Infant Feeding and Asthma: Is Breast Milk Best?

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Abstract

Asthma is the most commonly occurring chronic childhood disease in the United States and is the leading cause of hospitalization and missed school days. I examine whether socioeconomic disparities in asthma can be attributed to differences in breastfeeding incidence and duration. Using data from the Fragile Families and Child Wellbeing Survey, I examine whether unobserved hetereogeneity in the breastfeeding decision plays a role in childhood asthma propensity. I use the bivariate probit framework to account for potential endogeneity by modeling the breastfeeding and asthma equations jointly. Results indicate that after accounting for the unobserved heterogeneity found in infant feeding practices, breastfeeding leads to lower rates of asthma diagnosis in children at age one. Breastfeeding for at least three months appears to have the strongest effects in children diagnosed at age one. These results indicate that breastfeeding can result in lower rates of wheezing and better respiratory health in small children.

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1 Introduction

The American Lung Association defines asthma as a 'reversible lung disease caused by the narrowing or blocking of the lungs' airways', the symptoms of which can be triggered by various substances. Asthma triggers may include but are not limited to environmental irritants such as tobacco smoke and pollutants, household and industrial products, viruses, exercise and cold air (ALA, 2005). An asthma attack is characterized by wheezing, shortness of breath, coughing, chest pain or tightness and can be life-threatening (Adams, 1995). Pediatric asthma, or asthma among those under 18, is the most commonly occurring chronic childhood disease. In 2004, nine million U.S. children under 18 were reported as having been diagnosed with asthma in their lifetimes. Almost four million children were reported as having experienced an asthma attack in the preceding month (Dey and Bloom, 2006). The economic costs associated with childhood asthma are numerous. Asthma attacks result in more than 5 million hospitalizations, 14 million missed days of school and, more rarely, death(CDC, 2005; Akinbami and Schoendorf, 2002). Using data from the 1996 Medical Expenditure Panel Survey, Wang et al. (2005) calculate that the direct and indirect costs of asthma totaled almost 2 billion dollars in that year.

Childhood asthma is distributed unevenly with respect to gender and socioeconomic status, disproportionately affecting children who are male, poor, African-American and Latino (Dey and Bloom, 2006). Boys are more likely to be diagnosed with asthma than girls (15 percent vs. 9 percent). There are also differences in pediatric asthma outcomes along socioeconomic lines. Those more likely to be diagnosed over a lifetime include poor children (15 percent vs. 12 percent for children from non-poor households) and children from single parent households (16 percent vs. 11 percent for children in two-parent households). Inner-city children (who are disproportionately non-white) have been shown in numerous studies to have higher rates of asthma morbidity (Meyer et al., 1998). Among African-American children, asthma incidence, morbidity and mortality are higher compared to white children. For example, African-American children are more likely to report an asthma attack than white children (8 percent vs. 5 percent). Asthma incidence among Latinos is lower, but there is considerable heterogeneity within Latino subgroups. Mexican-American children have among the lowest incidence of lifetime asthma among all racial and ethnic groups, (10 percent) while Puerto-Rican children have the highest (over 25 percent)(Dey and Bloom, 2006; Flores et al., 2005).

While the origins of asthma are not altogether clear, researchers have generally concluded that asthma has both genetic and environmental/behavioral causes (Litonjua et al., 1998). This paper focuses on one behavioral component that has been hypothesized to play an important role: breastfeeding. Breastfeeding is thought to provide numerous health benefits to infants, including reduced risk of various infections, SIDS (Sudden Infant Death Syndrome), obesity and more (Kramer, 2003). Breastfeeding rates among poor and African-American mothers also tend to be significantly lower than those found among non-African American women (Forste et al., 2001). Although breastfeeding is often traditionally associated with a decreased likelihood of an asthma diagnosis (Wolf, 2007), the links between asthma and breastfeeding are far from clear. Many studies have found that breastfeeding has no effect on the incidence of asthma (Oddy et al., 2004), while others have found that breastfeeding actually may even *increase* the incidence of asthma (Sears et al., 2002).

However, little of the work examining the relationship between breastfeeding and asthma closely examines how the behavioral component of infant feeding can influence the statistical relationships being estimated. That is, breastfeeding is treated as an exogenous variable affecting child health outcomes when it is likely correlated with unobservable individual (and family) characteristics that also influence asthma outcomes. Failing to control for the endogeneity of important explanatory variables can lead to biased estimates of their effects. Adding to the economics and public health literatures, I explore the possible role of breastfeeding as an explanation of ethnic disparities in asthma diagnosis. To account for potential unobserved heterogeneity found in the infant feeding decision, I jointly model both the decision to breastfeed and asthma propensity using the bivariate probit framework. I find some evidence that breastfeeding behavior is indeed correlated with unobservables in the error term. When this unobserved heterogeneity is accounted for, I find that breastfeeding, particularly for at least three months, reduces the probability of the focal child being diagnosed with asthma by age one. However, there is limited evidence that breastfeeding reduces the likelihood of an asthma diagnosis by age three. These results suggest that breastfeeding plays a more important role in the health of infants than in older children.

I first provide a brief review of the literature on breastfeeding and pediatric respiratory health, as well as the economics of child health. I then describe the theoretical framework underlying the empirical model and the estimation methods that are used to analyze the relationship between breastfeeding and asthma. A description of the construction of my estimation sample from the Fragile Families data follows. I conclude with a discussion of the results, possible implications of findings and plans for future work.

2 Background

2.1 Breastfeeding

In its latest policy statement on breastfeeding, The American Academy of Pediatricians refers to the many 'health, nutritional, immunologic, developmental, psychological, social, economic and environmental' benefits of breastfeeding children (Gartner et al., 2005). These benefits include reduced risk of infectious disease and infant mortality, childhood obesity and more. The organization recommends that infants be breastfed exclusively for the first six months of life and that mothers continue to breastfeed infants for at least the first year of life (Gartner et al., 2005). Other studies have found that breastfeeding has important infant health benefits including protection from illness (e.g., diarrhea) and growth enhancement (Adair et al., 1993). Feeding duration and dosage of breast milk also appears to be important. Raisler et al. (1999), in their analysis of 7,092 infants from the National Maternal and Infant Health Survey find that while fully-breastfed infants tended to have the lowest rates of illness, mixed (formula and breast milk) feeding was not protective. Despite the known health benefits, there are significant racial differences in the initiation and duration of breastfeeding. Using a nationally representative sample, Forste et al. (2001) find after controlling for a wide variety of socioeconomic factors, black women were 2 1/2 times less likely to breastfeed than white women. The authors postulate that increases in breastfeeding among black women would significantly decrease the infant mortality gap between U.S. blacks and whites. Other studies agree that black women are significantly less likely to breastfeed (Li et al., 2005)

However, the causal links between breastfeeding, respiratory health, allergy and asthma are far from clear. Many researchers have found that breastfeeding has positive effects on respiratory health and correlates with a reduced risk of asthma. However, there is considerable heterogeneity in the findings of these studies, with the effects of breastfeeding depending on the age of the subjects, characteristics of the study sample and how breastfeeding is defined (e.g., length and exclusivity). Kull et al. (2004) find a protective effect of exclusive breastfeeding for at least four months during the first four years of life, with longer and more exclusive breastfeeding extending more protection against an asthma diagnosis. Oddy (2004) echoes these findings, concluding that exclusive breastfeeding for four months or more is associated with a significant reduction in the risk of asthma and atopy at the age of six. Other researchers have concluded that more extensive breastfeeding is required for it to have any discernible protective effects. In a case control study of Sri Lankan children aged 6-10, Karunasekera et al. (2001) find that only breastfeeding for more than six months is protective. Other studies have found either no association or positive correlations between breastfeeding and asthma. A recent study of 13,000+ mother-infant pairs by Kramer et al. (2007) finds no protective effect of prolonged or exclusive breastfeeding on allergy or asthma. These findings do not appear to be solely predicated on age. Other domestic and international studies find no significant relationships between infant feeding and asthma at ages sixteen (Lewis et al., 1996), ages seven to fourteen (Romiu et al., 2000) and ages six months to eleven years (Schwartz et al., 1990). Another longitudinal study in New Zealand found that breastfeeding had no protective effect against allergy or atopy[1] and that breastfeeding for more than four months may even increase the risk of developing asthma (Sears et al., 2002). Still other studies find that breastfeeding has differential effects, depending on whether the population in question is nonatopic (protective effect) or an asthmatic population (increased risk) (Wright et al., 2001).

Clinical research on this subject is also somewhat agnostic. On one hand, human milk contains specific defenses against infectious agents that lead to respiratory infection in children. Breastfed infants also tend to have more mature lungs, possibly leading to lower rates of respiratory infections. On the other hand, researchers hypothesize that breastfeeding may actually increase asthma risk by reducing children's exposure to microbes, leading to a subsequent decrease in immune response (Wright, 2005). There is also speculation that differences in milk of allergic and non-allergic mothers can affect a child's susceptibility to allergy. For example, Wright et al. (1999) show in their analysis of the Tuscon Children's Respiratory Study that when mothers who were in the highest tertile

[1] Atopy refers to the genetic tendency to develop allergic reactions to substances. Atopy commonly results in development of asthma and other similar conditions.

of IgE (a marker for allergens) breastfed their children for more than four months, that behavior was associated with higher IgE levels in their children, compared to those in infants who were breastfed less or never breastfed.

3 Empirical Model

I begin by specifying an empirical model of a mother's breastfeeding decisions and the health of outcomes of her child in subsequent years. Infant health and related factors are measured over a span of three periods. At the end of the first period, t=0, an infant is born. Initial infant health is represented by birth weight, W_0. (Birth weight is treated as exogenous.) During the second period, a mother chooses whether or not to initiate breastfeeding and whether to breastfeed for at least one month, three months, or six months. The decision to breastfeed is a function of birth weight, W_0, individual and family level factors, X_t, and tract- and MSA-level variables, N_t and Z_t^f. A child may be diagnosed with asthma at the end of the second or third period (t=1 or t=2). Pediatric asthma, A_t, is a function of birth weight, W_0, breastfeeding, F_t[2], socioeconomic variables, X_t (including factors such as ethnicity, child's age and parents' age) and N_t ,which includes tract-level housing conditions. Z_t^f represents formula prices, which are thought to affect the breastfeeding propensity, but do not independently influence the likelihood of an asthma diagnosis.

More specifically, both breastfeeding and asthma are characterized by underlying, unobserved latent variables, such that:

$$F_t^* = \theta_0 + \theta_1 W_0 + \theta_2 X_t + \theta_3 N_t + \theta_4 Z_t^f + \epsilon_t^f, t = 1$$

[2]Note that the coefficient on breastfeeding, χ_2^m, is allowed to vary with age in years, m.

$$F_t = 1 \;\; if \;\; F_t^* > 0, \;\; = 0 \;\;\; otherwise$$

and

$$A_t^* = \chi_0 + \chi_1 W_0 + \chi_2^m F_t^* + \chi_3 X_t + \chi_4 N_t + \epsilon_t^a, t = 1, 2$$

$$A_t = 1 \;\; if \;\; A_t^* > 0, \;\; = 0 \;\;\; otherwise$$

Although some of the previously discussed studies make an attempt to deal with the issue of sample selection, none of them adequately deals with issues of endogeneity that may significantly bias their parameter estimates. Ignoring the endogeneity inherent in the breastfeeding decision can lead to biased effects of breastfeeding on subsequent child health(χ_2^m in equation 2). That is, $(E[\epsilon_1^f, \epsilon_1^a] = \rho \neq 0)$.[3] Several methods have been developed to address the issue of endogeneity bias. The linear probability model has been used to estimate simultaneous equation models where an endogenous dummy variable is present (Heckman, 1978). The key advantage of the linear probability model is that it is computationally simple to estimate. However, there are some drawbacks, including predicted probabilities that lie outside of the unit interval[4], the assumption that marginal effects are constant for all possible values of independent variables (an impossibility) and heteroskedastic standard error terms (resulting in invalid standard errors)(Wooldridge, 2006).

The bivariate probit model offers an alternative, full-information maximum likelihood approach to the linear probability model in the two-equation case where there is a binary, explanatory variable that is potentially endogenous. The bivariate probit model can be thought of as an extension of the univariate probit model, where both equations are estimated together, rather than separately. If

[3]The direction of the potential bias is unclear, a priori. For example, if children with a family history of asthma have mothers who are more likely to breastfeed, it will appear as if breastfeeding 'causes' a diagnosis of asthma. On the other hand, mothers who do not breastfeed may also be more likely to smoke–and have children who are more likely to develop asthma.

[4]On this subject, Heckman and Macurdy (1985) note that: 'For empirical studies focusing on hypothesis testing and exploration of structural relations among discrete endogenous variables, such problems are of less concern. For empirical studies that seek to develop forecast equations, these problems are a source of great concern.'

both the error terms associated with breastfeeding and asthma (ϵ_1^f and ϵ_1^a) are correlated ($E[\epsilon_1^f, \epsilon_1^a] = \rho \neq 0$) then estimating breastfeeding and asthma jointly will yield consistent estimates (Greene, 1998). I also perform likelihood-tests to determine whether or not the error terms across equations are correlated in a significant way. I model the breastfeeding decision as a 0/1 variable that indicates whether the mother breastfed or not, and asthma propensity as a 0/1 variable indicating whether or not the child had ever been diagnosed with asthma. I also estimate models that examine the effects of breastfeeding duration (still dichotomous variables). That is, whether the mother breastfed for at least one month, 3 months, and six months.

Any model attempting to make causal inferences regarding breastfeeding and pediatric asthma must deal with issues of identification. In the instrumental variables framework, achieving identification requires finding an exogenous variable that affects the ultimate outcome (e.g. asthma) only indirectly through its effects on the endogenous regressor of interest (breastfeeding) (Angrist, 2001). Parents face constraints when investing in child health. They must allocate their limited time and other resources not only to child health inputs (e.g. food, medical care) but to other goods and services valued by the household. Consistent with the law of demand, increases in the prices of child health inputs will likely result in a decrease in the quantity demanded. However, an increase in the price of a substitute good would likely cause the demand for that good to increase. Ideally, any model of the breastfeeding decision would contain information on formula prices, Z_t^f . Given that formula is a substitute for breastfeeding, one would expect the demand for breastfeeding to vary inversely with the price of formula; this is also borne out in empirical research (Blau et al., 1996; Adair et al., 1993). Another attractive feature of using prices is that one can easily argue that formula prices are independent of each survey respondent. Unfortunately, complete information on formula prices in the U.S. is proprietary and the cost of obtaining complete data is prohibitive. However, data on formula prices for the year 2000 is available in various USDA reports (Oliveira et al., 2004).

My original strategy was to use formula price information in conjunction with indicators of breastfeeding legislation in order to identify the breastfeeding equation. Variations in breastfeeding laws over time can provide important information on barriers to breastfeeding. Approximately 39 states have enacted breastfeeding legislation. These laws generally are grouped into 7 major areas: public breastfeeding; jury duty; workplace accommodations; health, education and insurance measures; custody/visitation; and miscellaneous provisions (Vance, 2005). I proxy for the state legal environment using an indicator of whether or not the mother lived in a state with a law protecting public breastfeeding. In the sample, approximately 40 percent mothers lived in areas with laws addressing public breastfeeding (Texas, Maryland, New Jersey, Pennsylvania[5],and New York.) However, I found that variations in breastfeeding laws were extremely weak instruments. When the model is overidentified, using more weak instruments that are not highly correlated with the endogenous regressor of interest proportionately increases the bias. Therefore, using fewer weak instruments tends to reduce bias. In fact, the bias is equal to zero if the number of instruments equals the number of endogenous regressors (Angrist and Krueger, 2001). Therefore, I only use formula prices to identify the breastfeeding equation.[6]

[5]While Pennsylvania does not have specific state legislation addressing breastfeeding, Philadelphia does have laws on the subject.

[6]To further test for the validity of formula price variation as an exclusion restriction, I estimate the breastfeeding and asthma equations both jointly and separately, including formula prices as a regressor. I find that formula prices still have a consistent, statistically significant effect on the likelihood of being breastfed for any period, no effect on asthma propensity or the statistical significance of the breastfeeding coefficient. I also estimate a group of models that do not include tract-level variation, and still find that the effect of formula prices on breastfeeding continues to be statistically significant. Results are available upon request.

4 Data and Sample Considerations

The Fragile Families and Child Wellbeing study (FF), also called 'The Survey of New Parents', provides data on a cohort of 4,898 children (and their parents) from birth to age five. The survey oversamples unwed, low-income and black and Hispanic parents. These data are unique due to the relatively high response from unwed fathers. The information provided on the unwed fathers allows for the study of a wide variety of social and economic outcomes among families with unmarried parents such as the involvement of single fathers, how public policies (e.g., marriage) affect union formation and the consequences of stricter child support and welfare laws on parents and children.

The national study is a stratified random sample of large U.S. cities with a population of at least 200,000. Cities were stratified on the basis of variance in policy and labor market conditions, labor market demand, strength of child support enforcement and welfare generosity. More information on the Fragile Families Study can be found in Reichman et al. (2001).

The original Fragile Families sample consists of a cohort of 4,898 children and their mothers and fathers. I excluded every observation in the sample without valid measures for birth weight. For the second wave, I excluded all observations without valid values for the dependent variables, including the number of weeks the mother breastfed and whether or not the child had been diagnosed with asthma. In the third wave, I excluded all observations with missing values child's asthma status. Using the above criteria, I retained all individuals who had valid values for the endogenous variables being estimated. My final estimation sample consists of 2,105 individuals observed over three periods. Table 4 in the appendix provides a comparison of the mean values of key variables between the excluded observations and the final sample. The two samples are fairly similar across values/proportions of gender, parents' age, and mother's high school graduation status. However, there are a greater proportion of white and black mothers in the final sample, and less

Latino mothers. Also, there are more married parents in the final sample, while less of the parents report cohabiting.

Information on birth weight is found in the baseline survey of the Fragile Families data. Birth weight is used as a measure of initial health. Nepomnyaschy and Reichman (2006), using the Fragile Families data, find that low birth weight is strongly associated with the likelihood of having ever been diagnosed with asthma by age three. The breastfeeding decision is only measured during the second wave of the survey. I use several measures of breastfeeding incidence and duration, including whether breastfeeding was ever initiated and if a child was breastfed at least one month, three months and six months. It should be noted that the survey did not indicate whether or not the mother breastfed exclusively. Child asthma outcomes in the second and third waves are represented by incidence of asthma diagnosis. Asthma diagnosis is a dichotomous indicator for whether or not parents reported having been told by a doctor that their child had asthma.

4.1 Summary Statistics

Table 1 provides summary statistics for infant/child health outcomes and maternal breastfeeding behavior in the estimation sample (N=2105) by race/ethnicity of the mother.[7] Low birth weight in the estimation sample is 9.8 percent, with black children having the highest rates (12.8 percent). Most national statistics on pediatric asthma reflect a lifetime diagnosis among children up to age 18. Even so, the rates of asthma diagnosis at age three in the sample are much higher than the national average in 1999 (19.71 percent vs. 11.8 percent) and reflect the urban nature of the sample. Finally, breastfeeding initiation and duration rates in the Fragile Families sample are higher among mothers belonging to the 'other' ethnicity category, followed by whites, Latinos and blacks.

[7] The 'other ethnicity' category is included for descriptive/statistical purposes and includes Asians, Pacific Islanders, Native Americans and other groups. Due to the extremely heterogenous nature of this category (and small size, N=70), it is difficult to form any inferences regarding this group.

Table 2 provides summary statistics for family and individual characteristics in the estimation sample, such as race, income and mother's age and educational status. Table 3 contains information on exogenous neighborhood, city and MSA-level variables. Tract-level characteristics include information such as the racial composition of the neighborhoods, percentage of welfare recipients and poor housing conditions. Neighborhood characteristics have been shown to have effects on asthma diagnosis and exacerbation (Nepomnyaschy and Reichman, 2006). As aforementioned, I include the price of infant formula in the year 2000 (for each MSA) to proxy for the opportunity costs associated with breastfeeding.

5 Estimation Results

In this section, I discuss the estimated effects of breastfeeding on whether a child had ever been diagnosed with asthma at age three and at age one. In general, an asthma diagnosis tends to be more accurate with increasing age of the child. More than 80 percent of children who wheeze during their first year belong to a category of 'transient wheezers' who do not have wheezing episodes after age three. However, only about 30 to 40 percent of 'transient wheezers' belong to this category of children who cease wheezing after their third birthday. Wright et al. (2004) notes that classic IgE-mediated (allergic) asthma becomes the predominant form of wheezing only after the first decade of life. Thus, an age three asthma diagnosis may be somewhat more accurate in predicting asthma, but distinguishing transient wheezers from children who will go on to develop allergic asthma is still problematic at best (Castro-Rodrìguez et al., 2000). Thus, I include both groups in my analysis. I compare the regression results from two different models: a simple probit model and a bivariate probit model that jointly estimates breastfeeding and asthma diagnosis/morbidity, treating breastfeeding as endogenous. Within each model category, I estimate sparse and fully specified models, where the fully specified models contain neighborhood effects. I only discuss the sparse models if results differ significantly from the more fully specified models. (Results of the more parsimonious models are available upon request).

I include both the marginal effects and coefficients of probit models. In the case of the bivariate probit models, I present the coefficients and the average partial effects (APE). That is, for each individual, I evaluate the partial effect of going from 'not breastfed' (alternatively, 'not breastfed for x months') to 'breastfed', holding all other exogenous regressors constant. I then take the average of the individual partial effects over entire sample. I calculate standard errors for the average partial effects using bootstrap methods in STATA.[8] The final and sparse models are included in the appendix and the average partial effects are included in the main body of the paper. The coefficient estimates for the breastfeeding equation, are available upon request.[9] The coefficient estimates for each of the first stage breastfeeding equations (in the bivariate probit specification) can be found in Tables 15 through 18.

5.1 Effects of Ever Having Initiated Breastfeeding on Incidence of Asthma Diagnosis

Table 5 displays the marginal effects of breastfeeding on the likelihood of an asthma diagnosis by age one and age three. Probit estimates show that children whose mothers initiated breastfeeding were somewhat more likely to be diagnosed with asthma, although both the coefficient estimate is statistically insignificant. In terms of ethnic disparities, blacks and Latino children are more likely,

[8]The average partial effect, δ_t, is calculated as $E(A_t|F_t = 1, W_0, X_t, N_t, Z_t) - E(A_t|F_t = 0, W_0, X_t, N_t, Z_t)$, where W_0, X_t, N_t, Z_t represent individual values of W_t, X_t, N_t and Z_t, respectively. I assume that any unobserved heterogeneity, ρ, is independent of the exogenous regressors. See Wooldridge (2002) for a discussion of average partial effects.

[9]The results of the Wald test on the identifying instrument in the breastfeeding equation, formula prices, are included in the footnote section of each of the tables.

compared to white children[10], to be diagnosed with asthma at age three (sparse model). However, including neighborhood effects appears to eliminate any statistical significance of the black ethnicity variable (full model), suggesting that these children may live in environments associated with higher rates of asthma.

The bivariate probit specification accounts for the potential endogeneity of breastfeeding behavior. Children whose mothers initiated breastfeeding were less likely to receive an asthma diagnosis at the age of one, at the ten percent level of significance. Latino children are still more likely to receive an asthma diagnosis by age one, at the one percent level of significance. A likelihood ratio (LR) test of the $\rho(\epsilon_t^a, \epsilon_t^f)$ coefficient indicates that $\rho(\epsilon_t^a, \epsilon_t^f)$ is negative but statistically insignificant. Thus, the LR test fails to reject the hypothesis that $\rho(\epsilon_t^a, \epsilon_t^f)$=0. However, the negative sign on the $\rho(\epsilon_t^a, \epsilon_t^f)$ coefficient and the fact that the coefficient on breastfeeding is negative (and statistically significant, albeit at the 10 percent level) in the bivariate probit specification suggests the importance of unobserved factors at work that influence both breastfeeding initiation and asthma diagnosis by age one. The average partial effect is also statistically significant, and indicates that children who are breastfed are about 11.2 percent less likely to be diagnosed with asthma at age one. Other factors related to an age one asthma diagnosis include low birth weight and being male (positive and significant at the one percent level) and if the mother was cohabiting with the father.

At age three [see Table 11 for the results of the complete model], I find that breastfeeding is positively related to the likelihood of being diagnosed with asthma in both the simple and bivariate probit specifications. However, none of the relationships are statistically significant. As with asthma at age one, low birth weight and male children are more likely to develop asthma at the one percent level of significance. Interestingly, family structure plays a very different role in the likelihood of an asthma diagnosis at age three than at age one. Children whose parents are married or cohabiting are

[10]White children serve as the omitted category.

less likely to receive an age three asthma diagnosis (at the one and five percent levels of significance, respectively), while there is a weak but positive relationship between parent's relationship status (cohabitation) and asthma diagnosis at age one. Medicaid receipt also is positively associated with a diagnosis of asthma, as are neighborhood effects. Children who live in predominantly Hispanic neighborhoods are more likely to receive an asthma diagnosis; the inverse is true for children who live in neighborhoods with a greater proportion of immigrants. As with the previous analysis of age one asthma, the LR test fails to reject the hypothesis that $\rho(\epsilon_t^a, \epsilon_t^f)$=0, indicating that endogeneity bias is likely not playing a large role in the results.

5.2 Effects of Breastfeeding Duration on Asthma

The next section will examine the potential effects of more extended breastfeeding on infant health. In the final sample, 46.32 percent of the mothers breastfed for at least one month, 33.11 percent for three months or more, while 14.82 percent breastfed for at least six months. Breastfeeding for one month has no statistically significant effect on an asthma diagnosis at age three [Tables 12 and 7]. However, there is a strong and statistically significant effect of breastfeeding for one month on the likelihood of developing asthma at age one [Table 8]. The average partial effect, shows that children who are breastfed for at least one month are 13 percent less likely to receive an age one asthma diagnosis. However, this effect is not statistically significant. Breastfeeding at least three months has a strongly negative relationship with the probability of an age one asthma diagnosis, at the one percent level of significance [Table 9]. Children who are breastfed for at least three months are 15.1 percent less likely to develop asthma at age one. The LR test rejects the hypothesis that $\rho(\epsilon_t^a, \epsilon_t^f)$=0 at the ten percent level of significance. Thus, I conclude that endogeneity bias is present in the decision to breastfeeding for three months or more. I also find no statistically significant relationships between breastfeeding for at least six months and an asthma diagnosis at either ages one or three [Tables 10 and 14].

6 Robustness Checks

I perform two robustness checks to determine whether my results are driven by the functional form of the age three asthma variable. The full alternative models, complete with coefficients and standard errors, are available upon request. The average partial effects for these models can be found in the appendix in Table 6. The first new specification is to alter the 'ever diagnosed with asthma at age three variable' to 'diagnosed only after age one'. This restricts the 'asthma positives' to the 184 children diagnosed after the age one survey. Although the probit coefficients are similar to those in the first age three asthma specification (see coefficient and APE estimates in Tables 14 through 11 and Table 6, respectively), both the coefficients and average partial effects are positive and statistically significant (at the ten and five percent levels, respectively) for having breastfed at all and at least for one month. In the bivariate probit models, only the coefficient on 'breastfed at least one month' is statistically significant. However, the APE is statistically insignificant.

In the next case, I test whether measurement error is important in this survey data. In the Fragile Families data, there are 56 mothers who reported that their child had 'ever' been diagnosed at age one, but subsequently reported having 'never' been diagnosed at age three. Here, I find that while the probit coefficients and average partial effects are similar to those found in the 'ever diagnosed up to age three' models. However, there are some differences in the coefficients and average partial effects in the bivariate probit specification. The average partial effects when the 56 new children are recorded as having 'ever been diagnosed' up to age three (total N=471) are much smaller than those in the first specification. Most notably, the average partial effects for 'breastfed at least three months' and 'breastfed at least six months' are negative. However, neither the coefficients or APEs are statistically significant.

7 Discussion of Estimation Results and Conclusions

I find that the effects of breastfeeding on a pediatric asthma differ significantly by age. While it appears that breastfeeding does not have a statistically significant effect on an asthma diagnosis by age three[11],I do find support for the idea that breastfeeding affects respiratory health in smaller children. Moreover, the effects of breastfeeding for three months appear to be stronger (in terms of statistical significance) than simply having initiated breastfeeding. This provides some evidence that in small children, breastfeeding duration may be more important than initiation. In the case of small children, it is admittedly difficult to distinguish between early onset allergic asthma and transient wheezing Wright et al. (2004). However, the potential costs attributable to asthma (or wheezing) in small children are considerable. Asthmatic children who exhibit early symptoms tend to have persistent symptoms into adulthood, as well as experience significant functional deterioration (Castro-Rodrìguez et al., 2000). Even the children characterized as 'transient wheezers' that do not go on to develop allergic asthma tend to have less developed lung function relative to those in their cohort who never wheezed. Taussig et al. (2003) hypothesize that these children may be at increased risk of conditions such as chronic obstructive pulmonary disease due to their smaller airways. Also important is the fact that low birth weight children are still much more likely to develop asthma, after controlling for child, parental and neighborhood factors. Given that birth weight results from both genetic factors and maternal behavior, I cannot be definitive on the role initial weight plays in asthma development. However, it still bears mentioning that low birth weight is a consistent risk factor for asthma development, although the mechanisms are far from clear.

[11] While there is a slightly positive coefficient on the 'breastfed for at least one month' variable, the average partial effect is statistically insignificant.

It is worth noting that parental relationships are correlated with the likelihood of developing asthma. At age three, there is a consistently negative relationship between asthma and parental marriage and cohabitation. However, at age one, married parents are more likely to have a child diagnosed with asthma (statistically insignificant) as are parents who cohabit (significant at the ten percent level). However, when breastfeeding duration is included, there is a negative relationship between marriage, cohabiting, and asthma. There is an extensive body of research examining the effects of family structure on child health and well-being (Dawson, 1991). Parents who marry or cohabit may have an advantage in that they can pool their resources to invest more in child health. Children on Medicaid are also more likely to receive a diagnosis of asthma at both ages one and three, perhaps reflecting the relative poverty of children on public health insurance.

Interestingly enough, black children are no more likely to develop asthma, especially when controls for neighborhood characteristics are included. Neighborhoods with greater proportions of vacant housing and poverty have been shown to influence the likelihood of a pediatric asthma diagnosis (Juhna et al., 2005). My own results indicate that children who reside in predominantly Hispanic and black neighborhoods may be more likely to develop asthma, while there appears to be a protective effect from living in a neighborhood with more immigrant residents. There is also a positive association between vacant housing and an asthma diagnosis. Other researchers have found large variations in the rates of asthma between predominantly black neighborhoods Gupta et al. (2008), these results help to support the notion that neighborhood characteristics are important for determining child health outcomes. However, including controls for neighborhood characteristics still do not explain why Hispanic children are more likely to get asthma. There is considerable heterogeneity among the Hispanic children in the survey. More than fifty percent are Mexican-American (N=250), and Puerto Rican children comprise another 16 percent. Both the breastfeeding behavior and asthma outcomes of the Mexican-Americans and Puerto Ricans are substantially different. In the FF sample, about 69 percent of Mexican-American mothers initiate breastfeeding, compared to 56 percent of Puerto Rican mothers. Differences in asthma rates are even more dramatic. At age one, asthma rates among Puerto Rican children are 27.85 percent, compared to 12.80 percent among Mexican-American children. At age three, 31.65 percent of Puerto Rican children have been diagnosed with asthma, compared to 16.40 percent of Mexican-American children. Although the relatively small sample of latinos makes it difficult to perform any meaningful statistical analysis, future work will involve examining differences among Latinos.

This study is limited by several factors. The most important is that it is unclear whether or not the mothers in the Fragile Families study engaged in exclusive breastfeeding. Therefore, the parameter estimates of the breastfeeding variable do my not reflect the true biological impact of exclusive breastfeeding. However, as my results suggest, even a limited amount of breastfeeding may be enough to confer protective effects. Also, I do not control for other variables that may influence asthma diagnosis, such as smoking. Since breastfeeding mothers are less likely to smoke, the generally negative relationship between breastfeeding and asthma may reflect this bias. Secondly, infants have smaller airways and are more prone to various respiratory ailments. For example, in very young children, wheezing (one of the common symptoms of asthma) can be caused by any number of factors, including prenatal smoking. Some of these wheezing phenotypes are benign and are outgrown by the third birthday. There are also wheezing symptoms that can be caused by viral or other respiratory infections that are not necessarily precursors to asthma (Mutius, 2000). However, this concern may not be a very important one. Nepomnyaschy and Reichman (2006), in their work on asthma and low birth weight find that prenatal smoking is not associated with a diagnosis of asthma. Lastly, low birth weight is treated as exogenous. While low birth weight (the initial infant health endowment) is certainly exogenous to the infant, it is certainly attributable in part to the mother's prenatal decision-making process. Those characteristics that influence prenatal health-seeking behaviors may also influence both breastfeeding decisions and a child's asthma outcomes. However, the number of low birth weight children in the sample is small (N=206) and prevents me from doing any meaningful analysis stratified on the basis of initial infant health.

Nevertheless, this paper fills an important gap in the economics and epidemiological literature by examining breastfeeding and asthma in U.S. context using a more rigorous methodology to yield more precise empirical results. In a policy context, it is very important to gain an accurate understanding of the true role of breastfeeding in the prevention of asthma. The results of this study indicate that breastfeeding may have a negative relationship with an early life asthma diagnosis. Given the tenacious nature of infant asthma diagnoses, these findings may point towards a negative relationship with infectious wheezing in infants. Given the additional hospitalizations (and subsequent costs) associated with non-breastfed infants (Bachrach et al., 2003), it is beneficial to consider what changes in behavior or policy can reduce these excess costs. Results from the breastfeeding equations consistently demonstrate that African-American mothers are much less likely to breastfeed. If this is the case, then increasing breastfeeding rates among African-American mothers may be one potential mechanism for reducing improving African-American infant health.

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APPENDIX

A Tables

Table 1: Summary Statistics for Health Inputs and Outcomes by Ethnicity[a], [b]

Dependent Variable		**All (n=2105)**	**White (n=504)**	**Black (n=1041)**	**Latino (n=490)**	**Other (n=70)**
Health Outcomes						
Birth weight	W_0	3.23	3.37	3.12	3.31	3.32
(kilograms)		(0.61)	(0.62)	(0.61)	(0.57)	(0.41)
Low Birth weight	$P(W_0 < 2.5)$	9.8	8.33	12.58	6.33	2.86
Ever Diagnosed with Asthma	$P(A_1 = 1 \text{ or } A_2 = 1)$	19.71	12.10	23.44	20.20	15.71
Asthma, Age One	$P(A_1 = 1)$	13.63	5.95	17.29	14.29	10.00
Asthma, Age Three	$P(A_2 = 1)$	10.12	8.23	10.69	11.43	7.94
Health Inputs						
Breastfeeding Initiated	$P(F_1 \geq 0)$	54.59	67.46	43.13	62.65	72.86
Breastfed at least 1 month	$P(F_1 \geq 1)$	46.32	57.14	36.12	53.67	68.57
Breastfed at least 3 months	$P(F_1 \geq 3)$	33.11	41.07	26.22	37.12	50.00
Breastfed at least 6 months	$P(F_1 \geq 6)$	14.82	18.83	12.01	15.31	24.29

[a] All numbers are percentages, except birth weight, W_0 , which is expressed as a mean.
[b] Standard errors are in parentheses.

Table 2: Summary Statistics for Parental and Child Characteristics at Baseline (Wave 1)

Variable	**Mean**	**Std. Dev.**
Male child	0.53	0.50
Mother is white	0.24	0.43
Mother is black	0.49	0.50
Mother is Latino	0.23	0.42
Mother's age, in years	24.84	5.91
Father's age, in years	27.51	6.50
Mother married to father	0.24	0.45
Mother cohabiting with father	0.37	0.48
No. of adults in household	2.29	0.99
Grandmother present	0.19	0.39
No. of children in household	1.30	1.31
Income (in thousands)	19.14	20.52
Mother is high school grad	0.69	0.46
Mother attended some college	0.26	0.44
Mother has bachelor's degree	0.10	0.30
Medicaid Insurance Coverage	0.62	0.40
Mother religious	0.35	0.48
Sample size	2105	

Table 3: Summary Statistics for Tract- and MSA-Level Characteristics

Variable	**Source of Variation**	**Mean**	**Std. Dev.**
Percent Hispanic	Tract	0.18	0.26
Percent black	Tract	0.41	0.38
Percent other ethnicity	Tract	0.01	0.01
Percent foreign-born	Tract	0.11	0.14
Percent with h.s. degree+	Tract	0.69	0.18
Percent unemployed	Tract	0.11	0.08
Percent vacant housing units	Tract	0.09	0.07
Percent on welfare	Tract	0.08	0.07
Tract variables, missing	Tract	0.02	0.13
Price of Infant Formula	MSA	2.56	0.11
Sample size	2105		

Table 4: Comparison of Excluded Observations and Final Sample[a]

	Excluded		**Included**	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Male Child	0.52	0.48	0.53	0.50
Mother is white	0.18	0.37	0.24	0.43
Mother is black	0.45	0.48	0.49	0.50
Mother is Latino	0.31	0.46	0.23	0.42
Mother's age, in years	24.29	6.07	24.84	5.91
Father's age, in years	27.21	7.33	27.51	6.50
Married to father	0.21	0.39	0.24	0.42
Cohabiting	0.43	0.51	0.37	0.48
No. of adults in household	2.49	1.10	2.29	0.99
No. of children in household	1.20	1.31	1.30	1.31
Mother high school grad	0.65	0.42	0.69	0.46

[a] Original sample consists of 4,898 observations total-the excluded sample (N=2793) and the final estimation sample, (N=2105).

Table 5: Average Partial Effects of Breastfeeding on Asthma Diagnosis[a,b]

	Probit		**Bivariate Probit**	
	APE	**Std. Error**	**APE**	**Std. Error**
Age One Asthma				
Breastfed	0.001	(0.015)	-0.112*	(0.059)
Breastfed $\geq$ 1 month	0.003	(0.015)	-0.130	(0.080)
Breastfed $\geq$ 3 months	-0.004	(0.016)	-0.151**	(0.062)
Breastfed $\geq$ 6 months	-0.006	(0.021)	0.014	(0.067)
Age Three Asthma				
Breastfed	0.056	(0.018)	0.051	(0.038)
Breastfed $\geq$ 1 month	0.029	(0.019)	0.051	(0.046)
Breastfed $\geq$ 3 months	0.012	(0.020)	0.017	(0.063)
Breastfed $\geq$ 6 months	-0.015	(0.025)	0.006	(0.041)

[a] *** indicates significance at the 1% level; ** 5%; * 10%.
[b] Standard errors are in parentheses.

Table 6: Average Partial Effects of Breastfeeding on Asthma Diagnosis: Alternative Models[a,b,c]

	Probit		Bivariate Probit	
	APE	**Std. Error**	**APE**	**Std. Error**
Asthma Diagnosis After Age One				
Breastfed (y/n)	0.025*	(0.013)	0.037	(0.040)
Breastfed ≥ 1 month (y/n)	0.026**	(0.013)	0.032	(0.027)
Breastfed ≥ 3 months (y/n)	0.015	(0.014)	0.022	(0.030)
Breastfed ≥ 6 months (y/n)	0.000	(0.017)	0.005	(0.034)
Age One but not at Age Three				
Breastfed (y/n)	0.027	(0.019)	0.008	(0.105)
Breastfed ≥ 1 month (y/n)	0.032	(0.020)	0.024	(0.092)
Breastfed ≥ 3 months (y/n)	0.012	(0.021)	-0.013	(0.079)
Breastfed ≥ 6 months (y/n)	-0.009	(0.026)	-0.004	(0.037)

[a] *** indicates significance at the 1 % level; ** 5%; * 10%.
[b] Standard errors are in parentheses.
[c] The average partial effect of breastfeeding for six months in the second specification is approximately -0.0003.

Table 7: Age One Asthma and Breastfeeding (yes/no), full model[a,b,c]

	Probit		***Bivariate Probit***	
Variable	Coeff.	Std. Error	Coeff.	Std. Error
Initial Child Health				
Low birth weight	0.374***	(0.109)	0.308***	(0.115)
Maternal Inputs				
Breastfed (y/n)	0.006	(0.078)	-0.760*	(0.397)
Child Characteristics				
Child's age, in years	0.158	(0.186)	0.151	(0.174)
Child is male	0.420***	(0.075)	0.394***	(0.075)
Parental Characteristics				
Mother is black	0.229	(0.141)	0.151	(0.142)
Mother is hispanic	0.329**	(0.070)	0.340**	(0.144)
Mother is other ethnicity	0.208	(0.248)	0.208	(0.239)
Mother's age	-0.006	(0.010)	-0.008	(0.009)
Mother married to father	-0.267**	(0.116)	0.048	(0.124)
Mother cohabiting with father	-0.209**	(0.092)	0.038*	(0.092)
Age of Biological Father	-0.009	(0.007)	-0.007	(0.007)
Number of adults in household	-0.034	(0.047)	-0.027	(0.046)
Grandmother present in household	-0.137	(0.116)	-0.127	(0.112)
Number of children in household	0.048*	(0.028)	0.035	(0.028)
Income	0.003	(0.003)	0.003	(0.003)
Mother completed high school	-0.098	(0.090)	-0.073	(0.088)
Mother attended some college	-0.012	(0.100)	0.106	(0.112)
Mother has bachelor's degree	-0.260	(0.215)	-0.147	(0.213)
Medicaid	0.183**	(0.093)	0.149	(0.092)
Mother religious	-0.019	(0.082)	0.052	(0.086)
Local Characteristics				
Percent Hispanic	0.004	(0.274)	0.001	(0.263)
Percent black	0.081	(0.200)	0.112	(0.193)
Percent other ethnicity	-0.471	(2.806)	-1.210	(2.683)
Percent foreign-born	0.226	(0.385)	0.612	(0.412)
Percent with h.s. degree	-0.373	(0.438)	-0.076	(0.451)
Percent unemployed	-0.184	(0.834)	0.185	(0.826)
Percent vacant housing	0.668	(0.604)	0.072	(0.582)
Percent on welfare	0.619	(0.792)	0.297	(0.791)
Tract variables missing	-0.304	(0.500)	0.044	(0.516)
2001 Interview	-0.092	(0.129)	-0.051	(0.124)
Intercept	-1.218**	(0.553)	-1.030*	(0.544)
$\rho(\epsilon_t^a, \epsilon_t^f)$			-0.467	(0.290)
χ_1^2			0.984	

[a] *** indicates significance at the 1 % level; ** 5%; * 10%.
[b] Standard errors are in parentheses.
[c] χ_1^2 test statistic on formula prices=5.95**.

Table 8: Age One Asthma and Breastfed at Least One Month (yes/no), full model[a,b,c,d]

	Probit		***Bivariate Probit***	
Variable	Coeff.	Std. Error	Coeff.	Std. Error
Initial Child Health				
Low birthweight	0.374**	(0.109)	0.269**	(0.116)
Maternal Inputs				
Breastfed at least one month (y/n)	0.018	(0.079)	-0.938***	(0.328)
Child Characteristics				
Child's age, in years	0.158	(0.186)	0.139	(0.166)
Child is male	0.42	(0.075)	0.377***	(0.075)
Parental Characteristics				
Mother is black	0.23	(0.141)	0.147	(0.136)
Mother is hispanic	0.328	(0.151)	0.35**	(0.140)
Mother is other ethnicity	0.206	(0.249)	0.245	(0.232)
Mother's age	-0.006	(0.010)	-0.006	(0.009)
Mother married to father	-0.268	(0.116)	-0.155	(0.119)
Mother cohabiting with father	-0.21	(0.092)	-0.159*	(0.090)
Age of Biological Father	-0.009	(0.007)	-0.008	(0.007)
Number of adults in household	-0.034	(0.047)	-0.025	(0.045)
Grandmother present in household	-0.137	(0.116)	-0.139	(0.109)
Number of children in household	0.048	(0.028)	0.043	(0.026)
Income	0.003	(0.003)	0.003	(0.003)
Mother completed high school	-0.099	(0.090)	-0.048	(0.088)
Mother attended some college	-0.013	(0.100)	0.129	(0.105)
Mother has bachelor's degree	-0.263	(0.215)	-0.061	(0.210)
Medicaid	0.183	(0.093)	0.141	(0.089)
Mother religious	-0.02	(0.082)	0.095	(0.086)
Local Characteristics				
Percent Hispanic	0.004	(0.274)	-0.03	(0.256)
Percent black	0.079	(0.200)	0.121	(0.187)
Percent other ethnicity	-0.447	(2.808)	-1.82	(2.632)
Percent foreign-born	0.218	(0.385)	0.736*	(0.398)
Percent with h.s. degree	-0.376	(0.437)	-0.098	(0.425)
Percent unemployed	-0.187	(0.834)	0.178	(0.799)
Percent vacant housing	0.665	(0.604)	0.66	(0.569)
Percent on welfare	0.623	(0.792)	0.224	(0.771)
Tract variables missing	-0.307	(0.499)	0.003	(0.483)
2001 Interview	-0.092	(0.129)	-0.051	(0.119)
Intercept	-1.216	(0.553)	-1.04**	(0.522)
χ^2_1				2.40

[a] *** indicates significance at the 1 % level; ** 5%; * 10%.
[b] Standard errors are in parentheses.
[c] The coefficient on $\rho(\epsilon_t^a, \epsilon_t^f)$=$1.69 * 10^{-5}$ and χ^2_1=$3.80 * 10^{-8}$.
[D] χ^2_1 test statistic on formula prices=5.79**.

Table 9: Age One Asthma and Breastfed at Least Three Months (yes/no), full model[a,b,c]

	Probit		***Bivariate Probit***	
Variable	Coeff.	Std. Error	Coeff.	Std. Error
Initial Child Health				
Low birth weight	0.372***	(0.109)	0.197*	(0.120)
Maternal Inputs				
Breastfed for $\geq$ 3 months (y/n)	-0.025	(0.084)	-1.145***	(0.253)
Child Characteristics				
Child's age, in years	0.158	(0.186)	0.137	(0.157)
Child is male	0.420***	(0.075)	0.356***	(0.073)
Parental Characteristics				
Mother is black	0.229	(0.141)	0.173	(0.129)
Mother is hispanic	0.331**	(0.151)	0.345**	(0.135)
Mother is other ethnicity	0.210	(0.249)	0.246	(0.221)
Mother's age	-0.006	(0.010)	-0.001	(0.009)
Mother married to father	-0.265**	(0.116)	-0.112	(0.115)
Mother cohabiting with father	-0.208**	(0.091)	-0.137	(0.087)
Age of Biological Father	-0.009	(0.007)	-0.007	(0.006)
Number of adults in household	-0.034	(0.047)	-0.027	(0.043)
Grandmother present in household	-0.138	(0.116)	-0.151	(0.106)
Number of children in household	0.048*	(0.028)	0.041	(0.026)
Income	0.003	(0.003)	0.003	(0.003)
Mother completed high school	-0.097	(0.090)	-0.038	(0.085)
Mother attended some college	-0.008	(0.100)	0.127	(0.097)
Mother has bachelor's degree	-0.252	(0.215)	0.023	(0.203)
Medicaid	0.183**	(0.093)	0.154*	(0.085)
Mother religious	-0.016	(0.082)	0.096	(0.079)
Local Characteristics				
Percent Hispanic	0.003	(0.274)	-0.045	(0.247)
Percent black	0.083	(0.200)	0.097	(0.181)
Percent other ethnicity	-0.512	(2.806)	-2.075	(2.552)
Percent foreign-born	0.241	(0.383)	0.737**	(0.366)
Percent with h.s. degree	-0.366	(0.437)	-0.088	(0.407)
Percent unemployed	-0.178	(0.834)	0.074	(0.773)
Percent vacant housing	0.675	(0.603)	0.686	(0.556)
Percent on welfare	0.611	(0.792)	0.107	(0.756)
Tract variables missing	-0.293	(0.498)	0.041	(0.462)
2001 Interview	-0.091	(0.129)	-0.090	(0.112)
Intercept	-1.223**	(0.553)	-1.145**	(0.496)
$\rho(\epsilon_t^a, \epsilon_t^f)$			-0.696	(0.160)
χ_1^2			3.760*	

[a] *** indicates significance at the 1 % level; ** 5%; * 10%.
[b] Standard errors are in parentheses.
[c] χ_1^2 test statistic on formula prices=4.85**.

Table 10: Age One Asthma and Breastfed at Least Six Months (yes/no), full model[a,b,c]

	Probit		***Bivariate Probit***	
Variable	Coeff.	Std. Error	Coeff.	Std. Error
Initial Child Health				
Low birth weight	0.373***	(0.109)	0.400***	(0.107)
Maternal Inputs				
Breastfed for $\geq$ 6 months (y/n)	-0.036	(0.113)	1.033	(0.807)
Child Characteristics				
Child's age, in years	0.158	(0.186)	0.135	(0.180)
Child is male	0.421***	(0.075)	0.403***	(0.075)
Parental Characteristics				
Mother is black	0.229	(0.141)	0.217	(0.137)
Mother is hispanic	0.330**	(0.150)	0.304**	(0.148)
Mother is other ethnicity	0.210	(0.249)	0.162	(0.243)
Mother's age	-0.006	(0.010)	-0.008	(0.009)
Mother married to father	-0.266**	(0.116)	-0.274**	(0.112)
Mother cohabiting with father	-0.209**	(0.091)	-0.202**	(0.089)
Age of Biological Father	-0.009	(0.007)	-0.009	(0.007)
Number of adults in household	-0.033	(0.047)	-0.042	(0.046)
Grandmother present in household	-0.138	(0.116)	-0.104	(0.115)
Number of children in household	0.048*	(0.028)	0.052*	(0.027)
Income	0.003	(0.003)	0.002	(0.003)
Mother completed high school	-0.097	(0.090)	-0.113	(0.088)
Mother attended some college	-0.009	(0.099)	-0.031	(0.097)
Mother has bachelor's degree	-0.252	(0.215)	-0.369*	(0.210)
Medicaid	0.182**	(0.093)	0.189**	(0.090)
Mother religious	-0.016	(0.082)	-0.069	(0.084)
Local Characteristics				
Percent Hispanic	0.004	(0.274)	0.014	(0.267)
Percent black	0.082	(0.200)	0.098	(0.195)
Percent other ethnicity	-0.500	(2.807)	-0.011	(2.756)
Percent foreign-born	0.236	(0.382)	0.123	(0.375)
Percent with h.s. degree	-0.370	(0.436)	-0.359	(0.427)
Percent unemployed	-0.172	(0.834)	-0.419	(0.816)
Percent vacant housing	0.683	(0.604)	0.422	(0.617)
Percent on welfare	0.605	(0.793)	0.889	(0.779)
Tract variables missing	-0.299	(0.498)	-0.305	(0.487)
2001 Interview	-0.092	(0.129)	-0.072	(0.123)
Intercept	-1.224**	(0.553)	-1.150**	(0.539)
$\rho(\epsilon_t^a, \epsilon_t^f)$			-0.537	(0.367)
χ_1^2			1.650	

[a] *** indicates significance at the 1 % level; ** 5%; * 10%.
[b] Standard errors are in parentheses.
[c] χ_1^2 test statistic on formula prices=5.42**.

Table 11: Age Three Asthma and Breastfed (yes/no), full model[a,b,c]

	Probit		***Bivariate Probit***	
Variable	Coeff.	Std. Error	Coeff.	Std. Error
Initial Child Health				
Low birth weight	0.279***	(0.102)	0.299***	(0.096)
Maternal Inputs				
Breastfed (y/n)	0.107	(0.070)	0.514	(0.523)
Child Characteristics				
Child's age, in years	-0.229	(0.206)	-0.227	(0.223)
Child is male	0.307***	(0.066)	0.299***	(0.065)
Parental Characteristics				
Mother is black	0.015	(0.119)	0.057	(0.124)
Mother is hispanic	0.135	(0.127)	0.117	(0.135)
Mother is other ethnicity	0.095	(0.209)	0.088	(0.202)
Mother's age	0.001	(0.009)	0.002	(0.009)
Mother married to father	-0.286***	(0.097)	-0.315***	(0.096)
Mother cohabiting with father	-0.163*	(0.092)	-0.161**	(0.077)
Age of Biological Father	-0.006	(0.007)	-0.006	(0.006)
Number of adults in household	-0.041	(0.048)	-0.042	(0.043)
Grandmother present in household	-0.011	(0.118)	-0.010	(0.102)
Number of children in household	0.029	(0.026)	0.033	(0.025)
Income	0.000	(0.002)	0.000	(0.002)
Mother completed high school	-0.126	(0.082)	-0.135	(0.083)
Mother attended some college	0.031	(0.089)	-0.037	(0.114)
Mother has bachelor's degree	0.024	(0.161)	-0.069	(0.199)
Medicaid	0.161*	(0.083)	0.173**	(0.079)
Mother religious	0.109	(0.069)	0.091	(0.078)
Local Characteristics				
Percent Hispanic	0.374*	(0.237)	0.392*	(0.226)
Percent black	0.288*	(0.171)	0.271	(0.185)
Percent other ethnicity	3.884*	(2.084)	4.172	(3.101)
Percent foreign-born	-0.667*	(0.360)	-0.863*	(0.476)
Percent with h.s. degree	-0.376	(0.393)	-0.470	(0.423)
Percent unemployed	-0.351	(0.793)	-0.432	(0.969)
Percent vacant housing	0.980*	(0.574)	0.954	(0.672)
Percent on welfare	0.010	(0.776)	0.076	(0.994)
Tract variables missing	0.050	(0.409)	-0.049	(0.407)
2001 Interview	0.128	(0.080)	0.144	(0.099)
Intercept	-0.308	(0.733)	-0.430	(0.821)
$\rho(\epsilon_t^a, \epsilon_t^f)$			-0.256	(0.348)
χ_1^2			0.778	

[a] *** indicates significance at the 1 % level; ** 5%; * 10%.
[b] Standard errors are in parentheses.
[c] χ_1^2 test statistic on formula prices=6.04**.

Table 12: Age Three Asthma and Breastfed at Least One Month (yes/no), full model[a,b,c]

	Probit		***Bivariate Probit***	
Variable	Coeff.	Std. Error	Coeff.	Std. Error
Initial Child Health				
Low birthweight	0.282***	(0.102)	0.305***	(0.104)
Maternal Inputs				
Breastfed (y/n)	0.106	(0.070)	0.482	(0.479)
Child Characteristics				
Child's age, in years	-0.234	(0.206)	-0.232	(0.203)
Child is male	0.306***	(0.066)	0.300***	(0.066)
Parental Characteristics				
Mother is black	0.011	(0.119)	0.036	(0.122)
Mother is hispanic	0.124	(0.127)	0.101	(0.130)
Mother is other ethnicity	0.079	(0.210)	0.057	(0.210)
Mother's age	0.001	(0.009)	0.001	(0.009)
Mother married to father	-0.283***	(0.097)	-0.307***	(0.098)
Mother cohabiting with father	-0.162*	(0.092)	-0.159*	(0.091)
Age of Biological Father	-0.006	(0.007)	-0.006	(0.007)
Number of adults in household	-0.042	(0.049)	-0.044	(0.048)
Grandmother present in household	-0.007	(0.118)	-0.003	(0.117)
Number of children in household	0.028	(0.026)	0.028	(0.025)
Income	0.000	(0.002)	0.000	(0.002)
Mother completed high school	-0.124	(0.082)	-0.139*	(0.083)
Mother attended some college	0.030	(0.089)	-0.025	(0.113)
Mother has bachelor's degree	0.016	(0.161)	-0.091	(0.212)
Medicaid	0.156*	(0.083)	0.166**	(0.082)
Mother religious	0.105	(0.069)	0.087	(0.073)
Local Characteristics				
Percent Hispanic	0.435*	(0.249)	0.437*	(0.247)
Percent Black	0.284*	(0.171)	0.269	(0.171)
Percent Other Ethnicity	4.068	(2.102)	4.347**	(2.092)
Percent Foreign Born	-0.733**	(0.370)	-0.886**	(0.409)
Percent with h.s. degree	-0.319	(0.397)	-0.381	(0.399)
Percent Unemployed	-0.337	(0.794)	-0.379	(0.785)
Percent Vacant Housing	1.065*	(0.583)	1.033	(0.579)
Percent on Welfare	0.038*	(0.778)	0.083*	(0.770)
Tract variables missing	0.111	(0.415)	0.042	(0.420)
2001 Interview	0.138*	(0.081)	0.144	(0.081)
Intercept	-1.004	(1.194)	-0.803**	(1.212)
$\rho(\epsilon_t^a, \epsilon_t^f)$			-0.232	(0.294)
χ_1^2			0.580	

[a] *** indicates significance at the 1 % level; ** 5%; * 10%.
[b] Standard errors are in parentheses.
[c] χ_1^2 test statistic on formula prices=3.84**.

Table 13: Age Three Asthma and Breastfed at Least Three Months (yes/no), full model[a,b,c]

	Probit		***Bivariate Probit***	
Variable	Coeff.	Std. Error	Coeff.	Std. Error
Initial Child Health				
Low birth weight	0.278***	(0.102)	0.295***	(0.114)
Maternal Inputs				
Breastfed $\geq$ 3 months(y/n)	0.045	(0.074)	0.236	(0.622)
Child Characteristics				
Child's age, in years	-0.234	(0.206)	-0.236	(0.205)
Child is male	0.309***	(0.066)	0.307***	(0.066)
Parental Characteristics				
Mother is black	0.003	(0.118)	0.007	(0.119)
Mother is hispanic	0.133	(0.127)	0.121	(0.132)
Mother is other ethnicity	0.088	(0.210)	0.080	(0.211)
Mother's age	0.000	(0.009)	0.000	(0.009)
Mother married to father	-0.275***	(0.096)	-0.288**	(0.103)
Mother cohabiting with father	-0.157*	(0.091)	-0.158*	(0.091)
Age of Biological Father	-0.006	(0.007)	-0.006	(0.007)
Number of adults in household	-0.041	(0.048)	-0.041	(0.048)
Grandmother present in household	-0.010	(0.118)	-0.006	(0.119)
Number of children in household	0.028	(0.026)	0.027	(0.026)
Income	0.000	(0.002)	0.000	(0.002)
Mother completed high school	-0.125	(0.082)	-0.131	(0.083)
Mother attended some college	0.043	(0.088)	0.024	(0.108)
Mother has bachelor's degree	0.036	(0.161)	-0.011	(0.221)
Medicaid	0.158*	(0.083)	0.160*	(0.083)
Mother religious	0.113	(0.069)	0.106	(0.073)
Local Characteristics				
Percent Hispanic	0.381	(0.236)	0.394*	(0.239)
Percent black	0.298*	(0.171)	0.295*	(0.171)
Percent other ethnicity	3.794*	(2.084)	3.937*	(2.120)
Percent foreign-born	-0.619*	(0.358)	-0.685*	(0.411)
Percent with h.s. degree	-0.338	(0.392)	-0.353	(0.393)
Percent unemployed	-0.316	(0.793)	-0.320	(0.791)
Percent vacant housing	1.009*	(0.573)	1.002*	(0.573)
Percent on welfare	-0.001	(0.776)	0.030	(0.781)
Tract variables missing	0.094	(0.408)	0.079	(0.409)
2001 Interview	0.122	(0.080)	0.120	(0.080)
Intercept	-0.280	(0.732)	-0.278	(0.730)
$\rho(\epsilon_t^a, \epsilon_t^f)$			-0.114	(0.370)
χ_1^2			0.097	

[a] *** indicates significance at the 1 % level; ** 5%; * 10%.
[b] Standard errors are in parentheses.
[c] χ_1^2 test statistic on formula prices=11.64***.

Table 14: Age Three Asthma and Breastfed at Least Six Months (yes/no), full model[a,b,c]

	Probit		***Bivariate Probit***	
Variable	Coeff.	Std. Error	Coeff.	Std. Error
Initial Child Health				
Low birth weight	0.271***	(0.102)	0.282***	(0.106)
Maternal Inputs				
Breastfed $\geq$ 6 months(y/n)	-0.056	(0.098)	0.202	(0.803)
Child Characteristics				
Child's age, in years	-0.240	(0.206)	-0.241	(0.205)
Child is male	0.310***	(0.066)	0.309***	(0.066)
Parental Characteristics				
Mother is black	-0.001	(0.118)	-0.001	(0.118)
Mother is hispanic	0.135***	(0.127)	0.128	(0.128)
Mother is other ethnicity	0.091*	(0.210)	0.083	(0.211)
Mother's age	0.001	(0.009)	0.000	(0.009)
Mother married to father	-0.272	(0.096)	-0.277***	(0.097)
Mother cohabiting with father	-0.159	(0.091)	-0.159*	(0.091)
Age of Biological Father	-0.005	(0.007)	-0.005	(0.007)
Number of adults in household	-0.038	(0.048)	-0.039	(0.048)
Grandmother present in household	-0.016	(0.118)	-0.013	(0.118)
Number of children in household	0.028	(0.026)	0.028	(0.026)
Income	0.000	(0.002)	0.000	(0.002)
Mother completed high school	-0.121	(0.082)	-0.127	(0.083)
Mother attended some college	0.050	(0.088)	0.041	(0.092)
Mother has bachelor's degree	0.055	(0.161)	0.011	(0.206)
Medicaid	0.158*	(0.083)	0.160*	(0.083)
Mother religious	0.121*	(0.069)	0.113	(0.073)
Local Characteristics				
Percent Hispanic	0.383	(0.236)	0.389*	(0.236)
Percent black	0.306*	(0.170)	0.309*	(0.170)
Percent other ethnicity	3.674*	(2.091)	3.747*	(2.094)
Percent foreign-born	-0.588*	(0.357)	-0.612*	(0.362)
Percent with h.s. degree	-0.325	(0.391)	-0.317	(0.391)
Percent unemployed	-0.304	(0.793)	-0.337	(0.796)
Percent vacant housing	1.022*	(0.572)	0.980*	(0.587)
Percent on welfare	-0.031	(0.777)	0.035	(0.799)
Tract variables missing	0.112	(0.407)	0.121	(0.407)
2001 Interview	0.125	(0.080)	0.117	(0.084)
Intercept	-0.280	(0.732)	-0.273	(0.730)
$\rho(\epsilon_t^a, \epsilon_t^f)$			-0.140	(0.428)
χ_1^2			0.109	

[a] *** indicates significance at the 1 % level; ** 5%; * 10%.
[b] Standard errors are in parentheses.

Table 15: Age One Asthma Diagnosis: 1st Stage Results in Bivariate Probit Models[a,b]

	Breastfed		***Breastfed at least one month***	
Variable	Coeff.	Std. Error	Coeff.	Std. Error
Initial Child Health				
Low birthweight	-0.145	(0.099)	-0.194*	(0.101)
Parental Characteristics				
Mother is black	-0.258**	(0.104)	-0.194*	(0.103)
Mother is hispanic	0.066	(0.113)	0.124	(0.112)
Mother is other ethnicity	0.081	(0.191)	0.226	(0.186)
Mother's age	-0.010	(0.006)	-0.002	(0.006)
Mother married to father	0.214**	(0.089)	0.145*	(0.088)
Mother cohabiting with father	0.012	(0.063)	-0.029	(0.062)
Age of Biological Father	0.002	(0.003)	0.003	(0.003)
Number of adults in household	0.004	(0.040)	0.006	(0.040)
Grandmother present in household	-0.006	(0.096)	-0.057	(0.096)
Number of children in household	-0.039	(0.024)	-0.006	(0.024)
Income	0.008***	(0.002)	0.004**	(0.002)
Mother completed high school	0.052	(0.074)	0.108	(0.075)
Mother attended some college	0.425***	(0.078)	0.381**	(0.077)
Mother has bachelor's degree	0.524***	(0.140)	0.694**	(0.135)
Mother religious	0.261***	(0.065)	0.331**	(0.065)
Medicaid	-0.065	(0.072)	-0.053	(0.071)
Local Characteristics				
Percent Hispanic	0.117	(0.225)	0.021	(0.223)
Percent black	0.135	(0.158)	0.165	(0.159)
Percent other ethnicity	-3.240	(2.139)	-4.283**	(2.180)
Percent foreign-born	1.395***	(0.317)	1.459***	(0.310)
Percent with h.s. degree	1.125***	(0.367)	0.739**	(0.367)
Percent unemployed	1.421*	(0.742)	1.031	(0.747)
Percent vacant housing	0.488	(0.538)	0.286	(0.538)
Percent on welfare	-1.040	(0.725)	-1.050	(0.736)
Tract variables missing	1.304***	(0.403)	0.863**	(0.402)
MSA Formula prices	0.739**	(0.303)	0.552*	(0.296)
2001 Interview	0.096	(0.071)	0.077	(0.071)
Intercept	-2.937***	(0.894)	-2.649	(0.875)

[a] *** indicates significance at the 1 % level; ** 5%; * 10%.
[b] Standard errors are in parentheses.

Table 16: Age One Asthma: 1st Stage Results in Bivariate Probit Models[a,b]

	Breastfed **least three months**		***Breastfed at least six months***	
Variable	Coeff.	Std. Error	Coeff.	Std. Error
Initial Child Health				
Low birthweight	-0.334***	(0.111)	-0.217	(0.139)
Parental Characteristics				
Mother is black	-0.070	(0.106)	0.022	(0.126)
Mother is hispanic	0.125	(0.114)	0.042	(0.135)
Mother is other ethnicity	0.118	(0.172)	0.092	(0.196)
Mother's age	0.010	(0.006)	0.016	(0.007)
Mother married to father	0.174**	(0.089)	0.085**	(0.110)
Mother cohabiting with father	0.026	(0.062)	0.068	(0.081)
Age of Biological Father	0.003	(0.003)	0.001	(0.003)
Number of adults in household	-0.007	(0.041)	0.062	(0.047)
Grandmother present in household	-0.071	(0.101)	-0.155	(0.123)
Number of children in household	-0.004	(0.025)	-0.026	(0.030)
Income	0.001	(0.002)	0.001	(0.002)
Mother completed high school	0.119	(0.080)	0.152	(0.099)
Mother attended some college	0.297***	(0.078)	0.194**	(0.094)
Mother has bachelor's degree	0.610***	(0.129)	0.582***	(0.142)
Mother religious	0.257***	(0.065)	0.329***	(0.074)
Medicaid	0.013	(0.073)	-0.074	(0.085)
Local Characteristics				
Percent Hispanic	0.071	(0.229)	0.229	(0.277)
Percent black	0.113	(0.165)	-0.097	(0.199)
Percent other ethnicity	-3.422	(2.245)	-1.926	(2.604)
Percent foreign-born	1.077	(0.309)	0.432	(0.364)
Percent with h.s. degree	0.602	(0.378)	0.206	(0.466)
Percent unemployed	0.456	(0.780)	1.763*	(0.909)
Percent vacant housing	0.406	(0.563)	1.539**	(0.621)
Percent on welfare	-1.149	(0.775)	-2.137**	(0.965)
Tract variables missing	0.808*	(0.414)	0.227	(0.520)
MSA Formula prices	0.674**	(0.306)	0.869**	(0.373)
2001 Interview	-0.063	(0.073)	-0.196**	(0.090)
Intercept	-3.347***	(0.905)	-4.358***	(1.119)

[a] *** indicates significance at the 1 % level; ** 5%; * 10%.
[b] Standard errors are in parentheses.

Table 17: 1st Stage Results in Bivariate Probit Models: Age Three Asthma[a,b]

	Breastfed		***Breastfed at least one month***	
Variable	Coeff.	Std. Error	Coeff.	Std. Error
Initial Child Health				
Low birthweight	-0.139	(0.098)	-0.181*	(0.099)
Parental Characteristics				
Mother is black	-0.258**	(0.104)	-0.190*	(0.104)
Mother is hispanic	0.072	(0.113)	0.124	(0.111)
Mother is other ethnicity	0.096	(0.196)	0.233	(0.191)
Mother's age	-0.010	(0.006)	-0.003	(0.006)
Mother married to father	0.225**	(0.090)	0.157*	(0.089)
Mother cohabiting with father	0.016	(0.065)	-0.023	(0.065)
Age of Biological Father	0.001	(0.003)	0.002	(0.003)
Number of adults in household	0.003	(0.039)	0.005	(0.039)
Grandmother present in household	-0.021	(0.096)	-0.076	(0.096)
Number of children in household	-0.033	(0.024)	0.002	(0.024)
Income	0.008***	(0.002)	0.005**	(0.002)
Mother completed high school	0.055***	(0.074)	0.109	(0.075)
Mother attended some college	0.420***	(0.078)	0.379***	(0.077)
Mother has bachelor's degree	0.527***	(0.141)	0.700***	(0.136)
Mother religious	0.261***	(0.065)	0.330***	(0.064)
Medicaid	-0.070	(0.071)	-0.057	(0.070)
Local Characteristics				
Percent Hispanic	0.102	(0.224)	0.022	(0.224)
Percent black	0.134	(0.158)	0.156	(0.159)
Percent other ethnicity	-3.421	(2.143)	-4.433**	(2.180)
Percent foreign-born	1.437***	(0.321)	1.498***	(0.313)
Percent with h.s. degree	1.127***	(0.366)	0.795**	(0.367)
Percent unemployed	1.323*	(0.737)	1.006	(0.743)
Percent vacant housing	0.494	(0.531)	0.305	(0.532)
Percent on welfare	-0.867	(0.718)	-0.849	(0.726)
Tract variables missing	1.329***	(0.404)	0.926**	(0.404)
MSA Formula prices	0.755**	(0.307)	0.596**	(0.304)
2001 Interview	0.100	(0.071)	0.077	(0.071)
Intercept	-2.972***	(0.905)	-2.801***	(0.901)
$\rho(\epsilon_t^a, \epsilon_t^f)$			-0.140	(0.428)
χ_1^2			0.109	

[a] *** indicates significance at the 1 % level; ** 5%; * 10%.
[b] Standard errors are in parentheses.

Table 18: 1st Stage Results in Bivariate Probit Models: Age Three Asthma[a,b]

	***Breastfed* at least three months**		***Breastfed at least six months***	
Variable	Coeff.	Std. Error	Coeff.	Std. Error
Initial Child Health				
Low birthweight	-0.303***	(0.109)	-0.260*	(0.036)
Parental Characteristics				
Mother is black	-0.067	(0.107)	0.022	(0.129)
Mother is hispanic	0.121	(0.114)	0.050	(0.135)
Mother is other ethnicity	0.110	(0.178)	0.108	(0.197)
Mother's age	0.009	(0.006)	0.016**	(0.007)
Mother married to father	0.173*	(0.091)	0.099	(0.109)
Mother cohabiting with father	0.039	(0.069)	0.078	(0.083)
Age of Biological Father	0.003	(0.003)	0.000	(0.004)
Number of adults in household	-0.009	(0.041)	0.064	(0.048)
Grandmother present in household	-0.073	(0.103)	-0.176	(0.128)
Number of children in household	0.000	(0.025)	-0.028	(0.032)
Income	0.001	(0.002)	0.001	(0.002)
Mother completed high school	0.116	(0.080)	0.160	(0.100)
Mother attended some college	0.299***	(0.078)	0.180*	(0.094)
Mother has bachelor's degree	0.621***	(0.130)	0.568***	(0.142)
Mother religious	0.260***	(0.066)	0.328***	(0.075)
Medicaid	0.010	(0.073)	-0.076	(0.086)
Local Characteristics				
Percent Hispanic	0.107	(0.232)	0.217	(0.278)
Percent black	0.105	(0.166)	-0.108	(0.200)
Percent other ethnicity	-3.569	(2.283)	-1.785	(2.622)
Percent foreign-born	1.057***	(0.312)	0.386	(0.367)
Percent with h.s. degree	0.695*	(0.387)	0.136	(0.460)
Percent unemployed	0.511	(0.782)	1.633**	(0.909)
Percent vacant housing	0.472	(0.557)	1.499**	(0.636)
Percent on welfare	-0.964	(0.794)	-2.149**	(0.994)
Tract variables missing	0.900**	(0.424)	0.181	(0.517)
MSA Formula prices	0.841***	(0.317)	0.850**	(0.380)
2001 Interview	-0.069	(0.074)	-0.208**	(0.089)
Intercept	-3.846***	(0.943)	-4.228***	(1.130)

[a] *** indicates significance at the 1 % level; ** 5%; * 10%.
[b] Standard errors are in parentheses.

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