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A COST-EFFECTIVENESS ANALYSIS OF STRATEGIES TO REDUCE INFANT MORTALITY

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ABSTRACT

This study compares the cost-effectiveness of various health inputs and government programs in reducing race-specific neonatal mortality or death in the first twenty-seven days of life. Approximately two-thirds of all infant deaths occur within this time period. The programs and inputs at issue are teenage family planning use, the supplemental food program for women, infants and children (WIC), use of community health centers and maternal and infant care projects, abortion, prenatal care, and neonatal intensive care. Using an economic model of the family as the analytical framework, effectiveness is determined by using ordinary least squares and two-stage least squares to estimate infant health production functions across large counties in the U.S. in 1977. Estimates of costs are from a number of published sources. We find the early initiation of prenatal care to be the most cost-effective means of reducing the neonatal mortality rate for black and whites. Moreover, blacks benefit more per dollar of input use than whites. Neonatal intensive care, although the most effective means of reducing neonatal mortality rates, is one of the least cost-effective strategies.

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I. Introduction

Despite the rapid decline in infant mortality rates between 1964 and 1983**, large cross-sectional differences in infant mortality persist. The most notable of these is the excess death rate of black babies. The black infant mortality rate was twice as large as the white rate both in 1964 and in 1983. In addition, the U.S. infant mortality rate remains relatively higher than those of a number of other developed countries even when the U.S. rate is limited to whites.[1,2]

These statistics imply that there is room for improved birth outcomes in the U.S., especially for blacks, but also for whites. The most recent evidence, however, suggests a deceleration in the downward trend in mortality rates.*** The purpose of this paper is to examine which health policies and programs have the potential to be the most cost effective in improving U.S. birth outcomes. We consider the benefits in terms of infants lives saved and costs in terms of the expanded utilization of various health inputs and government programs. The former include prenatal care, neonatal intensive care and abortion; the latter include the following Federally subsidized initiatives: family planning clinics, community health centers, maternal infant care projects, and the Special Supplemental Food Program for Women, Infants and Children (WIC).

The policy evaluations in this paper are based on our recently completed research project on the determinants of race-specific neonatal mortality rates (deaths of infants within the first 27 days of life per thousand births) across large counties in the U.S in 1977.[3,4,5] These results are combined with cost data from a variety of sources to compare the cost effectiveness of alternative intervention strategies.

Our paper is unique because we examine a range of programs in one analytic framework and cover almost the entire U.S. population empirically. Other excellent cost-effectiveness studies examine only one medical input.[6,7,8] A drawback of such a broad scope is the use of aggregate data and the potential for ecological fallacy, a form of specification error arising from omitted variables related to the grouping process. To minimize the potential bias we use only large counties and we examine black and whites separately. Moreover, we directly test for misspecification in our aggregate model; when present, we employ a two-stage-least-squares estimation procedure to reduce the bias.

II. Effectiveness

In this section, we describe the basis for our calculations of the effects of health policies and programs on improved birth outcomes. The calculations are derived from previous results by the authors.[3,4,5] For a fuller description of the analytic framework, specifications, variables and results, the reader should refer to those papers. Our analysis is based on a widely used economic model of the family[9,10,3,4,5] which results in the following equations to be estimated using a multiple regression analysis:

$$d = f_1(n,m,a,f,c,w,b,e) \quad (1)$$

$$b = f_2(m,a,f,c,w,s,r,g,e) \quad (2)$$

$$g = f_3(m,a,f,c,w,s,r,e) \quad (3)$$

$$r = f_4(a,c,x,e) \quad (4)$$

$$(n,m,a,f,c,s) = f_j(p,y,x,e) \quad j = 5...10$$

The probability that an infant's health deteriorates to the point that he or she does not survive the first month of life is represented by equation (1). Equations (2) and (3) give the likelihood that a newborn is of low weight (less than 2500 grams or 5.5 lbs) or preterm, (less than 37 weeks gestation) respectively. The basic set of inputs used in the production of infant health are neonatal intensive care (n), prenatal care (m), abortion (a), organized family planning use (f), BCHS project use (c), WIC (w), and smoking (s). The other variables are (r), a vector of endogenous risk factors such as age, marital status, parity, and spacing between births; (x), a demographic measure that determines the age of a mother at the time of birth; and (e), the unobserved health endowment. Equations (1)-(4) are considered "production functions" because they relate output to utilization of inputs. Equations (5) - (10) are input demand functions because they relate use of a health input to price and availability (p), income constraints (y) and other factors.

The empirical focus of this paper is restricted to the estimation of equation (1). The coefficients from this estimated equation represent the direct effect of an input on early infant survival -- that is, the impact on neonatal mortality holding birthweight constant. However, all the inputs except for neonatal intensive care may also affect neonatal mortality indirectly through their impact on birthweight. In order to measure the indirect effects of the health inputs, we replace birthweight in equation (1) by its determinants. Specifically, we substitute recursively equation (4) into equation (3), equation (3) into equation (2), and equation (2) into equation (1) which yields the following:

$$d = f_{11}(n,m,a,f,c,w,s,x,e) \quad (11)$$

Equation (11) allows us to estimate the total effect (both direct and indirect) of each of the health inputs. The estimation of equations (1) and (11) is the basis of the estimates of the effectiveness of each of the health inputs in reducing neonatal mortality.

Since the quality of the results depends on the quality of the estimation, much care was given to the choice of the unit of observation, the exact specification of each of the variables and the functional form. Ours is a cross-sectional regression analysis of differences in race-specific neonatal mortality rates among U.S. counties in 1977. Counties are our unit of observation since they are the smallest geographic units for which aggregate national data are available. Regressions are run separately for blacks and whites. We attenuate random elements by including only large counties -- counties with at least 50,000 persons in 1970, and for black regressions, at least 5,000 blacks. The 677 counties included for whites and 357 counties for blacks account for about 80 percent of the white and black populations in the U.S. in 1970.

Table 1 contains definitions, means, and standard deviations of the variables used in this study. The key inputs at issue in this paper are prenatal care, abortion, organized family planning clinic services, maternal and infant care (M and I) projects, community health centers (CHCs), WIC, and neonatal intensive care. All of these measures are expected to have negative regression coefficients in the neonatal mortality rate production function. Additonal risk factors such as smoking and women in

Table 1

Definitions of Variables[a]

Variable Name	Definition
Neonatal Mortality*	Three-year average neonatal mortality rate centered on 1977; deaths of infants less than 28 days old per 1,000 live births (μ_w = 8.837, σ_w = 1.595, μ_b = 16.387, σ_b = 3.299)
Low Birth Weight*	Three-year average percentage of low-birth weight (2,500 grams or less) live births centered on 1977 (μ_w = 5.992, σ_w = .741, μ_b = 13.016, σ_b = 1.228)
Prenatal Care*	Three-year average percentage of live births for which prenatal care began in the first trimester (first three months) of pregnancy centered on 1977 (μ_w = 78.111, σ_w = 8.290, μ_b = 59.359, σ_b = 10.236)
Abortion	Three-year average state-specific resident abortion rate centered on 1976; abortions performed on state residents per 1,000 women aged 15-44 in the state (μ_w = 24.969, σ_w = 8.716, μ_b = 24.754, σ_b = 8.603)
Teen Family Planning*[b+]	Percentage of women aged 15-19 with family income less than 200 percent of the poverty level in 1975 who use organized family planning services in 1975 (μ_w = 9.067, σ_w = 6.290, μ_b = 24.176, σ_b = 9.656)
BCHS Projects[c+]	Sum of maternity patients in maternal and infant care (M and I) projects and female users aged 15-44 of community health centers (CHCs) in 1976 per 1,000 women aged 15-44 with family income less than 200 percent of the poverty level in 1975; numerator termed Bureau of Community Health Services (BCHS) female project users (μ_w = 10.770, σ_w = 48.149, μ_b = 30.777, σ_b = 69.440)
WIC (Maternal Nutrition Program)+	State-specific number of eligible pregnant women served by the Special Supplemental Food Program for Women, Infants, and Children (WIC program) per 1,000 state-specific eligible women in 1980 (μ_w = 70.836, σ_w = 33.111, μ_b = 147.825, σ_b = 51.259)
Neonatal Intensive Care[c++]	Sum of state-specific hospital inpatient days in Level II, or Level III, or Levels II and III neonatal intensive care units in 1979 per state-specific three-year average number of low-birth weight births centered on 1977 (μ_w = .641, σ_w = .385, μ_b = 1.501, σ_b = 1.011)

(continued on next page)

Table 1 (concluded)

Variable Name	Definition
Smoking	State-specific daily number of cigarettes smoked per adult 18 years and older in 1976 (μ_w = 7.416, σ_w = .511, μ_b = 7.486, σ_b = .351)
High Risk Women*[b]	Number of women 15-19 and 40-44 as a fraction of women 15-44 in 1975 (μ_w = .335, σ_w = .022, μ_b = .350, σ_b = .026)

[a]An asterisk (*) next to a variable means that it is race-specific. All variables are county-specific unless otherwise indicated.

[b]Variable is available for whites and nonwhites as opposed to whites and blacks.

[c]Since numerator of this variable is not race-specific, denominator also is not race-specific.

+These variables were interacted with race-specific fraction of women 15-44 with family income less than 200 percent of the poverty level in 1980 (μ_w = .266, μ_b = .549). Given means denote interacted variable.

++This variable was interacted with the low birthweight variable. Again, given means are for interacted variable.

high-risk age groups are expected to have positive coefficients.

We used teenage family planning use for several reasons. First, only for teens was this variable available on a race-specific basis. Second, research indicates that family planning services by teenagers may have larger impacts on neonatal mortality than use of these services by older women.[5,11] Our smoking variable refers to both sexes because age- and sex-specific aggregate data were not available.

To reflect the fact that government health inputs are designed to be used by poor women, we defined our variables in a special manner. First, the denominators of family planning, BCHS Project use and WIC are poor women, since this is the appropriate pool of potential users. Second, since the government programs will be more effective the greater the incidence of poverty in a county, we "interacted" each of the three variables with the percent poor women. For similar reasons, NICU use is divided by low birthweight births and "interacted" with percent of births which are less than 2500 grams. Fortunately, this does not result in high correlations among the government program variables -- the highest simple r is .30 between family planning and BCHS Project use for whites. Also, even though NICU use is interacted with low birthweight, and low birthweight is a separate variable, the simple r between the two variables is only .10 for whites and .05 for blacks. It should be noted that in regressions using other specifications of the variables than those presented, the ranking of the input effectiveness is stable.

The production functions were estimated by least squares (OLS) and two-stage least squares (TSLS). We use TSLS to correct for the potential downward biases of OLS.[10] In particular, mothers with poor endowed reproductive capability may attempt to lower the likelihood of an unfavorable birth outcome by utilizing more health inputs. Thus, the use of the inputs not only affects the outcome, but the anticipated outcome may also affect utilization. Because of this reverse causality, TSLS is used to obtain unbiased and consistent estimates.

We test for the significance of the correlation between the error term and the health inputs, using Wu's statistical test.[12] If the null hypothesis of zero correlation is not rejected, then OLS is an appropriate technique. Since Wu's test is a general test of misspecification, it should signal the presence of cross-level bias and thus, lessen the risk of ecological fallacy.[#] We originally ran regressions using three different functional forms: linear, log-linear and logistic transformation of the dependent variable. Since results were similar for all three, we present the most easily interpreted -- the linear form.

For the first stage of our two-stage estimation procedure, birth weight, prenatal care, abortion, and neonatal intensive care use are predicted on the basis of female schooling, female poverty levels, the fraction of high-risk women, neonatal intensive care availability, BCHS project availability, and the Medicaid program. Predicted values of these four endogenous variables are then entered into the neonatal mortality equations. The public program input measures are all treated as exogenous for reasons spelled out in Corman, Joyce, and Grossman.[2]

Regression results are presented in Table 2. There are two specifications for each race; each specification is estimated by OLS and TSLS. The

Table 2

Regression Results[a]

	Whites				Blacks			
	A1	A2	A3	A4	B1	B2	B3	B4
	OLS	TSLS	OLS	TSLS	OLS	TSLS	OLS	TSLS
	(Total Effect)		(Direct Effect)		(Total Effect)		(Direct Effect)	
Constant	7.478	9.831	7.223	5.512	17.913	24.929	4.647	8.600
	(4.98)	(5.60)	(7.24)	(1.78)	(2.97)	(3.60)	(1.87)	(1.04)
Teen Family Planning*	-.021	-.011	-.025	-.014	-.024	-.025	-.029	-.024
	(-2.01)	(-1.03)	(-2.64)	(-1.32)	(-1.26)	(-1.27)	(-1.66)	(-1.37)
Maternal Nutrition Program (WIC)*	-.002	-.006	-.002	-.004	-.004	-.009	-.001	-.008
	(-.78)	(-2.34)	(-1.12)	(-1.46)	(-.99)	(-2.19)	(-.44)	(-2.06)
Neonatal Intensive Care*[b]	-.096	-.467	-.219	-1.176	-.306	-.475	-.356	-.772
	(-.63)	(-.93)	(-1.48)	(-2.26)	(-1.73)	(-.89)	(-2.22)	(-1.60)
Abortion[b]	-.029	-.033	-.025	-.021	-.044	-.085	-.030	-.044
	(-4.19)	(-3.57)	(-3.72)	(-2.13)	(-1.53)	(-2.01)	(-1.51)	(-1.58)
Prenatal Care*[b]	-.045	-.076	-.024	-.016	-.030	-.117	-.008	-.026
	(-5.40)	(-5.14)	(-2.99)	(-.79)	(-1.69)	(-2.81)	(-.49)	(-.56)
BCHS Projects*	.0003	-.0002	-.002	-.001	-.002	-.001	-.006	-.002
	(.23)	(-.13)	(-1.96)	(-.82)	(-.77)	(-.42)	(-2.37)	(-.96)
Smoking[b]	.535	.555			.600	1.045		
	(4.65)	(4.76)			(1.06)	(1.86)		
High Risk Women*	5.843	7.366			-4.263	-13.138		
	(2.05)	(2.50)			(-.52)	(-1.33)		
Low Birth Weight*[b]			.781	1.046			1.121	1.026
			(9.50)	(3.78)			(8.39)	(2.18)
R^2	.108		.184		.036		.195	
F	10.16[c]	9.78[c]	21.51[c]	9.35[c]	1.64[e]	2.66[c]	12.05[c]	3.55[c]
WU test F	2.61[d]		1.57[e]		3.86[c]		.19[e]	

[a]Asymptotic t-ratios in parentheses. The critical t-ratios at the 5 percent level are 1.64 for a one-tailed test and 1.96 for a two-tailed test. An asterisk next to a variable means it is race-specific.

[b]Endogenous in TSLS equations.

[c]Significant at the 1 percent level.

[d]Significant at the 5 percent level.

[e]Not significant at the 5 percent level.

first specification excludes low birth weight and thus measures the total effect of an input on neonatal mortality (regressions A1, A2, B1, B2). The second specification measures the direct effect (regressions A3, A4, B3, B4).

As indicated by their F-values, seven of the eight equations are statistically significant at the one percent level. Altogether, the model works well in predicting variations in neonatal mortality rates based on medical program usage.[##] The coefficient of determination, however, never exceeds .20 for both blacks and whites. By estimating race-specific equations we have removed the most powerful determinant of newborn survival among counties of the U.S. Put differently, a single equation predicting neonatal mortality with the percentage black in a county as a regressor would most likely have yielded higher R^2's.

In all regressions, the coefficients show the effect on neonatal mortality rates of a one unit increase in the variable. For example, in the case of whites, equation (A1) indicates that a one percentage point increase in the percent of births in which prenatal care began in the first trimester results in a reduction of .045 neonatal deaths per 1,000 live births. This can easily be converted to express the number of neonatal deaths averted by having 1,000 additional women begin care in the first trimester (in this case 4.5). Analogously, the other coefficients can be so interpreted to yield measures of effectiveness that are used in cost-effectiveness calculations described in Section III.

III. Cost-Effectiveness Procedure

This section presents estimates of the cost-effectiveness of the various programs and inputs discussed above. Effectiveness is measured by two birth outcomes: the number of additional neonatal deaths averted and the number of additional low birth weight births averted per 1,000 additional program and input users. Costs refer to the expense of increasing utilization of each program and input also by 1,000 users. The latter figure divided by the former yields the cost of preventing a neonatal death or low-birth weight birth.

We chose a cost-effectiveness approach as opposed to a cost/benefit analysis because the estimation and information requirements of the latter were beyond the scope of our study. For instance, estimating the benefits of averting a neonatal death or low-birth weight birth are fraught with problems. The former necessitates that we estimate the value of a life. Even with low birth weight, estimates of the costs for long-term morbidity vary a great deal.[7] We felt that the advantage of our work lay with its multivariate comparison of various programs. Since reductions in the neonatal mortality rate and the percentage of low-birth weight births are stated policy objectives[14], the relative effectiveness of each program as it pertains to these clear-cut goals should be very useful.

Tables 3 and 4 present high and low cost-effectiveness estimates for white and black neonatal deaths and low birth weight births respectively. The cost-effectiveness figures for each program vary depending on whether the impact coefficients were estimated by OLS or TSLS. Although we provide a conceptual as well as statistical justification for the use of TSLS, the latter estimates have larger standard errors and are more sensitive to

Table 3

Estimates of Cost-Effectiveness--Neonatal Mortality[a]

Program	Lives saved per 1000 additional participants High (1)	Lives saved per 1000 additional participants Low (2)	Cost per additional 1000 participants (in thousands) (3)	Cost per life saved ($1984) (in thousands)[b] High (4)	Cost per life saved ($1984) (in thousands)[b] Low (5)
Whites					
Teen Family Planning*	.8	.6	122	203	160
WIC*	3.7	1.2	145	118	39
Neonatal Intensive Care*	15.3	2.8	13,616	4,778	890
Abortion	2.1	1.9	356	191	169
Prenatal Care*	7.6	4.5	176	39	23
BCHS Project Use*	.1	.1	146	2,281	1,123
Blacks					
Teen Family Planning*	1.1	.9	122	130	107
WIC*	6.9	3.1	145	47	21
Neonatal Intensive Care*	10.0	4.6	13,616	2,940	1,361
Abortion	7.6	4.0	356	90	45
Prenatal Care*	11.7	3.0	187	62	16
BCHS Project Use*	.5	0	146	--	270

Notes to Table 4

[a] An asterisk (*) next to a variable means that it is race-specific

[b] The high estimate is obtained by dividing column (3) by column (2); for the low estimate column (3) is divided by column (1). Due to rounding the estimates of cost-effectiveness may differ slightly than if calculated directly from the table.

Table 4

Estimates of Cost-Effectiveness--Low Birth Weight[a]

Program	Low birth-weight births averted per 1000 additional participants High (1)	Low (2)	Cost per additional 1000 participants ($ in thousands) (3)	Cost per low-birth weight birth averted ($1984) High (4)	Low (5)
			Whites		
Teen Family Planning*	0	0	$ 122	0	0
WIC*	30.5	0	145	---	4.7
Abortion	6.4	3.2	356	111.2	55.6
Prenatal Care*	66.0	27.0	176	6.5	3.2
BCHS Project Use*	0	0	146	0	0
			Blacks		
Teen Family Planning*	0	0	$ 122	0	0
WIC*	53.3	23.1	145	6.3	2.6
Abortion	44.0	12.5	356	28.4	8.1
Prenatal Care*	97.0	20.0	187	9.4	1.9
BCHS Project Use*	0	0	146	0	0

Notes to Table 4

[a] An asterisk (*) next to a variable means that it is race-specific

[b] The high estimate is obtained by dividing column (3) by column (2); for the low estimate column (3) is divided by column (1). Due to rounding the estimates of cost-effectiveness may differ slightly than if calculated directly from the table.

changes in specification than are the OLS estimates. Moreover, to the extent that the OLS estimates are biased downwards in absolute value,[10,4] they may be considered conservative or lower bound estimates of a program's effectiveness.

The cost figures (Column 3 in each table) are from a variety of sources which are discussed below. The costs reflect only those expenses associated with utilization of the programs or inputs. The costs of attracting more women to enroll in WIC, family planning clinics, BCHS projects, etc. are not included. If a dramatic increase in utilization became a policy objective, these outreach costs could be substantial. It should also be noted that all costs are in 1984 dollars. When necessary, the cost estimates obtained from the various sources are inflated by the Medical Component of the Consumer Price Index to reflect 1984 prices. In the case of WIC, the Food and Beverage Component of the CPI is used instead.

To estimate the cost of prenatal care, we compute the cost of having all women initiate care in the first trimester using the procedure in Joyce, Grossman and Goldman.[15] For women in our sample, some initiated care in the first trimester, some initiated in the second, some initiated in the third and some received no prenatal care. For those who initiated prenatal care in the first trimester, the (additional) cost is zero. For those who initiated in the second and third trimesters, they must obtain an additional three and six physician visits, respectively. Those who received no care must obtain 12 visits, the first being a lengthier (and more expensive) examination. The final estimate is an average of the four groups, weighted by the fraction of women in each group. Costs of a visit include the payment to the physician, transportation costs plus time costs of travel and waiting. This gives a total cost in 1984 dollars of $176 and $187 for whites and blacks, respectively.

The Institute of Medicine[7] estimated the cost of initial hospitalization in a Level II or Level III neonatal intensive care unit to be $13,616 in 1984 dollars. This assumed the average length of stay was thirteen days. Because our measure of effectiveness is neonatal mortality, we did not include the costs of rehospitalization under the assumption that the majority of these expenses would be incurred after the first month of life.

Figures for the cost of services provided by organized family planning clinics are obtained from the Alan Guttmacher Institute. Total state and federal expenditures for family planning clinics in 1980 ($401,147,000) were divided by the number of users in that year (4,644,000). This yielded an average cost of $122 per user when adjusted for 1984 prices.[16] Fuchs and Perreault[17] estimated the average cost of an abortion as $307 in 1982 dollars. Schramm[8] estimates the cost per WIC mother calculated from redeemed food vouchers in 1980. A twenty percent administrative overhead charge is added to the cost of food. He reports an average cost of $122 per recipient in 1980 dollars. Finally, the cost of BCHS project use is from Goldman and Grossman.[18] They estimated the average total medical care cost per encounter in a community health center to be $28.67 in 1978 dollars. There were 21,285 encounters per center per year with an average of 7,187 users per center. Hence, the average cost per user was $84.90 [($28.67x21,283)/7,187]. When adjusted to reflect 1984 prices, this figure became $146.###

The number of neonatal deaths averted per 1,000 additional program participants (Table 3, Column 1) is derived from the regression results presented in Table 2. Except neonatal intensive care, the low estimates are from the coefficients estimated by OLS in equations A1 and B1, the specification excluding low birth weight. The high estimates are based on the coefficients generated by TSLS except in the case of family planning and BCHS project use. Contrary to expectations, these latter two inputs had their greatest impact on neonatal mortality in specifications that included low birth weight. That is, the direct effect exceeded the total effect.

The number of additional low birth weight births prevented per 1,000 additional users (Table 4, Columns 1 and 2) represents the indirect effect of a program on neonatal mortality. These estimates are obtained by subtracting the direct effect of an input on neonatal mortality from its total effect and dividing by the coefficient for low birth weight. In other words, separate regressions with the percentage of low-birth weight births as the dependent variable were not fitted to arrive at these estimates. Results in which a subset of these inputs were regressed on the percentage of low-birth weights and preterm births can be found in Joyce.[5]

IV. Results

Among the six inputs examined in Table 3, initiation of prenatal care in the first trimester is the most cost-effective way to prevent white neonatal deaths. With respect to blacks, prenatal care ranks second to WIC when the lower-bound estimate is used and first when using less conservative estimates. With few exceptions, WIC is the second most cost-effective program, regardless of race, followed by abortion, family planning, BCHS project use, and neonatal intensive care.

The same pattern of cost-effectiveness exists with respect to low birth weight (Table 4). Prenatal care is the most cost-effective input for whites and blacks based on upper bound estimates, but it is eclipsed by WIC when more conservative estimates are used in the case of blacks. Results for teenage family planning use and BCHS project use are set to zero since these programs are found to have an (unexpected) positive indirect effect on low birth weight.

With but one exception, all the programs are more cost-effective for blacks than whites. This is an important finding given the racial differences in adverse birth outcomes. It is also worth noting that the measure of effectiveness employed in this study is rather narrow. The benefits to women and adolescents from avoiding an unwanted birth or pregnancy can be substantial, as discussed by Burt.[19] In other words, the costs of unhealthy babies go well beyond the first month of life.

Although we did not attempt a cost-benefits analysis, the Institute of Medicine (1985) provides figures for the first-year average cost of a low-birth weight birth. This cost consists of three components: the expense of initial hospitalization in Level II or Level III neonatal intensive care unit; the cost of rehospitalization; and the long-term, single year cost of long-term morbidity. Using this figure, $14,799, as an estimate of the benefits of averting a low-birth weight birth, the benefit/cost ratio for each program with respect to this outcome can be calculated by dividing the Institute of Medicine's estimate by the cost-effectiveness figures in

Column 3. As can be seen, prenatal care has a benefit/cost ratio well in excess of one regardless of which estimates are used.

A striking result in Table 3 is the cost-effectiveness of early prenatal care relative to neonatal intensive care. This results holds even if the conservative estimate of prenatal care's cost-effectiveness (Column 4) is compared to the upper-bound estimate for neonatal intensive care (Column 5). It should also be noted that in making this comparison, neonatal intensive care is three times more effective than prenatal care in averting neonatal deaths (Columns 1 and 2). The difference in cost-effectiveness, therefore, resides with the dramatic discrepancy in cost. If the cost estimates are accepted as reasonable, then attempts to explain the difference must look more closely at these measures of program use.

For example, neonatal intensive care is a relatively specific measure of medical intervention. Moreover, it represents but one aspect of "high-tech" perinatal care. Thus, the inclusion of other measures of high-quality perinatal care might lessen the impact of prenatal care relative to neonatal intensive care if the former is more highly correlated to these other perinatal inputs than the latter. Put differently, women who receive early prenatal care are more likely to receive higher quality perinatal care than those who start prenatal care later in their pregnancies.

Along similar lines, the percentage of women who initiate prenatal care in the first trimester may proxy a cohort of pregnant women for whom early prenatal care is but one aspect of healthy behavior. These women may eat more nutritiously, suffer less stress, and be less likely to smoke, use alcohol, or take drugs. Except for smoking, we are unable to control for these other factors. It should also be noted that our measure of smoking is neither race- nor sex-specific. Hence, if these other behaviors are more responsible for the association between early care and healthy birth outcomes, then a program to initiate first-trimester prenatal care among "high-risk" women may have less impact than reported here.

Finally, this study uses aggregate data and as a result has to rely on broad measures of program use. There is also a degree of overlap between some of the programs.[9] Moreover, this study is intended to complement the findings from micro studies with more refined measures of medical intervention. The advantage of our data is that they reflect the outcome of approximately eighty percent of all the U.S. births between 1976 and 1978. Further, what should not be overlooked is that our results with respect to the impact of prenatal care are in general agreement with the findings of the Institute of Medicine (1985) which summarized hundreds of studies.

In conclusion, therefore, it is highly improbable that neonatal intensive care is more cost-effective than prenatal care. The magnitude of the cost difference could not be overcome unless the effectiveness of prenatal care were reduced essentially to zero. Even if neonatal intensive care were interpreted more broadly to include other advances in perinatal care (e.g., ultra sonography and fetal monitoring), the same could be done for prenatal care by including WIC and other prenatal interventions. Moreover, some infant health analysts have argued that the application of neonatal intensive care may have reached the point of severely diminished returns.[2] Not only will such care become more expensive when utilized in more marginal cases, but its impact on neonatal mortality should also decline. In short, for the U.S. to maintain the rate of decline in neonatal mortality that it has enjoyed over the past 20 years, more attention will have to be focused on reducing the incidence of low birth weight. Our results show that prenatal interventions such as early care and supplemental food programs are relatively cost-effective.

Another result relevant to infant health policy in the U.S. is that with minor exceptions the programs and health inputs are more cost effective for blacks than whites. Thus, funds spent on program expansion and increased input utilization should lessen the difference in adverse birth outcomes between black and whites. It should be stressed, however, that our results are based on two closely related assumptions: first, that increased funding would increase the utilization of these inputs and not simply their availability; and second, that the costs of expanding utilization are similar to existing average costs. Both these assumptions point to the importance of outreach. Efforts to enhance the number of family planning clinics, BCHS projects or WIC coupons may yield disappointing results unless steps are taken to insure that the targeted population makes use of these resources. Such efforts could alter the second assumption. That is, contacting high-risk women may require more creative, but more costly, means of outreach than the estimated costs employed in this study.

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Endnotes

**The infant mortality rate declined by 4.3 percent per year between 1964 and 1983, reaching a level of 11.2 deaths per thousand live births in the latter year.

***Infant mortality fell by only 3.0 percent per year between 1981 and 1983 and by only 2.6 percent per year between 1982 and 1983.

#A major source of bias in ecological studies arises when individuals are grouped by a risk factor that is excluded from the analysis.[13] It is probably safe to assume that poor women from central-city, urban counties are more likely to experience less favorable birth outcomes than their suburban counterparts due in part to a host of unobservables ranging from stress and pollution to weaker reproductive capability. We have referred to these unobserved factors as the women's health endowment. The TSLS procedure is an attempt to lessen the bias generated by these county-specific characteristics by regressing the utilization of each input on a set of socioeconomic variables and availability measures and using the predicted values in the structural equations. TSLS may not be necessary in the specifications that include low birth weight since it is the most important risk factor associated with neonatal survival.

##According to the Wu test, we do not reject the null hypothesis of zero correlation between the error term and health inputs for both blacks and whites when estimating equations (A3) and (B3). That is, in equations holding birth weight constant, OLS is found to be appropriate. For equations (A1) and (B1), the Wu test results in statistically significant correlations [F=2.61 (p.<.05) and F=3.86 (p<.01), respectively] indicating biased results in the OLS specifications without birth weight.

###Data were not available on the cost per type of service at a BCHS project. Consequently, this figure is a rather gross estimate of both prenatal and perinatal care. However, this figure is not out of line with the estimate obtained for prenatal care reported above. Given that many BCHS project users are from disadvantaged households, initiation of prenatal care is likely to be later, on average, than the more national estimates used above. As such, this figure should underestimate the incremental cost of having all BCHS project users begin prenatal care in the first trimester. At the same time, this variable refers to project use by all women ages 15-44 as opposed to only pregnant women of the same age. Thus, the effectiveness of this input may also be understated. In sum, the biases from underestimating both cost and effectiveness may offset each other to some degree.

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