Empirical Analyses

Socioeconomic Gradients and Low Birth-Weight: Empirical and Policy Considerations

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Objective. To examine whether socioeconomic status (SES) gradients emerge in health outcomes as early as birth and to examine the magnitude, potential sources, and explanations of any observed SES gradients.

Data Sources. The National Maternal and Infant Health Survey conducted in 1988.

Study Design. A multinomial logistic regression of trichotomized birth-weight categories was conducted for normal birth-weight (2,500–5,500 grams), low birth-weight (LBWT; $<2,500$ grams), and heavy birth-weight ($>5,500$ grams). Key variables included income, education, occupational grade, state-level income inequality, and length of participation in Women-Infants-Children (WIC) for pregnant mothers.

Principal Findings. A socioeconomic gradient for low birth-weight was discovered for an adjusted household income measure, net of all covariates in the unrestricted models. A gross effect of maternal education was explained by maternal smoking behaviors, while no effect of occupational grade was observed, net of household income. There were no significant state-level income inequality effects (Gini coefficient) for any of the models. In addition, participation in WIC was discovered to substantially flatten income gradients for short-term participants and virtually eliminate an income gradient among long-term participants.

Conclusions. Although a materialist explanation for early-life SES gradients seems the most plausible (vis-à-vis psychosocial and occupational explanations), more research is needed to discover potential interventions. In addition, the notion of a monotonic gradient in which income is salutary across the full range of the distribution is challenged by these data such that income may cease to be beneficial after a given threshold. Finally, the success of WIC participation in flattening SES gradients argues for either: (a) the experimental efficacy of WIC, or (b) the biasing selection characteristics of WIC participants; either conclusion suggests that interventions or characteristics of participants deserves further study as a potential remedy for socioeconomic disparities in early-life health outcomes such as LBWT.

Key Words. Socioeconomic status gradients, low birth-weight

Disparities have been a puzzling fact of life for the health of populations in most developed countries whose death rates are driven by chronic, rather than infectious disease. In the United States, health disparities by race/ethnic group and socioeconomic status (SES) are a burgeoning aspect of health outcomes and health services research. These disparities are not reducible to behavioral differences between populations (Williams and Collins 1995) and are even found to manifest themselves early in life (House and Williams 2000). For example, large birth-weight disparities between black and white infants have been observed over the past 30 years and evidence indicates that this gap is not narrowing (James 1993; Shiono et al. 1997). Paradoxically, disparities between Hispanic and white infants are virtually nonexistent in spite of the disadvantaged socioeconomic position among Hispanic mothers. In addition, some of the largest birth-weight disparities exist between the poor and nonpoor in the United States (Kramer et al. 2000). While these patterns are also generally observed for adult health and mortality, it has been further argued that health benefits accrue along the entire socioeconomic gradient such that even the very rich are healthier than the slightly less rich (Marmot, Kogevinas, and Elston 1987).

The consideration of low birth-weight (LBWT) as a particularly important health outcome is crucial for several well-established reasons. First, LBWT is highly associated with the risk of infant mortality, particularly in the neonatal period (Gortmaker and Wise 1997). Second, LBWT infants are at higher risk for several crucial developmental and health outcomes including cognitive development (Hack, Klein, and Taylor 1995), school difficulty and hyperactivity (McCormick, Gortmaker, and Sobol 1990), and a higher prevalence of respiratory distress and asthma (Boardman, Finch, and Hummer 2001)—just to select a few. In addition it has been argued and documented that the disadvantages of adverse birth outcomes such as LBWT persist into late adolescence and adulthood (Elo and Preston 1992; Barker 1995; Boardman et al. 2002). Due to the potential for prenatal intervention that is both politically feasible/desirable and due to the potential to avert adverse health and developmental consequences across the life-course—the study of LBWT and its potential linkage with socioeconomic disparities across the gradient is crucial. To continue to treat birth outcomes as a "poverty" problem may lead to inappropriate or misdirected interventions if, in fact, birth outcome disparities exist across a gradient.

Recent research has argued that the shape of the relationship between SES and health is actually curvilinear such that there are decreasing returns to

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health as SES increases (Backlund, Sorlie, and Johnson 1996; Ecob and Davey Smith 1999). Although SES is not a theoretically nuanced concept in the social sciences and generally represents whatever it is that we are measuring—it is clear that the various measures of SES have a relationship with health, and although the mediating (proximate) causes for health differentials and the actual health outcomes themselves may change over time, the fundamental relationship between SES and health persists across various outcomes and behaviors (Link and Phelan 1995).

What is not so clear is the exact shape or even the presence of a graded relationship between SES and birth outcomes. In general, most studies have addressed these problems as they relate to adults in whom direction of causality may be difficult to disentangle (Deaton 2002). Only a handful of studies have specifically addressed whether socioeconomic gradients for health exist among adolescents (see, e.g., Goodman 1999; Brooks-Gunn, Duncan, and Britto 1999; Case, Lubotsky, and Paxson 2002) and three recent studies have indirectly addressed the presence or absence of these gradients among infants (Conley and Bennett 2000, 2002; Finch 2004). On the other hand, a recent review of child and adolescent health outcomes and behaviors suggests that while there are certainly socioeconomic differentials in health during early-life, gradients may emerge as early as birth (Chen, Matthews, and Boyce 2002).

Research Questions

In light of the importance of birth outcomes and the potential applicability of the SES gradient, this study seeks to answer four general questions: (1) Is there a graded relationship between SES and the probability of LBWT? (2) What is the shape of any relationship between SES and LBWT and what are the implications for theory and health policy? (3) What are some of the potential mediators between any SES-LBWT relationships and do known interventions account for any observed gradients? (4) Among the competing hypotheses that explain the gradient, which explanations are most relevant for explaining the transmission of socioeconomic privilege in families to advantaged birth-weight status among infants?

SES-Health Gradient

As mentioned above, only two studies in the United States have documented whether SES disparities in children's health are similar to those observed among adults. In one study, SES gradients for both education and income were discovered for self-rated health, depression, and obesity—only income was related to attempted suicide (Goodman 1999). In the other, large gradients were found between income and verbal ability, moderate relationships between income and socioeconomic achievement (e.g., completing high school, job status, earnings) and between income and stunting and fighting behaviors, and no effects for a host of other developmental outcomes such as obesity, anxiety, hyperactivity, and self-reported grades (Brooks-Gunn, Duncan, and Britto 1999). One recent paper investigated the presence of income gradients for low-birth-weight status in an ongoing panel study (Conley and Bennett 2000); the authors found no income or education effects on the probability of LBWT among infants, net of parental birth-weight (BWT).

Therefore, in the absence of a significant amount of data, it remains possible that birth outcome differentials exhibit a purely threshold effect and that the high rates of LBWT are peculiar to those living in poverty. The observed gradients among adults could be due to either a social hierarchy effect that is not manifested until individuals at least partly determine their own health or due to accumulations of poverty effects over the life-course that begin to exhibit a gradient nature in adulthood. However, the presence of moderate SES/health gradients during adolescence suggests that gradients in the United States may exist even as early as birth (Chen, Matthews, and Boyce 2002). Further, since gradients are observed for the health of women, it is entirely likely that these gradients are translated into infant health.

Since adult health differentials are not simply peculiar to poverty, many hypotheses have been offered to explain the presence of SES gradients. An early hypothesis offered by Wilkinson (1996) suggested that SES gradients were simply markers for one's position on a social hierarchy; this would explain why average income explained little of international health differentials while the levels of inequality in a country were highly predictive of these differentials. Although Wilkinson recognized that the shape of the income–health relationship was curvilinear (Wilkinson 1996), he still argued that the psychosocial effects of social hierarchies—marked by distributions of income inequality and mediated by stress processes—were the most important determinants of health inequalities within countries (Marmot and Wilkinson 2001).

In a slight revision of this hypothesis, Marmot argues that income gradients are actually proxies for occupational gradients and controlling for occupational grade will reduce income–health relationships to statistical nonsignificance (Marmot 2002). Marmot offers an explanation for these occupationally driven gradient effects as being the result of the ability to control one's destiny that also exists along a continuum. Both of these positions rely heavily on psychosocial determinants and stress processes as the mediating factors between SES and health relationships while simultaneously recognizing the importance—but not the primacy—of absolute material standards in maintaining health. Log-linear income gradients are generally the empirical marker for these hypothesized relationships.

More recently, materialist arguments have been offered by empirically demonstrating that not only are there diminishing health returns to income, but that these returns flatten out and sometimes decline at the far-right of the income distribution. Proponents of the material conditions hypothesis argue that income is an important indicator of health in and of itself, not simply because it is a proxy for other hierarchies; the presence of a declining/zero relationship at higher incomes indicates that status hierarchies may be playing a secondary role to material conditions (Ecob and Davey Smith 1999; Lynch and Kaplan 2000; Davey Smith 1997), but nonetheless may play a significant role.

METHODS

The dataset chosen for these analyses is the National Maternal and Infant Health Survey (NMIHS) conducted in the United States in 1988 (National Center for Health Statistics 1991). This dataset contains a unique combination of vital records information (i.e., birth and death certificates) and survey data that are combined as a sample of nationally representative births among women in 1988 (Sanderson, Placek, and Keppel 1991). Most of the variables related to birth outcomes, length of gestation, and birth-weight, for instance, are obtained from birth certificate records. Due to a purposive oversampling strategy, the probability of selection of live births was 1 of every 354, and for infant deaths, 1 of every 6 (Sanderson, Placek, and Keppel 1991). The NMIHS contains oversamples of black infants and low- and very low birth-weight infants.

The NMIHS was conducted using a complex sampling design that oversampled for low BWT and black infants; therefore, in order to avoid biasing effects, the use of design effects adjusted models are appropriate. All models specified in these analyses use the *svy* estimation techniques from *STATA* 7.0 to apply appropriate weights and to adjust for the sampling effects

(STATA 2001). The following cases are excluded from the analyses: women who are not white, black, or Hispanic, multiple births; extraordinarily low birth-weight infants (less than 500 grams); very high BWT infants (more than 8,165 grams); infants less than 22 weeks of gestation; and infants for whom gestational age is unknown.

Dependent Variable. The dependent variable is a trichotomized indicator of birth-weight and includes: (1) normal BWT (2,500–5,500 g), (2) low BWT ($<$2,500 g), and high BWT ($>$5,500 g); a multinomial logistic regression model (Long 1997) is specified for this regression in which normal BWT serves as the reference category and high and low BWT (LBWT) as the effect categories. High BWTs are separated from the normal BWT range due to known elevated risks for subsequent health and mortality. However, since the focus of this analysis is on the risks for LBWT, only these results are presented although the statistical models do simultaneously estimate the effects of heavy birth-weight. Rather than simply exclude the high-BWT cases from analysis, they are included in the multinomial logistic regression models to improve efficiency of the estimates (Agresti 1990).

Independent Variables. The first key independent variable was a measure of total household income that is adjusted for nonincome payments such as SSI, food stamps, and AFDC. This variable was measured in the year prior to giving birth and therefore (theoretically) includes the three months prior to pregnancy as well as the approximately nine months of gestation. In addition to including nonwage income, this measure is adjusted for household size by dividing household income by a size elasticity raised to .38 (Rogers, Hummer, and Nam 2000). Therefore, income in this study is measured as: Income / $(\text{HH Size})^{.38}$; this method assumes diminishing costs for additional family members. However, there are no measures of household debt or wealth and failure to control for wealth and debt could potentially bias the magnitude of the income effects downward.

Most statistical models pay little attention to the functional form of the income–health relationship and as such, the notion that health benefits accrue across the entirety of the gradient are preserved since health is usually modeled as a linear or log-linear function of income. These functions force a monotonic fit of the income/health relationship and do not consider the possibility that health returns to income may cease after a given income threshold, for example. For this reason, I employ a fractional polynomial regression to consider a range of functional forms for the income/low birth-weight relationship (Royston and Altman 1994). This procedure considers a multiplicity of functional forms of various degrees and allows for a greater flexibility than traditional polynomials that are often limited in their range of curve shapes and that often produce undesirable artifacts ("edge effects" and "waves," e.g.) in curve shapes (STATA 2001).

Starting with a first-order polynomial and proceeding as high as a fifth-order polynomial, it becomes apparent that the although several functional forms can be fit to the data at hand—the general tendency is for the income–BWT gradient to flatten out past a given threshold. Based on this visual criteria as well as *t*-tests for the significance of higher-ordered terms, the best fit for the relationship was a raw income variable plus a cubic transformation of the income variable. A third-order relationship ($Income^{-2}$, Income, and $Income^{2}$) did not improve the fit of the data nor did other higher order terms. Therefore, the income–BWT relationship is modeled as a function of both raw- and cubic-income.

The second key SES variable was operationalized as years of mother's education completed at the time of childbirth; the same process is repeated for father's education. Since education is a precursor to both income levels and occupational attainment, these variables are treated as controls and appear in the model simultaneously with the other SES measures.

The third key socioeconomic variable is *occupational grade* as measured by the Nakao and Treas (1990, 1994) occupational prestige score (NTOP). Rather than being an imputed value (i.e., from the educational and income level of occupational incumbents), this measure uses actual assessments of occupational prestige (OP) for more than 500 occupations using data from respondents to the 1989 General Social Survey. Therefore, occupational prestige is less a measure of occupation and more measure of the social benefits that accrue for occupational incumbency. An independent evaluation of these rankings (Garbin and Bates 1961) noted that rankings of occupational prestige were highly correlated to the following constructs: interesting/challenging work, .90; intelligence required, .90; scarcity of personnel, .90; originality and initiative, .87; influencing others, .86; desirable to associate with, .84; training required, .84; education required, .83; supervisory responsibility, .79; security, .79; income, .78; honorable/morally good work, .75; advancement opportunities, .71; service to humanity, .59; being one's own boss, .57; clean work, .51; dealing with people, not things, .49; flexible hours, .44; safe work, .35; and free time on the job, .15. Although this study is relatively old, it is worth noting that occupational prestige ratings have been one of the most stable social ratings we have over the past five decades, and rankings change *very little* from decade to decade (Nakao and Treas 1994).

Since data are available from both the mother and father of the infants, several different operationalizations of OP were considered, including the mother's only, the father's only, the higher of the two (unless the mother is unmarried or does not work), and an average of the two scores. The highest of the two scores was chosen for the primary analyses although each operationalization is considered, especially as they relate to hypotheses regarding causes of the gradient. Measuring occupational grade by other means, such as the Duncan SEI index for example, yielded less-promising results and did not change the substantive conclusions of this study—therefore, although alternative operationalizations were considered, the NTOP outperformed all the other measures.

The fourth socioeconomic variable is a measure of income inequality at the state level. Although it would seem more desirable to use a more disaggregate level of analysis, confidentiality issues prohibit us from determining anything other than the state of birth among infants. Further, most significant income inequality results in the United States have been observed at the state level (Ellison 2002). Our measure of income inequality is the Gini coefficient that ranges from a score of perfect income *equality* (0) to a score of perfect income *inequality* (100). Internationally, Gini coefficients range as far as 25 in Denmark, Austria, and Belarus to more than 60 in Brazil and Sierra Leone (Ellison 2002). However, within the United States (mean = $\sim$45) our range is attenuated to scores of 38.5–49.2. A state-level Gini coefficient is appended to each mother/infant file in this study. In addition, since average income is negatively correlated with income inequality, a measure of median state household income is included to ensure that any observed effects are truly inequality effects, rather than average state-level income effects.

Sociodemographic characteristics are controlled for including race/ethnicity, parity/age, marital status, and insurance status. Race/ethnicity is a dummy variable representing the race/ethnicity of the mother as black, Hispanic, or white. Parity is operationalized using the Kleinman and Kessel index (1987) and takes into account the interactions between birth order and maternal age, including: first birth, low parity, and high parity. Marital status is a single dummy variable indicating whether a woman is married at the time of birth, and insurance status is represented by three dummy variables including self-pay, Medicaid, and private insurance.

A set of behavioral variables includes participation in Women-Infants-Children (WIC), weight gain during pregnancy, adequacy of prenatal care, and key health behaviors (smoking, drinking, exercise, and vitamin use). Participation in WIC is a dummy variable in the models and short-term WIC participation is any term less than six months while long-term participation is for six months or more. Weight gain during pregnancy calculates the difference between weight in pounds at the time of pregnancy and weight in pounds at the time of childbirth; this variable includes weight gains of: 0–15 pounds (low), 16–40 pounds (normal), and 41+ pounds (high). Prenatal care is measured using Kotelchuck's Adequacy of Prenatal Care Utilization Index (APNCU), a four-category measure that distinguishes the "adequate plus" group of women who record a higher level of care than that recommended by the American College of Obstetrics and Gynecologists (Kotelchuck 1994). This variable includes the following categories of prenatal care: (1) inadequate, (2) intermediate, (3) adequate, and (4) adequate plus. Dummy variables are added to the equations to indicate whether mothers engaged (or failed to engage) in any of the following health behaviors: (1) smoking (any amount), (2) drinking alcohol (average of two times a week or more), (3) no vitamin use, (4) and no exercise.

Two more variables are added to the models including whether or not early delivery was prevented during the pregnancy and the mother's body mass index—operationalized as low (between 9.0 and 19.8), medium (19.8–26), and high (greater than 26). A final control for mother's birth-weight is added that represents a mixture of potentially biological, genetic, and social factors that may have an independent effect on birth outcomes and may be correlated with the income measure. Descriptive characteristics for each of these variables are presented in Table 1.

Statistical models are built hierarchically after specifying the effects of income (model 1), income inequality (model 2), and occupational prestige (model 3)—net of controls for parental education. After simultaneously estimating all of the SES variables (model 4), blocks of variables are then added as: sociodemographics (model 5), behavioral variables (model 6), and pregnancy-related variables (model 7). Finally, interaction effects between WIC participation and income are specified in Model 8.

RESULTS

Income and LBWT. Income has a significant and curvilinear relationship with the probability of LBWT (see model 1, Table 2; and "unadjusted" in Figure 1). Adjusting for other indicators of SES (i.e., education, income inequality, and occupational grade) changes this relationship slightly, but does not account for the relationship (see model 4, Table 2; and "+SES" in Figure 1). On the other

Table 1: Descriptive Statistics

Variable	*N-size (Unweighted)*	*Mean*	*LBWT*	$\rho_{x,lbwt}$
Total	12,814		.0621	
Birth-weight		3374.98		
Income (thousands)		14.08		– .067**
Income^3 (thousands)		11456.92		– .050**
Mom's Education (years)		12.66		– .051**
Dad's Education (years)		12.83		– .049**
NT Occupational Prestige		40.45		– .050**
Income Inequality (Gini)		44.10		.020**
Median State HH Income (thousands)		29.62		– .011**
Race/Ethnicity (White)	5,300		.0491	
Black	6,340	0.16	.1234	
Hispanic	1,174	0.13	.0552	
Parity (First Birth)	5,227		.0699	
Low	5,052	0.44	.0510	
High	2,465	0.14	.0729	
Marital Status (Married)	7,374		.0480	
Unwed	5,440	0.26	.1019	
Payer for Birth (Insurance)	5,931		.0476	
Medicaid	5,314	0.27	.0994	
Self-Pay	1,569	0.13	.0524	
WIC Participation (No)	7,949		.0567	
Short-Term (<6 months)	2,777	0.17	.0778	
Long-Term (6+ months)	2,088	0.13	.0773	
Pregnancy Weight Gain (16–40 lbs.)	3,221		.0561	
0–15 lbs.	7,208	0.13	.1503	
40+lbs.	2,385	0.23	.0322	
Prenatal Care (Adequate)	3,538		.0349	
Inadequate	2,738	0.10	.0881	
Intermediate	1,901	0.17	.0429	
Adequate Plus	4,637	0.32	.0877	
Smoke During Pregnancy (No)	9,545		.1038	
Yes	3,269	0.23	.1038	
Alcohol Use (No)	12,356		.0606	
Yes	458	0.03	.1176	
Vitamin Use (No)	1,725		.0602	
Yes	11,089	0.10	.0780	
Exercise (No)	7,726		.0563	
Yes	5,088	0.57	.0664	
Prevent Early Delivery (No)	8,462		.0457	
Yes	4,352	0.26	.1099	
Body Mass Index (Medium)	7,122		.0552	
Low	3,056	0.24	.0827	
High	2,636	0.18	.0567	
Mom's BWT (Normal)	7,252		.0587	
Mom LBWT	1,300	0.09	.1086	
Mom's BWT (Missing)	4,262	0.27	.0733	

Note: Proportions and % LBWT are presented for categorical variables; means and correlations with LBWT status are presented for continuous variables; *$p<.05$; **$p<.01$

Table 2: Regression of LBWT on SES: Controlling for Sociodemographics, Health Behaviors, Health-Related Variables, and Mother's BWT

Variable	*Model 1*	*Model 2*	*Model 3*	*Model 4*
Income (thousands)	– .0445**			– .0437**
$Income^3$ (thousands)	1.45e–05**			1.42e–05**
Mom's Education (years)	– .0259	– .0529**	– .0486**	– .0244
Dad's Education (years)	– .0166	– .0382**	– .0293†	– .0141
Occupational Grade			– .0067†	– .0014
Income Inequality (Gini)		3.0692		2.0935
Median State HH Income		– 8.86e–06		6.57e–06
Race/Ethnicity (White)				
Black				
Hispanic				
Parity (First Birth)				
Low				
High				
Marital Status (Married)				
Not Married				
Payer (Insurance)				
Medicaid				
Self-Pay				
WIC Participation (No)				
Short-Term				
Long-Term				
Weight Gain (Normal)				
Low				
High				
Prenatal Care (Adequate)				
Inadequate				
Intermediate				
Adequate Plus				
Smoke While Pregnant (No)				
Yes				
Alcohol Use (No)				
Yes				
Vitamin Use (Yes)				
No				
Exercise (Yes)				
No				
Prevent Delivery (No)				
Yes				
Body Mass Index (Medium)				
Low				
High				
Mom LBWT				
Mom's BWT (Missing)				

continued

Table 2: *Continued*

Variable	*Model 1*	*Model 2*	*Model 3*	*Model 4*
Constant	– 1.6536	– 2.7799	– 1.4554	– 2.6686
Wald Chi-Square (*df*)	152.83 (8)	72.23 (8)	73.49 (6)	156.77 (14)
N-size	12,814	12,814	12,814	12,814

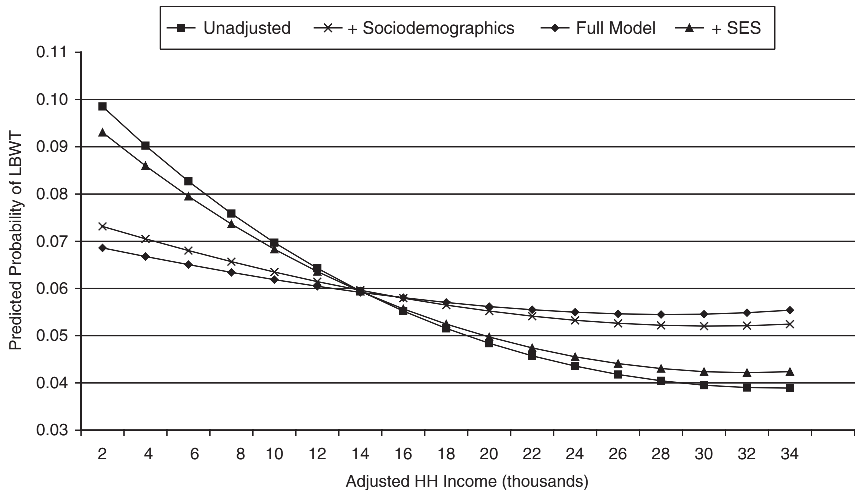
Variable	*Model 5*	*Model 6*	*Model 7*	*Model 8*
Income (thousands)	– .0142*	– .0162*	– .0144*	– .0267**
Income^3 (thousands)	5.80e–06*	6.66e–06*	5.99e–06*	9.23e–06**
Mom's Education (years)	– .0363*	– .0282	– .0182	– .0435
Dad's Education (years)	– .0284†	– .0068	– .0131	– .0241
Occupational Grade	.0033	.0031	.0025	.0030
Income Inequality (Gini)	– .1876	– .2348	– 1.1432	– .6191
Median State HH Income	3.75e–06	– 1.14e-05	– 5.14e-08	– 6.38e–06
Race/Ethnicity (White)				
Black	.6712**	.7162**	.7359**	.6788**
Hispanic	– .1512	.0372	.1469	– .0886
Parity (First Birth)				
Low	– .2539**	– .4276**	– .4133**	– .2611**
High	– .2113†	– .4293**	– .3856**	– .1853**
Marital Status (Married)				
Not Married	.2444	.2357	.1796	.2861
Payer (Insurance)				
Medicaid	.2516**	.3433**	.3037**	.3720**
Self-Pay	– .1033	– .0666	– .0833	– .0645
WIC Participation (No)				
Short-Term		– .3723**	– .4109**	– .5891**
Long-Term		– .4469**	– .4521**	– .7133**
Weight Gain (Normal)				
Low		.8394**	.9429**	
High		– .7231**	– .7907**	
Prenatal Care (Adequate)				
Inadequate		.2655**	.2806**	
Intermediate		– .1246	– .1119	
Adequate Plus		.6946**	.6288**	
Smoke While Pregnant (No)				
Yes		.7489**	.6997**	
Alcohol Use (No)				
Yes		.4002*	.5264**	
Vitamin Use (Yes)				
No		.0403	.0738	
Exercise (Yes)				
No		.2160**	.2444**	
Prevent Delivery (No)				
Yes			.9048**	
Body Mass Index (Medium)				
Low			.4379**	
High			– .2969**	

Table 2: *Continued*

Variable	*Model 5*	*Model 6*	*Model 7*	*Model 8*
Mom LBWT			.5371**	
Mom's BWT (Missing)			.2406**	
Interaction Terms				
Short-Term WIC*Income				.0173†
Long-Term WIC*Income				.0299*
Constant	– 1.9995	– 2.6331	– 2.9419	– 1.5713
Wald Chi-Square (*df*)	566.24 (28)	1056.28 (50)	1227.98 (60)	761.30 (42)
N-size	12,814	12,814	12,814	12,814

Note: †$p<.10$, *$p<.05$, **$p<.01$; Normal BWT is the reference category—high BWT results are modeled simultaneously to improve efficiency of the estimates, but results are not presented.

Figure 1: Predicted Probabilities for LBWT by Income: Separate Unadjusted and Adjusted Models



Note: Predicted values are plotted between the 10th and 90th percentiles of the income distribution.

hand, adjusting for sociodemographic characteristics (model 5, Table 2; and "+sociodemographics" in Figure 1) accounts for a larger proportion of this relationship. Much of this explained effect is due to adding controls for race/ethnicity and maternal parity (age/birth-order interactions). On the other hand, failing to control for prenatal behaviors actually suppressed this relationship in previous models (compare model 5 with model 6, table 2)—much of this suppression was due to failure to control for participation in WIC since most of the WIC participants are low-income women who may be observed to have given birth to fewer LBWT infants in spite of their low incomes. Finally, a further portion of the income–LBWT relationship is accounted for by the pregnancy/health-related variables and birth-weight inheritance in particular (model 7, Table 2; and "full model" in Figure 1).

It is difficult to assess the actual percentage of the gross income/low birth-weight relationship that is accounted for by each of the control variables, given that the nonlinearity of the income/low birth-weight relationship changes as variables are added to the model. However, Figure 1 gives a brief graphical summary of the magnitude of explanation/mediation of each of the variables added to the model. In sum, the income relationship is not fully "explained" by variables that control or mediate the income–LBWT relationship. The final model does not necessarily represent the "true" (or net) income effect given that many of the mediating/control variables may also be dependent upon income. However, the results indicate that there *is* a net effect of income that is independent of many of the more proximal causes of LBWT—or that income was not fully "explained" due to measurement error in the control variables or failure to observe and include all relevant explanatory variables.

Occupational Grade and LBWT. Occupation grade has a marginally significant effect on the probability of being born LBWT (model 3, Table 2) although this effect works largely through improved income status within families (model 4, Table 2). More theoretically important, however, is the observation that occupational grade does not explain the observed income effects as hypothesized by Marmot. Although occupational grade is highly correlated with family income ($r = .44$ in this sample), there are no independent effects of social status that affect the probability of an infant being born LBWT and the absolute material conditions seem to overwhelm the social status components of the gross occupational grade effects observed in model 3 (Table 2).

Income Inequality and LBWT. There are no significant effects of state-level income inequality on the probability of LBWT, neither net of median levels of state income (model 2, Table 2) nor is there a gross effect (not shown). In light of this finding, many different operationalizations of income inequality were considered—although not all are shown here—including: the relative income hypothesis, the relative position hypothesis, and the income inequality hypothesis demonstrated here by the Gini coefficient (Wagstaff and van Doorslaer 2000). However, none of these indicators of income inequality yielded significant state-level effects on the LBWT models.

Finally, given the efficacious results of WIC participation found in previous studies (see Moss and Carver 1998, e.g.) as well as in this one, interaction terms between short-term and long-term WIC participation were specified with the first-order (raw) income variable (see model 8, Table 2). The results indicate that short-term WIC participation flattens the income/LBWT gradient—although marginally significantly so—while long-term WIC participation considerably (and significantly) flattens out the income gradient. Given that WIC is a means-tested program requiring both income and nutritional deficiencies for qualification, plotting income only among those for whom it is plausible to have received WIC (observations with incomes below the 50th percentile) may indicate that WIC has the ability to partially stave off the deleterious effects of poverty on LBWT. This interaction indicates the gradient is steepest (i.e., disparities are largest) among the poor and near-poor who did not participate in WIC and virtually nonexistent among those who did participate in WIC.

Discussion and Conclusions

One of the most important processes that may determine an infant's chance of survival is birth-weight; birth-weight also has important implications for a child's future health, development, and socioeconomic attainment. Birth-weight is heavily linked to neonatal mortality although the fact that rates of LBWT have remained relatively steady over the past few decades while the rates of NM have steadily declined argue for the increasing role that neonatal intensive care unit (NICU) technologies have played in saving babies of extremely LBWT (Gortmaker and Wise 1997). The evidence presented here may inform debates as to what the proper policies for rectifying inequalities might be—assuming of course that rectifying inequalities is an important policy goal and that these policies do not directly "take health away" from more advantaged populations.

In addition, the use of intergenerational relationships between familial SES and infant health outcomes eliminates some of the potential "reverse causation" that may be playing a role in the SES–health relationships. While poor child health may affect a family's income, it is a tough argument to make that an unborn infant's health will affect a family's SES, although it may affect a mother's ability to work as far along into the pregnancy as she may like if pregnancy complications are detected early. Regardless, these reverse effects seem to be much less harmful to arguments for causation than those among adults.

Relationships between income and health have been documented for several years; however, only recently has it been argued that these relationships are not peculiar to poverty but rather exist along a continuum of material advantage. In empirical investigations of adult health, this linear gradient has been modified to be a curvilinear association with decreasing marginal returns to each additional dollar earned. This has important policy implications in that progressive redistribution would help those more at the bottom of the distribution than it would harm those at the top—thus improving population health on the whole. This relationship assumes that the added costs of redistribution will not lead to an equal health gain and health loss. These data indicate that a similar curvilinear relationship exists for infants such that income above a given threshold may no longer be salutary.

Most recent empirical investigations between income and health, this included, have noted a curvilinear relationship; however, the choice of functional form may have serious implications for the conclusions drawn and policy advocated. The two most popular forms, a natural log conversion of income and a quadratic term for income (simultaneously estimated with a linear term) may yield different results. For example, a log-linear specification necessitates diminishing returns to each added dollar but a constant increase in health along the distribution of income. On the other hand, a quadratic specification necessitates a minimum/maximum to the curve, at which point the relationship begins to reverse itself. Assuming a prior relationship between income and health generally guides the choice of the functional form of income and therefore guides our interpretation of the gradient. Specifications that assume a monotonic relationship between SES and health presuppose the notion of an ever-beneficial gradient.

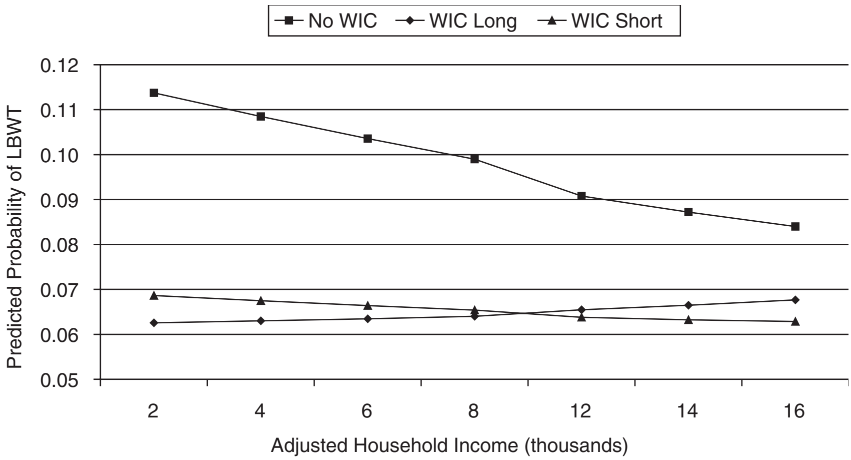
More explicitly, the notion that income is salutary across the full range of the distribution is challenged by these empirical models that do not a priori assume a monotonic relationship between income and health. Plotting income within the 10th and 90th percentiles of the sample distribution in Figure 1 show that the effect of income levels out at higher incomes. Employing a fractional polynomial approach indicates that while a log-linear income specification is the best first-order fit for the income–LBWT relationship, higher-order terms demonstrate that the true (population-level) relationship may be one in which there are no longer returns to income past a given point in the distribution (see Figure 3). In addition, the log-linear specification underestimates the deleterious effects of poverty as shown by the gentler curve at lower incomes. On the other hand, the fractional polynomials fit the data better and demonstrate a steeper gradient in poverty and a nonmonotonic effect across the gradient such that income is no longer beneficial past a given point.

While the fractional polynomial regression approach may not provide a definitive answer as to what the true population-level relationship looks like—it is important in redefining the notion of the gradient that formerly has been dominated by monotonic relationships between SES and health. Theoretical descriptions of the gradient may help to advance our understanding of relationships between social conditions and health in general and the notion of a gradient in particular. It is also worth noting that conditioning the results on gestational age indicates that the largest driving factor behind the observed gradients are low birth-weight infants born prior to term.

More importantly, perhaps, than the actual shape of these distributions for understanding the mechanisms that link SES to LBWT across this observed continuum is the empirical results for the income-inequality and occupational-grade hypotheses. The results here are conclusive in that while there are marginally significant (gross) effects of occupational grade on LBWT, these effects are largely accounted for by higher incomes among the higher grades; conversely, occupational grade does not explain the observed income gradient as Marmot has hypothesized. Further, there are no state-level effects of income inequality on LBWT in any of our models. The shape of the gradient plus the empirical tests conducted here lend support to the material conditions hypothesis; that is, although psychosocial variables may be important in creating SES gradients, the bulk of the relationships are due to the material conditions associated with wealth and material inputs.

One further way to consider the plausibility of the material conditions hypothesis may be to look at interventions that would mimic material inputs to a pregnancy; one obvious example is participation in the WIC program. The WIC foods and information are supplied to low-income families ostensibly to compensate for nutritional deficiencies among the most deprived mothers. The results here corroborate results found elsewhere that participation in WIC is beneficial for birth outcomes; in fact, longer-term participation is more salutary than short-term participation (although long-term participation may be correlated with first trimester participation which may further be correlated with more crucial fetal development stages). Therefore, an obvious question arises: Can WIC overcome the income gradient differentials observed in these models? Model 8 in table 2 interacts household income with WIC

Figure 2: Predicted Probabilities for LBWT (held at averages) for Income *WIC Participation Interaction

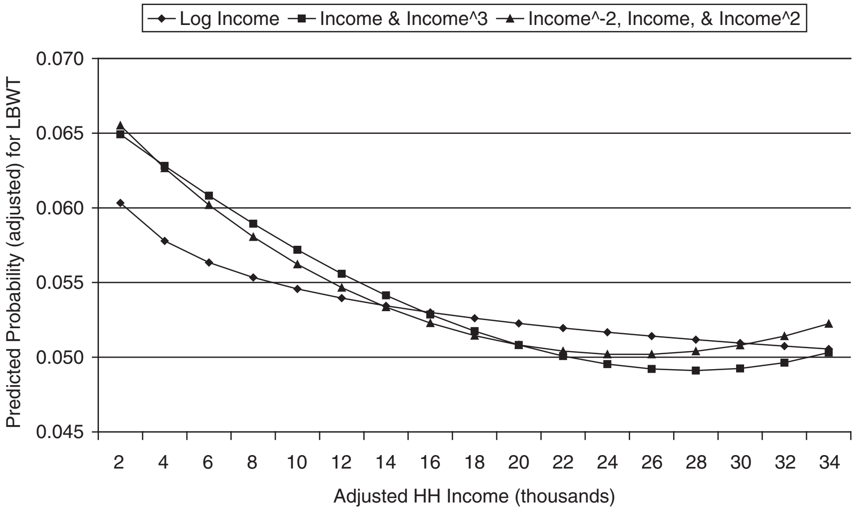


Note: Interactions are considered only for lower incomes (i.e., those more likely to have participated in WIC).

participation in a limited model and the results are plotted in Figure 2. The results here suggest that short-term WIC participation substantively reduces income gradients although this effect is statistically marginal ($p < .10$). On the other hand, long-term WIC participation virtually flattens out the gradient and elevates low-income participants to a level of health virtually equivalent with the more wealthy women/infants in our sample.

Two questions immediately arise, however. (1) Are the effects of WIC purely material or does some aspect of social support arise that allows women to stave off the deleterious psychosocial stressors of their low statuses? The data here cannot answer this. (2) Are participants in WIC simply self-selecting themselves according to some unobserved characteristics and therefore these women (although poor) might also have had healthy weight babies independent of their WIC participation. While the endogeneity of WIC participation has been empirically uncovered (see, e.g., Brien and Swann 2001), there is some evidence in support of the efficacy of WIC participation, independent of self-selection biases (see, e.g., Kowaleski-Jones and Duncan 2000). In addition, the NMIHS data suggest that WIC participants are clearly in higher-risk categories than nonparticipants (since WIC is a means-tested program) but that for other than prenatal care (which may be one result to

Figure 3: Fractional Polynomial Regression Results of Alternate Specifications of Income



Note: Predicted values are plotted between the 10th and 90th percentiles of the income distribution.

WIC participation), long-term WIC participants are in higher-risk categories than short-term WIC participants (see Table 3).

Clearly, further consideration of the ability of WIC to partially eliminate income gradients and the self-selective characteristics of WIC participants to stave off the generally harmful effects of low-income are worthy of further attention.

In sum, these data suggest that not only does an intergenerational transfer of social privilege occur from families to babies, but that this transfer occurs along a curvilinear income hierarchy. Although these data do not definitively support or deny the curvilinear/threshold gradient shape, whether or not income has no added health benefit beyond a given level is still an important substantive question worth considering; the shape of the polynomial relationships observed for these birth outcomes does suggest that this shape is plausible. Further, social status gradients do not explain away income effects as other researchers have found among truncated adult populations. It may be that prestige per se is not an adequate proxy for occupational grade, but it is worth noting that even composite measures such

Table 3: Selected Characteristics of WIC Participants

Receive WIC	*% Smoked*	*% Inadequate Prenatal Care*	*Weight Gain (lbs.)*	*% on Welfare*	*% in Poverty (100% Level)*	*Average HH Income (Thousands)*	*Average Education (Years)*
No	19.92	07.87	31.42	07.69	12.48	21.95	13.23
Short-Term	25.96	22.01	31.11	43.68	55.00	8.17	11.30
Long-Term	35.91	08.26	31.53	50.46	58.84	7.23	11.29

as the Duncan SEI (Hauser and Warren 1997) do not explain away the income effects. Also, while health behaviors are extraordinarily important (substance use in particular), they do not explain away the whole of the predicted income effects. In conclusion, there is additional evidence here that the relationship between SES and health is causal, that the relationship is largely due to material circumstances of infants (although some psychosocial effects are clearly at play), and that potential interventions at the individual level may be effective—even interventions that fall short of major structural changes in income distribution patterns.

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