DISCUSSION PAPER

July 2016 ■ RFF DP 16-29

What Is the Economic Value of Improved Labor Market Outcomes from Infant Nutrition?

The Case of Breastfeeding in the United States

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Abstract

We seek to estimate the effects of breastfeeding on the present value of future earnings increases resulting from IQ increases. Using new estimates of the effect of cognitive performance on lifetime earnings in the United States, based on the National Longitudinal Survey of Youth, developed by Lin, Lutter, and Ruhm (2016) and new baseline estimates of the present value of lifetime earnings following methods of Grosse et al. (2002), we find that the expected value of increases in the present value of lifetime earnings from breastfeeding is about $20,000, assuming a 3 percent discount rate, with a 95 percent confidence interval from $2,900 to $38,700. If half of all US infants born each year were better breastfed, we estimate the total increase in the present value of future earnings to be $40 billion annually.

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Contents

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Marc Hafstead and Randall Lutter*

1. Introduction

Over the last few decades there has been increasing recognition that events early in life, either in utero or during the first years of life, have subtle but important long-term consequences. Echoing earlier research on human milk by Jelliffe and Jelliffe (1978), David Barker (1990) hypothesized that adult disease often has both fetal and infant origins, indirectly prompting rigorous testing of effects on obesity, diabetes, and heart disease (Almond and Currie 2011; Currie 2011). Effects on adult disease may be large, even from hazards that appear to be mild and are measured only in aggregate, such as the hours of daylight that observant Muslims fast at different latitudes during the month of Ramadan. For example, Almond and Currie (2011) reported that daytime fasting by pregnant women during Ramadan increased the likelihood of disability in their adult children by 20 percent. These findings for prenatal nutrition suggest that breastfeeding—perhaps the cornerstone of good infant nutrition—also has important implications for adult health.

A recent systematic review found that breastfeeding reduces infants' risks of developing long-term, noncommunicable conditions (Victora et al. 2016). In particular, breastfeeding lowers infants' later risks of overweight or obesity, Type 2 diabetes, and childhood leukemia, while also reducing risks to infants or young children of sudden infant death, necrotizing enterocolitis, diarrhea, respiratory infections, acute otitis media, dental caries, and malocclusion (Victora et al. 2016). The aggregate effects of breastfeeding on health of infants are large (e.g., Lutter and

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Lutter 2012). Bartick and Reinhold (2010) reported that if "90 percent of US families could comply with medical recommendations to breastfeed exclusively for 6 months, the United States would save $13 billion per year and prevent an excess 911 deaths, nearly all of which would be in infants ($10.5 billion and 741 deaths at 80 percent compliance)." Bartick and Reinhold (2010) considered long-term health effects, including childhood obesity, childhood leukemia, and Type 1 diabetes mellitus, but did not consider the effects of improvements in IQ.[1]

Recent meta-analyses (e.g., Horta et al. 2013, 2015) have found effects of the duration of breastfeeding on IQ. Effects of breastfeeding are generally estimated using observational studies (rather than controlled and blinded randomized experiments), but Kramer et al. (2001) reported IQ effects of breastfeeding based on a clinical trial with random assignment of hospitals. Victora et al. (2016) discussed effects of breastfeeding duration on educational performance as well as IQ, and Victora et al. (2015) showed effects on IQ, educational performance, and earnings. These effects of breastfeeding on nonhealth outcomes can be seen as consistent with nonhealth effects of the in utero environment reported by Currie and Hyson (1999) and Black et al. (2007).

Here we seek to estimate the effects of breastfeeding on the present value of future earnings increases resulting from IQ increases and to compare these estimates with the value of health benefits to children of breastfeeding (Bartick and Reinhold 2010). Our work speaks to the relative importance of health and nonhealth outcomes of nutritional and other early childhood interventions. Small differences in IQ represent normal variability in human populations and thus do not reflect disease or health as conventionally defined. As a result, effects on IQ are typically excluded from estimates of the burden of disease, even though for some hazards, such as emissions of lead into the air, the IQ effects are important in aggregate.[2]

We use new estimates of the effect of cognitive performance on lifetime earnings in the United States, developed by Lin et al. (2016), based on the National Longitudinal Survey of Youth. We develop new baseline estimates of the present value of lifetime earnings following the methods of Grosse et al. (2002). To assess the permanence of breastfeeding-related IQ effects

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[1] In related work, Bartick et al. (2013) estimated that with a 3 percent discount rate, the social costs for mothers who do not optimally breastfeed is $17.4 billion in total, including costs from premature death (95 percent confidence interval [CI] $4.38–$24.68 billion), $733.7 million in direct costs (95 percent CI $612.9–$859.7 million), and $126.1 million in indirect morbidity costs (95 percent CI $99.00–$153.22 million).

[2] EPA (1997), for example, estimated that the present value in 1990 of the IQ-related benefits of reducing lead emissions between 1970 and 1990 was $399 billion in 1990$, given a 5 percent discount rate.

we show that the Peabody Picture Vocabulary Test, a measure of cognitive performance commonly linked to breastfeeding, has effects on earned income comparable to measures of cognitive performance more commonly used in the labor economics literature. We also use estimates of the effects of breastfeeding on IQ from Horta et al. (2015). We employ Monte Carlo methods to estimate the expected present value of increases in lifetime earnings that may be attributable to breastfeeding.

We find that the expected value of increases in the present value of lifetime earnings from breastfeeding is about $20,000, assuming a 3 percent discount rate, with a 95 percent confidence interval from $2,900 to $38,700. We calculate aggregate increased earnings to be $40 billion annually, if half of all US infants born each year were better breastfed. This estimate is roughly triple the estimated annual value of all health benefits to US infants from breastfeeding, $13 billion annually, or $15 billion in 2014$, if 90 percent complied with WHO recommendations for exclusive breastfeeding. The WHO recommends exclusive breastfeeding for 6 months (and continued breastfeeding to 24 months of age). It also exceeds the total value of health benefits to both infants and mothers, since Bartick et al. (2013) estimated maternal benefits to be $17.4 billion annually for a scenario where 90 percent of mothers were able to breastfeed for at least one year after each birth. We explore the uncertainty in our estimates and their sensitivity to alternative discount rates. Our results suggest that the labor market consequences to infants of breastfeeding during the first year or two of life may be more important economically than the value of reduced health risks from breastfeeding.

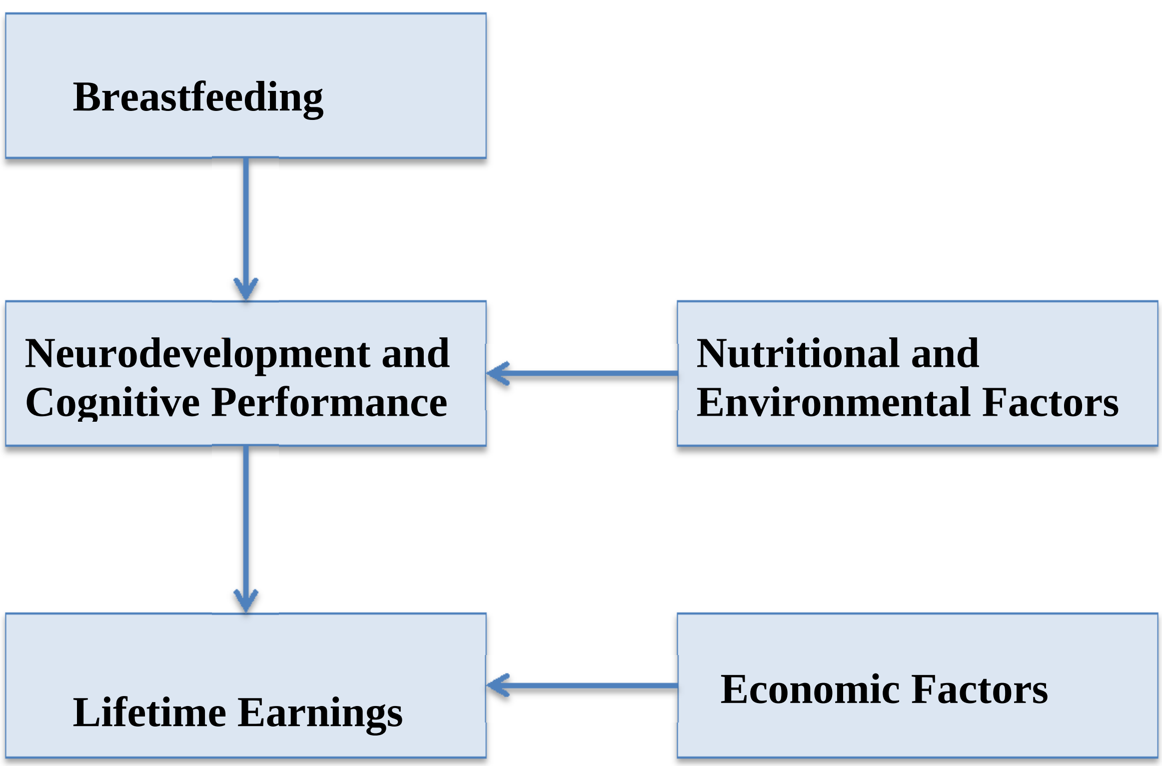
Our findings also raise the net benefits expected to result from interventions to promote breastfeeding. Specifically, with a 3 percent discount rate, including the IQ-related benefits in analyses of interventions to promote breastfeeding in the United States would raise the estimated economic benefits by more than a factor of two. Assuming a discount rate of 7 percent would imply that IQ-related economic benefits fall by about 80 percent. The increases in net benefits of interventions to promote breastfeeding may be larger for African Americans and Hispanics. Lin et al. (2016) found that the labor market consequences of gains in cognitive performance for these groups are larger than for non-Hispanic whites.

In Section 2 of this paper, we present a model and methods to link changes in breastfeeding to changes in lifetime earnings. In Section 3, we describe the existing data and evidence underlying the various components of the Monte Carlo simulations and present our findings on the value of the cognitive gains from breastfeeding. Section 4 examines IQ measures and whether the effects of interventions are lasting. In the final section, we discuss the implications of our findings.

2. Analytic Framework

Our methodology closely follows Grosse et al. (2002), which explored earnings gains from reducing lead exposure in children. Grosse et al. (2002), Schwartz (1994), and Salkever (1995) found that reduced exposure to lead during childhood contributes to improvements in IQ (or improved performance on cognitive tests), and those improvements in cognitive performance lead to increases in lifetime earnings. This framework has also been adopted in various forms by US government agencies, including EPA (1997, 2008). Our framework follows a similar approach, summarized in Figure 1. Breastfeeding contributes to increases in cognitive ability (relative to no breastfeeding or insufficient breastfeeding), and this increase in cognitive ability leads to higher levels of lifetime earnings. Factors that affect cognitive performance include genetic endowments, exposure to environmental hazards, nutrition, and education, to the extent that cognitive tests measure concepts taught in classrooms, such as language, math, and logic. Economic factors including labor market institutions influence lifetime earnings. The channels through which cognitive ability leads to higher earnings can be direct (higher wages) or indirect (more years of education or more steady periods of employment).

Figure 1. A Conceptual Model for the Effects of Breastfeeding on Lifetime Earnings



Here we are less interested in these various channels and focus only on the overall impact of cognitive ability on earnings.

The dollar value of cognitive gains from optimal breastfeeding in the United States can be summarized using the following equation:

$$\Delta E = \Delta BF \times \frac{\Delta IQ}{\Delta BF} \times \frac{\Delta E / E}{\Delta IQ} \times E$$

where $\Delta \mathrm{E}$ is the change in earnings, ΔBF is the change in breastfeeding status, $\Delta IQ / \Delta BF$ is the change in IQ points given a change in breastfeeding status, $(\Delta E / E) / \Delta IQ$ is the percentage change in earnings per IQ point, and E is the dollar value of expected discounted earnings of a newborn child.

We assume that the change in breastfeeding status, ΔBF, is a zero-one variable: a child either is or is not breastfed optimally according to World Health Organization (WHO) guidelines. The percentage change in lifetime earnings from optimal breastfeeding can therefore be estimated by multiplying the breastfeeding-IQ effect $\Delta IQ / \Delta BF$ by the IQ-earnings effect $(\Delta E / E) / \Delta IQ$. The dollar value of expected infant cognitive gains is then found by multiplying this derived breastfeeding-earnings effect by the expected lifetime earnings of an infant born today.

Despite substantial research on the breastfeeding-IQ and the IQ-earnings links and widespread agreement about the causal links between each, significant uncertainty remains as to the size of the effects. The uncertainty surrounding these links, as well as the uncertainty surrounding the expected lifetime earnings estimates, will lead to uncertainty in the dollar value of infant cognitive gains from breastfeeding. To characterize this uncertainty, we use standard errors from the best-in-practice point estimates for each link to create a joint distribution of $\frac{\Delta IQ}{\Delta BF} \times \frac{\Delta E / E}{\Delta IQ} \times E$. This joint distribution assumes the independence of each of the three underlying individual distributions. From this distribution, we use a Monte Carlo simulation to estimate the underlying distribution of $\Delta \mathrm{E}$ and characterize the uncertainty around the economic value of the cognitive benefits of breastfeeding.[3]

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[3] This framework is equivalent to the following. Let α denote the value (in earnings) of an IQ point. Using the above notation, $\alpha = \left((\Delta E / E) / \Delta IQ \right) \times E$. The distribution of earnings without breastfeeding is given by αIQ, and the distribution of earnings with breastfeeding is $\alpha (IQ + \Delta IQ)$. The change in earnings, ΔE, is the difference, $\Delta E = \alpha (IQ + \Delta IQ) - \alpha IQ = \alpha \Delta IQ$.

3. Data and Analysis

3.1. Breastfeeding and IQ

We use existing meta-analysis results to characterize the distribution of the effect on breastfeeding on IQ. Victora et al. (2016) report that breastfeeding raises IQ by 3.44 IQ points (95 percent confidence interval: 2.30–4.58). They also report that nine studies with adjustment for maternal IQ showed differences of 2.62 points (1.25–3.98). Horta et al. (2015) identified four studies that had a large sample size (≥ 500 participants), controlled for confounding by maternal IQ and whose recall time on breastfeeding duration was less than three years. According to these high-quality studies, breastfeeding improved the performance on intelligence tests, with a mean difference of 1.76 points (95 percent confidence interval: 0.25; 3.26). Thus the results of the meta-analyses vary with the specific studies they cover. A new structured expert judgment study also reports effects of breastfeeding on IQ that are somewhat larger (Colson et al. 2016). For this study, we use the lower (more conservative) estimates from the high-quality studies identified by Horta et al. (2015). We fit a normal distribution around the point estimate of 1.76 with a standard deviation of 0.77 to match the 95 percent confidence interval of [0.25 3.26].

Horta et al. (2015), like earlier meta-analyses, did not describe the change in breastfeeding that would generate these gains in IQ, perhaps because the studies included in this meta-analysis used a variety of definitions for breastfeeding. These ranged from ever breastfed, to breastfed more than one month, to breastfed more than eight months, to exclusively or predominantly breastfed at six months (Horta et al. 2015, Table 1). The articles analyzed in Horta et al. (2015) also used a variety of definitions for the comparison group, ranging from never breastfed, to breastfed less than two months, to breastfed less than six months. Two of the eighteen studies used a measure of exclusive breastfeeding, but only one of these yielded a confidence interval that excluded no effect. Thus the meta-analyses provide no information about the specific change in breastfeeding behavior most likely to bring about the estimated IQ increases. Colson, Cooke, and Lutter (2016), however, conduct a structured expert judgment study that does shed light on this issue.

3.2. IQ and Earnings

We use new estimates from Lin et al. (2016) on the effects of IQ on earnings that may be superior to earlier estimates. Specifically, Lin et al. used data on National Longitudinal Survey of Youth (NLSY) respondents from the 1979 cohort observed from age 20 through age 48 to estimate the present value of lifetime earnings from work, extrapolated to age 65 and assuming different discount rates. They then estimated how a measure of cognitive performance collected between late adolescence and early adulthood (ages 16–22) predicts this measure of lifetime earnings. Their estimation process takes into account two measures of noncognitive skills or attributes, as well as a broad set of time-invariant controls, such as the years of schooling of both parents and various measures of the county of residence where the respondents lived as a child. Their approach differs from prior work by explicitly incorporating the faster growth in earnings in workers with higher cognitive performance. Although they focused on the NLSY 1979 cohort, who were youths when data were first collected in 1979, they compared the trend in earnings growth for this cohort with a later 1997 cohort and found the results to be similar.

In Table 1 we provide an excerpt of their results. Lin et al. (2016) presented their estimates for a change in the Armed Forces Qualification Test (AFQT) equal to 10 percent of one standard deviation. For comparison with effects of IQ, these estimates need to be multiplied by 10/15, since one IQ point represents 1/15 of a standard deviation.

The overall effect of cognitive performance is a 1.43 percent (2.15*10/15) gain in lifetime earnings for each additional IQ point. Thus the Lin et al. estimate implies that a one-unit gain in IQ among children born in 1961 would generate about $7,900 in increased earnings over a lifetime, after discounting at 3 percent per year. This estimate does not reflect any new employment opportunities at higher wage rates that young people born since 1960 might enjoy. In fact, employment opportunities and wage rates have both changed markedly in recent decades. Lin et al. adjust for these opportunities by multiplying by the growth in earnings per worker between 1961 and 2014; this estimate implies that a one IQ point gain for an infant born in 2014 would increase the present value of lifetime earnings by $13,030, assuming a 3 percent discount rate. We instead apply the percentage estimates from Lin et al. to the estimates of lifetime earnings derived from earnings information reported by a recent Current Population Survey. This approach follows closely EPA (2008).

Table 1. Cognitive Performance Effects on Lifetime Income through Age 65

(3 percent discount rate)

	All	Male	Female	Non-Hispanic white	Non-Hispanic black	Hispanic
Percentage Change	2.15% (0.16%)	1.71% (0.21%)	2.62% (0.24%)	1.92% (0.17%)	3.59% (0.28%)	3.13% (0.31%)
Lifetime incomes NLSY79 cohort	$11,846 (886)	$12,560 (1,489)	$10,168 (905)	$11,294 (1,004)	$13,107 (1,027)	$14,010 (1,361)
Lifetime incomes, 2014 births	$19,545	$20,724	$16,778	$18,635	$21,626	$23,117
N	3,950	1,860	2,090	3,206	1,892	1,177

Source: Lin et al. (2016)

Notes: Table shows estimated effects of a 0.1 standard deviation increase in AFQT score for the representative NLSY79 sample as a percentage change or dollar amount change on the net present value of the sum of annual incomes from age 20 through age 65 for the specified population group. Lifetime income results are based on incomes discounted to the birth year using an annual discount rate of 3 percent and are expressed in 2014$. For Americans born in 2014, Lin et al. adjusted the estimates by the real earnings growth rate from 1961 to 2014, so that the estimates apply to children born in 2014. For all individuals, males and females, data are from the nationally representative NLSY79 sample. The race/ethnicity estimates use the full sample, including the supplementary samples of blacks and Hispanics. “Whites” refer to nonblack non-Hispanics. In addition to AFQT scores, models control for background, age-varying, and noncognitive characteristics and survey year fixed effects. Robust standard errors are shown in parentheses.

3.3. Expected Present Value of Lifetime Earnings

Our calculations of the expected present value of lifetime earnings generally follow the steps laid out in Grosse (2002) by using estimates of the current age-earnings profile, adjusted for fringe benefits and payroll taxes, and adjusting for survival and growth in real earnings over time. Finally, this stream of expected lifetime earnings over time is discounted to the year of birth.

Money earnings by age group are reported in the Current Population Survey (CPS) March supplement. By age group, we calculate annual average earnings using the variable *pearn_val*, which includes wage and salary earnings and self-employment earnings. Annual average earnings are equal to the fraction of the group with earnings times the annual earnings of group members that report earnings.[4]

Employee compensation also includes benefits such as paid leave, supplemental pay, insurance, retirement and savings contributions, and legally required benefits such as payroll taxes, unemployment insurance, and workers compensation. The Bureau of Labor Statistics (BLS) conducts the Employer Costs for Employee Compensation survey quarterly. In 2014, wages and salaries accounted for 69.1 percent of employee compensation for all civilian workers, with the remaining 30.9 percent of compensation classified as a benefit (average of four 2014 quarterly surveys). Included in the definition of total benefits are paid leave (7 percent of compensation) and supplemental pay (2.4 percent of compensation). Both paid leave and supplemental pay are included in the earnings reported by the CPS, and therefore we remove both from fringe benefits. Paid leave is an added cost to firms of work on an hourly basis, but not on an annual basis, and therefore we remove it as a source of compensation for our purposes. Money earnings are therefore the sum of wages and salaries plus supplemental pay. For every dollar of annual money earnings, the average civilian worker receives fringe benefits of 30.1 cents (.301 = (.309 – .070 – .024)/(.691 + .024)). As benefits data are not available by age, we apply the same 30.1 percent fringe benefits for each age group. Table 2 displays the 2014 earnings data by age group.

Increased cognitive ability will generally lead to higher productivity both in the workplace and at home. In addition to calculating the value of earnings over the life cycle, we also place a dollar value on the returns to home production. The BLS American Time Use Survey reports average hours spent daily on household activities such as food preparation, cleaning, and lawn work, as well as average time spent caring for household and nonhousehold members by age group. We convert daily time use into an annual estimate of household production. The value of an hour spent in home production can be measured in multiple ways. One way is to value an hour spent in childcare, as an example, at the market rate of childcare. An alternative would be to use an opportunity cost method that values an hour of home production at the level of earnings the person could expect to receive in the marketplace. We use the opportunity cost method and multiply total hours in home production by the average hourly

[4] We include earners that report negative earnings from self-employment in our sample. Excluding them does not substantively change the estimated present discounted value of lifetime earnings.

earnings (of workers who receive and report hourly pay) by age group.[5] Table 2 also includes the value of household production by age group.

Table 2. Earnings by Age Group, Total for Men and Women, 2014 Data

Age	*Proportion with Earnings*	*Annual Mean Earnings of Earners*	*Annual Mean Earnings*	*Annual Fringe Benefits*	*Total Annual Earnings and Fringe Benefits*	*Annual Hours Worked in Household Production*	*Average Hourly Wage*	*Value of Household Production*	*Total Annual Earnings, Fringe Benefits, and Value of Household Production*
15 years	0.081	5,304	430	129	560	394	8.30	3,272	3,831
16 and 17 years	0.219	4,346	951	286	1,237	394	8.20	3,231	4,468
18 and 19 years	0.477	8,299	3,962	1,193	5,155	394	8.97	3,536	8,691
20 and 21 years	0.662	13,528	8,960	2,697	11,658	555	9.82	5,449	17,106
22 to 24 years	0.744	21,177	15,760	4,744	20,504	555	11.56	6,416	26,920
25 to 29 years	0.796	34,216	27,238	8,199	35,436	989	15.14	14,977	50,413
30 to 34 years	0.817	43,490	35,532	10,695	46,227	989	17.17	16,980	63,207
35 to 39 years	0.820	49,973	40,996	12,340	53,336	1,142	18.19	20,777	74,113
40 to 44 years	0.828	55,621	46,064	13,865	59,930	1,142	18.02	20,591	80,521
45 to 49 years	0.823	56,715	46,676	14,050	60,726	971	18.38	17,847	78,572
50 to 54 years	0.795	56,677	45,061	13,563	58,625	971	18.54	18,002	76,627
55 to 59 years	0.734	57,550	42,234	12,712	54,946	938	19.34	18,137	73,083
60 to 61 years	0.663	50,285	33,334	10,034	43,368	938	19.57	18,357	61,725
62 to 64 years	0.559	53,813	30,100	9,060	39,160	938	18.71	17,546	56,706
65 to 69 years	0.375	45,096	16,906	5,089	21,995	1,066	17.59	18,749	40,744
70 to 74 years	0.231	39,917	9,211	2,772	11,983	1,066	15.79	16,828	28,812
75 years and over	0.103	35,157	3,622	1,090	4,712	887	18.00	15,969	20,681

Using Table 2, we can forecast the expected real earnings over time using an estimation of real wage growth over the next 100 years. Grosse at al. (2002) and EPA (2008) have assumed real wage growth of 1 percent. We used data from the CPS from 1982 to 2005 to estimate average real wage growth and find it has been only 0.65 percent (95 percent confidence interval of [0.56 to 0.74]). We incorporate this uncertainty from our regression of earnings from the CPS

[5] We use the CPS variable *a_hrspay*, which is reported for only a subsample of the survey. An alternative would be to calculate hourly pay from earnings data and reported hours worked. The former method more likely captures the hourly wage a worker could expect to receive from a part-time job and reflects the marginal opportunity cost of time.

into our Monte Carlo simulation, though this most likely seriously underestimates the uncertainty surrounding real wage growth over the next century. Finally, we use CDC mortality tables to calculate the probability of surviving to each age and use discount rates of 3 and 7 percent to calculate the expected discounted lifetime earnings of an infant born today. The choice of discount rate has a large impact on the level of expected discounted lifetime earnings. We choose the values of 3 and 7 percent recommended by the US Office of Management and Budget for analyses of federal regulations, though we prefer the 3 percent value for this purpose, as it is closer to the long-run real return on risk-free investments. Table 3 displays our results, including the confidence intervals introduced by uncertainty over wage growth.

Table 3. Expected Discounted Lifetime Earnings, 2014$

	Discount Rate	
	3%	7%
Earnings and Benefits	$812,000 [$783,000 $843,000]	$184,000 [$179,000 $190,000]
Earnings, Benefits, and HH Production	$1,143,000 [$1,102,000 $1,186,000]	$257,000 [$249,000 $265,000]

Based on our estimates, an infant born in 2014 could expect to earn approximately $812,000 in discounted lifetime earnings (and benefits) using a 3 percent discount rate. Including the value of nonmarket work raises the estimate to $1,143,000.

3.4. Monte Carlo Simulations

As previously discussed, we use the distributions around the point estimates for breastfeeding-IQ, IQ-earnings, and the expected lifetime earnings using the respective standard errors to create a joint distribution for $\frac{\Delta IQ}{\Delta BF} \times \frac{\Delta E / E}{\Delta IQ} \times E$.[6] Importantly, independence among the three individual distributions is assumed. From this joint distribution, we take one million separate draws to calculate the distribution of $\Delta \mathrm{E}$. Table 4 displays the mean of the distribution and the 95 percent confidence intervals. From the Monte Carlo simulations, we estimate that the

[6] Lin et al. (2016) report an impact on lifetime earnings equivalent to 1.26 percent (1.89/1.5) per IQ point using a discount rate of 7 percent. Therefore, we use this estimate in our Monte Carlo simulations of lifetime earnings using a 7 percent discount rate.

gains in the United States from breastfeeding would amount to approximately $20,000 per child using the earnings and benefits measure of discounted lifetime earnings and a 3 percent discount rate. Adding the value of household services increases the gains to over $28,000 per child. As noted earlier, the meta-analysis that we use does not identify the change in breastfeeding behavior most likely to bring about these gains.

Table 4. Economic Value of Cognitive Benefits of Optimal Breastfeeding

	Discount Rate	
	3%	7%
Earnings and Benefits	$20,481 [$2,867 $38,661]	$4,077 [$568 $7,726]
Earnings, Benefits, and HH Production	$28,819 [$4,077 $54,351]	$5,699 [$804 $10,787]

There is a large amount of uncertainty in the estimates, as demonstrated by the large confidence intervals. To determine the source of the total uncertainty, we conduct further Monte Carlo simulations in which we remove specific sources of uncertainty by using only the point estimate for a particular distribution. Table 5 displays the new confidence intervals from these simulations that use the earnings and benefits measure of earnings using a 3 percent discount rate.

Table 5. Sources of Uncertainty (Earnings and Benefits, 3% Discount Rate)

	Confidence Interval
Benchmark	[$2,867 $38,661]
No ΔIQ/ΔBF Uncertainty	[$17,609 $23,398]
No (ΔE/E)/ΔIQ Uncertainty	[$2,894 $38,082]
No ΔIQ/ΔBF and No (ΔE/E)/ΔIQ Uncertainty	[$19,753 $21,215]

The confidence interval shrinks significantly if we remove uncertainty from the estimates of the breastfeeding-IQ link. Noticeably, the confidence intervals do not change significantly if we remove the IQ-earnings uncertainty. This leads us to conclude that the majority of the uncertainty we find in the results displayed in Table 4 comes from draws in the Monte Carlo simulations from the tails of the breastfeeding-IQ link. More evidence on the causal link between breastfeeding and IQ would significantly reduce the uncertainty in our estimates of the value of the cognitive gains from breastfeeding.

We are also able to estimate the effects on lifetime earnings of IQ gains from breastfeeding for major demographic groups. For this exercise, we apply the estimates of the percentage change in lifetime earnings by Lin et al. (2016) presented in Table 1 above, and we then combine these with estimates of *E* for each of these groups, assuming the effects of breastfeeding on IQ are the same for each group. Our estimates of the value of breastfeeding for non-Hispanic blacks is $25,400 ([$3,620 $48,100]), and our estimate for Hispanics is $21,200 ([$3,000 $40,500]), both larger than the central estimates we found for the general population. While non-Hispanic blacks and Hispanics have much lower expected lifetime earnings, $603,000 and $578,000, respectively, the much larger impacts of IQ on earnings found by Lin et al. for these groups lead to larger per capita estimates of the value of breastfeeding for these two demographic groups.

4. IQ Measures and Whether the Effects of Interventions Are Permanent

Our analysis has so far avoided a question raised in some of the literature on labor market effects of interventions that boost IQ during childhood: Are such effects permanent? A closely related concern is how well the measure of cognitive performance studied by Lin et al. (2016), the AFQT, correlates with the different measures of IQ used in the studies of the effects of breastfeeding on cognitive performance. We address these issues by analyzing the children of the respondents in the NLSY 1979 cohort. Our analysis, presented in the appendix, predicts labor income at age 30 using a collection of variables to control for demographic and family-specific factors, including noncognitive traits identified as important by Lin et al. (2016).

We show that a one-unit increase in the Peabody Picture Vocabulary Test (PPVT) score leads to an increase in annual earnings at age 30 of $293, or about 1.09 percent, with standard error of $81.91. Converted to a percentage gain in annual earned income, per 1/15 of a standard deviation in the PPVT score—which is equivalent to one IQ point—implies an earnings gain of 1.23 percent with 95 percent confidence interval from 0.63 percent to 1.83. This confidence interval includes 1.43, which is the point estimate—expressed per IQ point—reported by Lin et al. using a 3 percent discount rate and the nationally representative NLSY79 data, for which AFQT scores but not PPVT scores are available. This confidence interval also includes 1.26, which is the estimate from Lin et al. assuming a 7 percent discount rate. PPVT is the measure of cognitive performance that was most commonly used among the studies considered in the meta-analysis by Horta et al. (2015). Specifically, it figured in 7 of the 18 studies that Horta et al.

considered, as well as some others. Thus this analysis, presented in detail in appendix, supports our implicit assumption that IQ effects of breastfeeding may be seen as permanent and having lasting effects that matter for adult earnings.

5. Discussion and Conclusions

Most infants in the United States are breastfed much less than recommended by relevant authoritative organizations. The recommendations of the World Health Organization are for exclusive breastfeeding for six months and continued breastfeeding for two years or more with complementary foods, but US breastfeeding practices fall well short of the more modest goals of the US Department of Health and Human Services, as shown in Table 6. The data in Table 6 are from the Centers for Disease Control and Prevention (CDC), which issued a 2014 Breastfeeding Report Card to summarize national breastfeeding statistics, behaviors, and trends in comparison with state averages from the National Immunization Survey (NIS) (see CDC 2014, 2015; US Breastfeeding Committee 2016; ODPHP 2016).

Table 6. US Breastfeeding Rates and Goals

Type and duration of breastfeeding	Healthy People 2020 goals, (percent)	Most recent rates
Any breastfeeding at 6 months	60.6	49.4
Any breastfeed at 12 months	34.1	26.7
Exclusive breastfeeding at 3 months	46.2	40.7
Exclusive breastfeeding at 6 months	25.5	18.8
Any breastfeeding at 3 months	no goal	65.1 ± 1.5
Exclusive breastfeeding at 4 months	no goal	35.3 ± 1.5
Percentage of infants receiving formula before 2 days of age	14.2	19.4

These data indicate that about 59 percent of infants are not exclusively breastfed at three months, and half are not breastfed at all at six months. As noted earlier, the meta-analyses of the effects of breastfeeding on IQ do not identify what type or duration of breastfeeding behavior is associated with different IQ gains. As a result, modeling hypothetical changes of different types of breastfeeding seems unlikely to provide useful insights. Instead we note simply that half of US infants are not now breastfed and could in principle be breastfed at a level consistent with WHO guidelines. We focus on the implications of shifting that many infants to breastfeeding consistent with WHO recommendations.

Applying our $20,000 per child central estimate of the value of cognitive gains to this population, the aggregate annual value of optimal breastfeeding is over $40 billion. These gains are much greater than the estimate of health benefits to infants of $15 billion annually in 2014$ (Bartick and Reinhold 2010). Bartick et al. (2013) estimated that optimal breastfeeding in the United States would provide health benefits to mothers of about $17.4 billion annually (or $18.5 billion in 2014$). Our estimate of $40 billion annually is thus larger than the sum of all quantified and monetized health benefits for children and for mothers.

These aggregate estimates should not obscure differences among demographic groups, a concern recently highlighted by the surgeon general of the United States (HHS 2011). His call for action specifically noted that among non-Hispanic African American infants, only 58.1 percent were ever breastfed in 2007, while about 12.5 percent were still breastfed at 12 months. For non-Hispanic white infants, the comparable figures were 76.2 percent and 23.3 percent. Our analysis suggests that the IQ-related dollar benefits of breastfeeding may be more for African American infants than for white infants.

These estimates should not be seen as a comprehensive estimate of IQ-related benefits of breastfeeding. First, any activity that increases IQ should reduce the number of children with IQs below 70, commonly seen as a threshold meriting special education classes, which are much more costly than conventional schooling. Second, willingness to pay for improved cognitive performance—the conventional concept used in benefit-cost analysis—may well exceed the associated increases in income, at least to the extent that it improves people's utility as well as their productivity. On the other hand, increases in IQ, to the extent that they raise earnings through additional schooling, come with schooling costs that merit consideration. EPA (2008) recognized similar issues in its analysis of the effects of lead. These issues are beyond the scope of this paper.

One implication of our work is that additional research is needed to identify the component of breastfeeding behavior most likely to bring about improvements in IQ. While the effects we estimate are large, our analysis, like the meta-analyses it relies on, does not address whether the IQ effect is primarily from exclusive breastfeeding early in infancy; exclusive breastfeeding between, say, 3 and 5 months; or breastfeeding (along with complementary foods) between 6 and 12 or 18 months. Additional randomized trials may be needed to help resolve this uncertainty.

A second key implication is that there may be substantial merit in reevaluating programs and policies that can affect breastfeeding rates in the United States, such as the US Department of Agriculture's Special Supplemental Nutrition Program for Women, Infants and Children. Our estimates, along with previously estimated health benefits to infants and mothers alike, suggest that improving breastfeeding could bring about more than $70 billion in annual benefits. Reforming federal programs that influence breastfeeding may thus provide benefits to infants and mothers that substantially outweigh the associated costs.

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Appendix

We present here simple models of annual earned income at age 30 as a function of cognitive performance using Peabody Picture Vocabulary Test scores measured in early childhood, non-cognitive traits, and demographic variables, using data from the National Longitudinal Survey of Youth 1979- Children. We use these data because they are from a publicly available large-scale lengthy longitudinal study linking a measure of IQ used in breastfeeding studies—the Peabody Picture Vocabulary Test (PPVT)--with labor market outcomes. Horta et al., (2015), mention several studies that link breastfeeding with PPVT scores.

Table 1 provides descriptive statistics and variable definitions. Table 2 provides selected ordinary least squares models linking PPVT and annual earnings at age 30, with robust standard errors. We use the simple arithmetic average of all available PPVT scores for each subject. These scores were from tests administered at ages four, six, eight, ten and twelve. Model 1 suggests that a one-unit change in PPVT is associated with an increase in annual earned income at age 30 of $293, or about 1.09 percent. Expressed as a percentage increase from a one-unit gain in IQ, (i.e., expressed as an effect from a PPVT gain of 1/15 of a standard deviation), the effect is 1.23 percent (95 percent CI: 0.63 percent to 1.83 percent). This confidence interval encompasses the estimates of Lin, Lutter and Ruhm (2016). Specifically, they estimated average effects on the present value of lifetime earnings (assuming a three percent discount rate), for the NLSY79 cohort of 2.15 for a tenth of a standard deviation in the Armed Forces Qualification Test, which amounts to an increase of 1.43 percent per IQ point (Table 7). They also reported, focusing on the cohort at age 28, effects per 1/10 of a standard deviation in the AFQT of 1.7 percent, these would amount to effects of 1.13 percent per IQ point.

These results suggest that cognitive performance measures from childhood may have effects on labor market outcomes similar to those of AFQT scores. They show that the effect of a small change in PPVT is similar to the effect of a comparable change in AFQT scores for tests taken at the end of adolescence. In model 2 of Table 2, we test for nonlinearities in the effect of PPVT scores on earned income and cannot reject the assumption of linearity. We also introduce measures of the home environment, using variables for the number of magazines or newspaper present during childhood. These variables do not have statistically significant effects and the estimated effect of PPVT scores is little changed. We also test for effects of dummy variables for the birth years and find that these have no material effect on our results. These models offer support for our assumption that IQ gains from breastfeeding may be seen as equivalent to the measures of cognitive performance linked to labor market outcomes. We note, however, several caveats.

- The sample is not representative. Although the NLSY79 sample is nationally representative, with oversampling of minorities, the children of this sample, i.e., the NLSY79-C cohort differ from the US population in various ways. First they have a disproportionately large share of African Americans—48.9 percent. Second, they have a disproportionately large number of girls—57.1 percent.
- The attrition is substantial. Specifically, the total number of people in the sample who would turn 30 in or before 2012, the most recent year for which data are available, is 3772. But the number of subjects included in the regressions is only 513. Such high attrition raises questions about self-selection.
- The set of explanatory variables available for this analysis is different than used by Lin, et al. For example, we have not controlled for possible place effects, although these had little consequence for the AFQT effects estimated by Lin, et al.

All of the variables in Table A1 have 513 observations, with the exception of the number of magazines and newspapers present, for where there are 362 observations.

Table A1. Descriptive Statistics

Variable Names	Mean	Standard Deviation	Minimum	Maximum
Total annual income from wages, salary, commissions, or tips from all jobs at age 30, in 2014 dollars adjusted using the CPI.	26841.29	25907.96	0	160888.5
Average Peabody Picture Vocabulary Test scores, arithmetic mean of tests at ages 4, 6, 8, 10 and or 12.	86.39864	16.882	20	137
Indicator variable for urban residence at age 16	.7719298	.4246225	0	2
Indicator variable for whether mother had finished high school when child was six	.4619883	.4990396	0	1
Indicator variable for whether mother had some college schooling when child was six.	.1559454	.3631577	0	1
Indicator variable for whether mother had a four year college degree when child was six.	.0194932	.1383854	0	1
Indicator variable for whether father had finished high school when child was 16	.5360624	.4991846	0	1
Indicator variable for whether father had some college when child was 16.	.1384016	.345658	0	1
Indicator variable for whether father had a four year college degree when child was 16.	.0526316	.2235148	0	1
Rosen self esteem score at age 16 Rosenberg Self Esteem Scale (personality test) raw score at age 16. Minimum score of 189, maximum score of 647	472.4815	83.74576	216	647
Pearlin Mastery Scale of Self-Concept Percentile Score at Age 16. Minimum score of 2, maximum score of 10000	4696.162	2817.357	6	9963
Dummy variable for female respondent	.5711501	.4953949	0	1
Dummy variable for African American respondent	.4892788	.500373	0	1
Dummy variable for Hispanic respondent	.1949318	.3965349	0	1
Number of siblings	2.013645	1.474327	0	8
Indicator variable for whether the mother's country of birth was outside the United States	.0721248	.2589469	0	1
Average number of newspapers present in the home when child is 10 and 12 years old	.3581952	.3992861	0	1
Average number of magazines present in the home when child is 4 and 6 years old	2.5	1.384521	1	5
Year of birth for the child	1980.797	1.598899	1978	1983

Table A2. Effects of PPVT Scores During Childhood on Annual Earned Income at Age 30

Variables	Models Coefficients and standard errors in ()		
	1	2	3
Average Peabody Picture Vocabulary Test score	293 (91.9)	364 (550)	272 (106)
Square of average PPVT score		-.426 (3.45)	
Pearlin Mastery Scale of Self-Concept Percentile Score at age 16	-.567 (.531)	-.564 (.537)	-.879 (.658)
Rosenberg Self Esteem Scale at age 16	40.2 (16.0)	40.0 (16.1)	44.5 (19.5)
Black	-3423 (2851)	-3474 (2896)	-1151 (3789)
Hispanic	5495 (3292)	5478 (3303)	6650 (3934)
Female	-6918 (2191)	-6923 (2196)	-7537 (2855)
Number of Siblings	-1200 (752)	-1189 (763)	-2567 (914)
Mother foreign-born	4762 (5152)	4818 (5216)	355 (5975)
Urban residency at age 16	-237 (2655)	-282 (2601)	-2852 (3399)
Mother high school diploma	332 (2545)	307 (2588)	-262 (3400)
Mother some college	3425 (4063)	3442 (4063)	1638 (5036)
Mother college degree	7352 (8799)	7484 (8648)	5510 (11818)
Father high school diploma	2356 (2439)	2373 (2443)	2230 (3237)
Father some college	5250 (4007)	5290 (4041)	5097 (4979)
Father college degree	4610 (5432)	4607 (5434)	3194 (7089)
Magazines			1496 (1021)
Newspapers			-478 (3576)
Dummy variables for regions	yes	yes	yes
R^2	.140	.1403	.1504
n	513	513	362