV	OLS	IV
Duration of breastfeeding		0.239***	0.891	0.211**	1.743
		(2.762)	(1.171)	(2.446)	(1.494)
Maternal age at the child's birth		0.162**	0.164*	0.181**	0.206**
		(1.982)	(1.888)	(2.193)	(2.001)
Maternal education at the child's birth; High School		1.363*	0.633	0.215	-1.624
		(1.690)	(0.528)	(0.263)	(0.894)
	College	4.204***	2.086	2.774***	-1.883
		(4.091)	(0.784)	(2.689)	(0.501)
Family socio-economic status;	Professional	2.221*	1.485	2.658**	0.756
		(1.909)	(1.017)	(2.232)	(0.379)
	Clerical	1.210	0.763	1.305	0.170
		(1.478)	(0.771)	(1.567)	(0.130)
Rating of standard of living		-1.654*	-1.792*	-1.344	-1.341
		(1.656)	(1.737)	(1.335)	(1.088)
Average family income		0.319*	0.318*	0.598***	0.589***
		(1.847)	(1.834)	(3.406)	(2.920)
Maternal smoking during pregnancy		-0.002	0.049	0.012	0.130
		(0.035)	(0.686)	(0.252)	(1.208)
Gender		-2.535***	-2.783***	-1.193*	-1.061
		(3.868)	(2.463)	(1.800)	(1.331)
Birth order	Second	-2.981***	-2.831***	-2.368***	-1.845*
		(3.809)	(3.418)	(2.985)	(1.851)
	Third	-2.459**	-2.743**	-1.296	-2.042
		(2.490)	(2.463)	(1.286)	(1.593)
	Fourth	-2.150	-1.859	-3.198*	-2.041
		(1.280)	(0.094)	(1.894)	(0.964)
	Fifth	-4.156*	-5.179**	-4.235**	-6.966**
		(1.947)	(2.299)	(1.972)	(2.449)
Child's birth weight		0.001**	0.001	0.001**	0.001
		(2.022)	(0.954)	(2.240)	(0.485)
Sargan statistic		0.179		1.783	
P-value		0.996		0.775	

Note: * indicates p<0.10, ** indicates p<0.05, *** indicates p<0.01

Table 2 (d)

Independent Variables		Progressive Achievement test of reading comprehension at age 12 years		Test of Scholastic achievement at age 13 years	
		OLS	IV	OLS	IV
Duration of breastfeeding		0.236***	1.702	0.207**	0.697
		(2.625)	(1.624)	(2.426)	(1.056)
Maternal age at the child's birth		0.116	0.156	0.222***	0.237***
		(1.370)	(1.469)	(2.715)	(2.530)
Maternal education at the child's birth; High School		1.150	-0.949	1.102	0.544
		(1.352)	(0.501)	(1.357)	(0.424)
	College	4.249***	-0.299	4.299***	2.794
		(4.008)	(0.086)	(4.261)	(1.192)
Family socio-economic status;	Professional	3.308***	1.583	3.227***	2.590
		(2.705)	(0.848)	(2.747)	(1.806)
	Clerical	1.545*	0.491	1.240	0.843
		(1.804)	(0.383)	(1.504)	(0.842)
Rating of standard of living		-0.828	-0.903	-0.057	0.020
		(0.791)	(0.713)	(0.057)	(0.018)
Average family income		0.222	0.236	0.696***	0.708**
		(1.220)	(1.124)	(3.998)	(3.910)
Maternal smoking during pregnancy		-0.005	0.113	-0.010	0.033
		(0.110)	(1.154)	(0.209)	(0.468)
Gender		-1.580**	-1.575*	-2.281***	-2.241***
		(2.306)	(2.017)	(3.481)	(3.310)
Birth order	Second	-2.181***	-2.054**	-3.237***	-3.252***
		(2.655)	(2.150)	(4.123)	(3.992)
	Third	-1.858*	-2.997**	-3.232***	-3.744***
		(1.799)	(2.221)	(3.266)	(3.158)
	Fourth	-3.458**	-2.725	-3.399**	-3.017
		(1.965)	(1.156)	(1.989)	(1.554)
	Fifth	-2.591	-5.327	-6.154***	-7.603**
		(1.149)	(1.679)	(2.707)	(2.982)
Child's birth weight		0.002**	0.001	0.001**	0.001
		(2.448)	(0.475)	(2.330)	(1.520)
Sargan statistic		2.344		3.195	
P-value		0.672		0.526	

Note: * indicates p<0.10, ** indicates p<0.05, *** indicates p<0.01

Table 3
Matching Estimator

	ATE		ATT		ATC	
Dependent Variable	Coefficient	Z	Coefficient	Z	Coefficient	Z
IQ at age 8	2.797	3.697	2.836	3.630	1.480	1.870
	(0.756)	(0.000)	(0.780)	(0.000)	(0.790)	(0.061)
IQ at age 9	1.132	1.451	0.952	1.230	1.232	1.520
	(0.779)	(0.147)	(0.776)	(0.220)	(0.813)	(0.130)
Reading ability at age 8	0.094	1.304	0.052	0.720	0.100	1.360
	(0.072)	(0.192)	(0.073)	(0.473)	(0.073)	(0.173)
Reading ability at age 12	0.129	1.845	0.143	1.890	0.247	3.250
	(0.070)	(0.065)	(0.075)	(0.059)	(0.076)	(0.001)
Mathematics at age 8	0.089	1.208	-0.001	-0.020	0.066	0.900
	(0.073)	(0.227)	(0.075)	(0.984)	(0.074)	(0.368)
Mathematics at age 12	0.201	2.770	0.198	2.560	0.286	3.680
	(0.072)	(0.006)	(0.077)	(0.010)	(0.077)	(0.000)
Reading comprehension at age 10	1.424	1.879	0.668	0.860	1.010	1.260
	(0.757)	(0.060)	(0.776)	(0.389)	(0.802)	(0.208)
Reading comprehension at age 12	1.269	1.569	0.934	1.130	1.091	1.300
	(0.809)	(0.117)	(0.828)	(0.259)	(0.840)	(0.194)
Mathematics at age 11	1.438	1.874	0.426	0.540	0.969	1.200
	(0.767)	(0.061)	(0.796)	(0.592)	(0.811)	(0.2320
Scholastic Achievement	1.520	1.974	1.564	1.940	1.040	1.270
	(0.770)	(0.048)	(0.806)	(0.053)	(0.820)	(0.205)

Note 1: standard deviations under coefficients in parentheses
Note 2: p-values under Z statistic in parentheses
Note 3: ATE : average treatment effect
ATT: average treatment effect on treated
ATC: average treatment effect on controls.

References

Abadie A, Drukker D O, Herr D L, Imbens G W. Implementing matching estimators for average treatment effects in Stata. The Stata Journal 2004; 4; 290-311

Abadie A, Imbens G W. Large sample properties of matching estimators for average treatment effects. Econometrica 2006; 74; 235-267

Anderson J W, Johnstone B M, Remley D T. Breast-feeding and cognitive development: a meta-analysis. The American Journal of Clinical Nutrition 1999; 70; 525-35

Angelsen N K, Vik T, Jacobsen G, Bakketeig L S. Breast feeding and cognitive development at age 1 and 5 years. Archives of disease in childhood 2001; 85; 183-188

Angrist J D, Lavy V. The effects of teen childbearing and single parenthood on childhood disabilities and progress in school. NBER Working Paper 5807 1996

Barrera A. The interactive effects of mother's schooling and unsupplemented breastfeeding on child health. Journal of Development Economics 1991; 34; 81-98

Berger L M, Hill J and Waldfogel J. Maternity leave, early maternal employment and child health and development in the US. The Economic Journal 2005; 115; F29-F47

Blanden J, Gregg P, Macmillan L. Explaining intergenerational income persistence: non-cognitive skills, ability and education. Working Paper, 2006

Booth A L, Kee H J. Birth order matters: The effect of family size and birth order on educational attainment. CEPR Discussion Paper 5453, 2006

Cebu Study Team. A child health production function estimated from longitudinal data. Journal of Development Economics 1992; 38; 323-351

Hastie T J and Tibshirani R J. Generalized Additive Models. Chapman and Hall/CRC: USA; 1990

Heckman J, Ichimura H, Todd P. Matching as an econometric evaluation estimator. Review of Economic Studies 1998; 65(2); 261-294

Horwood L J, Fergusson D M. Breastfeeding and later cognitive and academic outcomes. Pediatrics 1998; 101; 1-6

Jacobson S W, Chiodo L M, Jacobson J L. Breastfeeding effects on intelligence quotient in 4- and 11- year old children. Pediatrics 1999; 103; 1- 6

Jacobson S W, Jacobson J L. Breastfeeding and IQ: evaluation of the socio-environmental confounders. Acta pediatrica 2002; 91; 267-74

Kalmijn M, Kraaykamp G. Late or Later? A sibling analysis of the effect of maternal age on children's schooling. Social Science Research 2004; 34; 634-650

Kurinu N, Shiono P H, Ezrine S F, Rhoads G G. Does maternal employment affect breast-feeding? American Journal of Public Health 1989; 79; 1247-1250

Malloy M H, Berendes H. Does breast-feeding influence intelligence quotients at 9 and 10 years of age? Early Human Development 1998; 50; 209-217

Matthijs K, Gerbert K. Late or Later? A sibling analysis of the effect of maternal age on children's schooling. Social Science Research 2005; 34(3); 634-650

Michaelsen K F, Lauritzen L, Jorgensen M H, Mortensen E L. Breast-feeding and brain development. Scandinavian Journal of Nutrition 2003; 47(3); 147-151

Miller P, Mulvey C, Martin N. Birth weight and schooling and earnings: estimates from a sample of twins. Economic Letters 2005; 86; 387-92

Mortensen E L, Michaelsen K F, Sanders S A, Reinisch J M. The association between duration of breastfeeding and adult intelligence. The Journal of the American Medical Association 2002; 287; 2365-2371

Plug E, Vijverberg W. Does family income matter for schooling outcomes? Using adoptees as a natural experiment. The Economic Journal 2005; 115; 879-906

Roe B, Whittington L A, Fein S B, Teisl M F. Is there competition between breast-feeding and maternal employment? Demography 1999; 36; 157-171

Schimek M G. Smoothing and regression: Approaches, computation and application. Wiley: New York; 2000

Smith J, Ingham L H. Breastfeeding and the measurement of economic progress. Journal of Australian Political Economy 2001; 47; 51-72

Sullivan M L, Sonya J L, Michele A K. Family characteristics associated with duration of breastfeeding during early infancy among primiparas. Journal of Human Lactation 2004; 20(2); 196-205

Figure 1. Unadjusted relationship between breastfeeding and scholastic achievement