Biology as Destiny? Short- and Long-Run Determinants of Intergenerational Transmission of Birth Weight

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We use a unique data set of California births to ask whether intergenerational correlations in health contribute to the perpetuation of economic status. We find that if a mother was low birth weight, her child is significantly more likely to be low birth weight, even when we compare mothers who are sisters. Second, the intergenerational transmission of low birth weight is stronger for mothers in high poverty zip codes. Third, low birth weight affects proxies for later socioeconomic status. Fourth, these effects are stronger for women born in high poverty zip codes.

I. Introduction

Intergenerational correlations in socioeconomic status capture an important dimension of inequality. We want to know not only what fraction of the population is poor but also whether the children of the poor are destined for a life of misery. Most people find inequality less pernicious

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when it is not passed on from generation to generation. But while the literature on intergenerational correlations in economic status has made important strides in measurement, less is known about the mechanisms underlying the transfer of economic status between generations. Given the importance of "health capital" for education and earnings, one possibility is that poor health in childhood is an important mechanism for intergenerational transmission of economic status (Currie and Madrian 1999; Case, Fertig, and Paxson 2003).[1]

The goal of this article is to measure intergenerational transmission in health at birth and to see how it is related to intergenerational correlations in socioeconomic status (SES). We measure health at birth using birth weight, a key indicator of the health of newborns that has been linked to future educational attainment and earnings. We address three questions about intergenerational transmissions in birth weight. First, how large are they and to what extent do simple correlations reflect unmeasured parental characteristics (such as persistent poverty)? That is, do intergenerational correlations in low birth weight merely reflect intergenerational correlations in poverty?

Second, does low birth weight (birth weight less than 2,500 grams) predict lower future economic status? If it does, then it is possible that the intergenerational transmission of low birth weight contributes to the intergenerational transmission of income rather than vice versa. Third, does the strength of intergenerational transmission vary across SES groups? A significant interaction between SES and low birth weight would suggest that the poor are at increased risk of any negative effects of low birth weight which would speed intergenerational transmission.

To get at these questions, we have assembled a unique data set based on California birth certificates. We use confidential information about names and birth dates to link the birth records of mothers to the birth records of their children. This data set represents one of the first large-scale attempts to link siblings (i.e., across deliveries to the same mother) and generations (grandmothers, mothers, and children). It has three important features. First, it allows us to identify mothers who are siblings.

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[1] Eriksson, Bratsberg, and Raaum (2005) show that adding measures of the adult child's health status to a typical Solon model of intergenerational correlations in earnings reduces the estimated transmission of earnings by about a quarter, but although they show that children of poor parents are more likely to have adult health problems, they do not explicitly examine the intergenerational transmission of health conditions.

This is important because we can compare birth outcomes of children born to mothers who are sisters, thus accounting for many important genetic and environmental factors that are common within a family tree. Second, we have created two measures of the mother's socioeconomic status, one measured at the time of her own birth and one measured at the time of her child's birth. The former measure allows us to see whether there are long-lasting effects of birth SES, while the second measure allows us to capture the effect of current conditions. Third, the data set is large, allowing for higher precision than smaller data sets like the Panel Study of Income Dynamics or the British Cohort Studies.

We find that the probability that a child is low birth weight is almost 50% higher if her mother is low birth weight. This remains true when we compare mothers who are sisters and, therefore, share similar genetic material and some environmental factors. It is also true if we control for proxies for income or poverty levels in the mother's zip code of residence at the time of her own birth, suggesting that the correlation is not driven merely by intergenerational correlations in maternal economic status. Low SES also has an independent effect on the probability of low birth weight, increasing it about 6% relative to the baseline.

Second, we find that being born with low birth weight has significant effects on later socioeconomic achievement. In particular, after conditioning on grandmother fixed effects, we find that having been born with low birth weight is associated with a 4% higher probability of living in a poor area at the time of the delivery of one's own child, and with the loss of about a tenth of a year of education.

Third, we find that the intergenerational transmission of low birth weight is somewhat stronger for mothers who live in high poverty zip codes. The effect of low birth weight on later income and education is also stronger for women who are born in poverty. These findings suggest that the long-run effects of a bad health shock early in life are more severe for mothers who come from more disadvantaged backgrounds. Poverty not only increases the risk of bad health outcomes later in life, but it also strengthens the long-run negative effects of early health shocks.

Together with our previous findings that mother's SES affects birth outcomes (Currie and Moretti 2003), our findings suggest that some of the intergenerational transmission of economic status could be due to intergenerational transmission of low birth weight. If we consider that low birth weight is an imperfect measure of health at birth and that poor children's health tends to deteriorate relative to the health of other children as they age (Case, Lubotsky, and Paxson 2002; Currie and Stabile 2003), then our results suggest that poor health in childhood could be implicated in the intergenerational transmission of poverty. That is, children born to poor adults are more likely to have health problems, and this in turn makes it likely that they will be poor when they bear their own children.

The rest of the article lays out some background regarding the importance of birth weight, previous work on intergenerational correlations, and possible mechanisms in Section II. Section III provides an overview of the data. Section IV discusses our empirical methods. Results are in Section V. Section VI concludes.

II. Background

A. The Importance of Birth Weight

Low birth weight has been used as the leading indicator of poor health among newborns for many years. In 1996, the infant mortality rate for babies over 2,500 grams was 2.77 compared to 17.45 for babies between 1,500 and 2,500 grams, and 259.35 for babies less than 1,500 grams (Conley and Bennett 2001). Follow ups indicate that low birth weight babies have lower scores on a variety of tests of intellectual and social development (Breslau et al. 1994; Brooks-Gunn, Klebanov, and Duncan 1996). Currie and Hyson (1996) find that low birth weight was predictive of lower schooling attainments, earnings, and employment probabilities as of age 33, regardless of the parents' socioeconomic status. Using twins data, Behrman and Rosenzweig (2001) find that the higher birth weight twin is not only taller but also goes on to get more schooling. However, their sample is quite small, and they do not investigate the question of how SES interacts with low birth weight in the production of child outcomes. Conley and Bennett (2000) find that low birth weight reduces the probability of high school graduation in models that include mother fixed effects.

While there is broad agreement that low birth weight is a marker for poor infant health, Almond, Chay, and Lee (2005) question whether low birth weight per se has a major causal influence on health. It is possible that other factors that are correlated with birth weight, including genes, specific health problems, and/or socioeconomic factors, that are responsible for the high death rates and other adverse outcomes among low birth weight infants. In our context, we cannot use alternative measures such as APGAR scores to examine intergenerational correlations in health at birth because they were not routinely reported until 1989. Indeed, birth weight is one of the few measures of child health that has been recorded over a long period of time.

Nevertheless, several recent studies confirm that low birth weight is associated with poorer child outcomes (Black, Devereux, and Salvanes 2005; Royer 2005; Oreopoulos et al. 2006). For our purposes, what is important is that low birth weight be a meaningful predictor of future outcomes. We demonstrate below that among mothers born into the same family, those with lower birth weights were more likely to be residing in a low income/high poverty zip code and have less education than their sisters when they gave birth to their own children many years later. Thus, we also find that low birth weight is a meaningful predictor of future socioeconomic status in our data.

B. Intergenerational Correlations in Birth Weight

There are several studies that document intergenerational correlations in birth weight. Emanuel et al. (1992) document a positive association between infant birth weight and parent birth weight. They also find that the social class of the maternal grandparents had an independent effect, but they do not examine interactions. One caveat to the Emanuel et al. study is that because of the survey design, all of the births in this study had occurred to mothers by age 23. Coutinho, David, and Collins (1997) use Illinois vital statistics records to show that there is an intergenerational correlation in birth weight.[2]

A handful of studies look at intergenerational correlations in birth weight and ask whether the mother's socioeconomic status at the time of the child's birth can explain the observed correlations. Conley and Bennett (2000) document that income during pregnancy has no effect on the risk of low birth weight when the mother's birth weight is controlled or when family fixed effects are included in the model. However, Conley and Bennett (2001) also estimate models with mother fixed effects and find that if the mother was low birth weight, then income at the time of the birth has a significant impact on the probability that the child is low birth weight. In contrast, we find significant interactive effects of income in the entire sample, which may be due to our larger sample size.

Conley and Bennett (2001) suggest that there is an interaction between poverty at the time of the child's birth and maternal low birth weight in the production of child low birth weight. But their results cannot be regarded as definitive given the very small sample sizes in the PSID. The models for children of low birth weight parents include only 179 children, and only a subset of these would have been born to mothers who experienced a sizable change in income between births. We investigate these issues using a much larger sample. We also improve on previous studies by including grandmother fixed effects (in order to control for a wide range of background factors within families) and by measuring the moth-

[2] Collins, Wu, and David (2002) use the same data to examine correlations in birth weight among U.S.-born and foreign-born white and black women. They document a general increase in average birth weights across generations among native-born women. However, among black immigrant women the pattern was the reverse—black immigrant women have babies of higher birth weight than their native-born daughters. The rapid improvement of birth weight over time and the differential intergenerational trends suggest that environmental factors are important, but these factors are not directly measured.

er's SES using income at the time of her own birth as well as at the time of the child's birth.

Among the existing studies, Royer (2005) is closest to our study. Using restricted California natality data for the entire 1960–82 period, Royer is able to identify 3,000 maternal twin pairs. She compares the children of the twins and examines the intergenerational transmission of low birth weight as well as the effects of low birth weight on the mother's later outcomes. Consistent with our findings, she finds that mother's birth weight is positively correlated with birth weight of the next generation. She also documents a positive effect of the mother's birth weight on her educational attainment later in life. The effect of birth weight on educational attainment appears to be highest for individuals whose birth weight exceeded 2,500 grams. Overall, she concludes that while the estimated long-run and intergenerational effects of birth weight are statistically significant, they are small. While similar in some respects, our article and Royer's paper differ in many other respects.[3] Twin comparisons are a clearly more direct way to account for possible unobserved differences than sibling comparisons. On the other hand, we mainly focus on interactions of low birth weight with maternal SES, while Royer does not.

C. Possible Mechanisms

Intergenerational correlations in birth weight could reflect nature or nurture, or the interaction of the two. Herrnstein and Murray (1994) argue that factors such as intelligence that determine economic status are inborn and are passed from one generation to the next (nature). Certainly some part of the intergenerational correlation in birth weights is likely to be genetic.[4]

On the other hand, Charles and Hurst (2003) argue that much of the intergenerational correlation in labor market and savings behaviors of parents and children is due to similar learned behaviors (nurture). Similarly, intergenerational correlations in birth weight could also reflect behavioral factors. Many authors have identified a correlation between maternal poverty and low birth weight, although such a link does not

[3] Royer's paper and our article were written independently.

[4] Taller women tend to have heavier infants, and heavier infants tend to grow up to be taller adults. Emanuel et al. (1992, 67) comment that "the relation of maternal stature to infants' birth weight and/or gestational duration has been demonstrated in all populations studied." But the height of a population reflects both its genetic endowment and its long-run nutritional and health status (see, e.g., Floud, Wachter, and Gregory 1990; Fogel 1994). This observation suggests that a mother's socioeconomic status in childhood could be related to her future probability of bearing a low birth weight baby, a question we investigate below using our measure of SES at the time of the mother's own birth.

necessarily establish any causal relationship.[5] If the daughters of the poor are more likely than other girls to grow up poor, and if poverty is associated with factors such as smoking, stress, and poor nutrition that lead to lower birth weights, then this might explain the correlation. By controlling more thoroughly than previous studies for possible omitted factors, our study will shed light on this issue.

Drake and Walker (2004) review the literature regarding intergenerational correlations in birth weight and argue that there could also be intergenerational effects of low birth weight that did not operate either through purely genetic or through purely behavioral channels. For example, poor fetal nutrition could lead to low birth weight in the mother which in turn could lead to low birth weight in the next generation through a biological mechanism that was not genetic (this is known as "fetal programming"; see Barker [1998] and Huxley et al. [2004] for a discussion).[6]

Many observers reject a simple dichotomy between nature and nurture and investigate interactions between the two. For example, Turkheimer et al. (2003) develop a model of the heritability of IQ in which socioeconomic status matters most at low levels of income, while genes matter most at high levels. Similarly, it might be the case that socioeconomic status has a greater impact on the incidence of low birth weight than on mean birth weights, a question we investigate below. Research by Caspi et al. (2003) and Moffitt et al. (2005) suggest that carriers of specific genes are more likely to develop future pathologies only when they are exposed to specific environmental influences. Hence, it is of interest to examine the interaction between maternal low birth weight and maternal socioeconomic status in our models of child birth weight.

III. The Data

Our sample is based on individual birth records from California. The data set includes the mother's age, race, state of birth, county of residence, and/or hospital of delivery as well as the child's parity, sex, and birth weight. In addition, the confidential version of the file contains the moth-

[5] Gortmaker (1979) was one of the first. Starfield et al. (1991) find an effect for whites but not for blacks, while Duncan and Laren (1990) find effects of poverty on low birth weight among blacks. Collins and David (2000) examine 103,072 Chicago births from 1982 and 1983. They find that women in poorer Census tracts have more low birth weight infants and that racial differences in the fraction of low birth weight births are smaller in these areas.

[6] Lumey (1992) studied the intergenerational effects of the Dutch hunger winter, when pregnant women were reduced to eating tulip bulbs to survive the Nazi occupation. He reported that mothers exposed to famine in utero went on to deliver lower weight babies as adults. But a subsequent study of the same data (Stein and Lumey 2000) failed to replicate this finding.

er's and child's names and the mother's exact date of birth. For mothers who were born in California, it is possible to link their own birth records to those of their infants in order to create an intergenerational database. The data set also includes some information about fathers, although father information is often missing and the available information is less complete. For example, we do not have the father's first name or state of birth, which makes matching difficult. In what follows, we focus on mothers.

We began with all of the infants born between 1989 and 2001. If the mothers of these infants reported having been born in California then it was theoretically possible to match the infant's birth record and the mother's. We matched using the mother's first name, last name, exact date of birth, and state of birth. We focus on a subset of mothers who were born between 1970 and 1974 and use information from the mother's birth certificate about the mother's mother (the grandmother) to identify mothers who are siblings. We do this by matching the grandmother's name and year of birth across birth certificates. The exact date of birth of the mother is only recorded starting in 1989, and before that, the birth certificates record only the mother's (grandmother's) two-digit age.[7] Our final sample includes 638,497 births.[8]

Before 1989, the birth certificate data include the hospital of delivery but very little by way of potential measures of socioeconomic status beyond race and age at the birth. Hence, we use the median income and poverty rate of the zip code of the hospital where delivery took place as a measure of the socioeconomic status of mothers at the time of the birth.

[7] We do not use information of grandmother state of birth for the linkage because it is missing in too many cases. We drop individuals for whom grandmother's name or age are missing. We also drop grandmothers who, according to our match, appear to have more than 20 grandchildren. Finally, we drop individuals whose grandmother's hospital location could not be matched to a specific zip code.

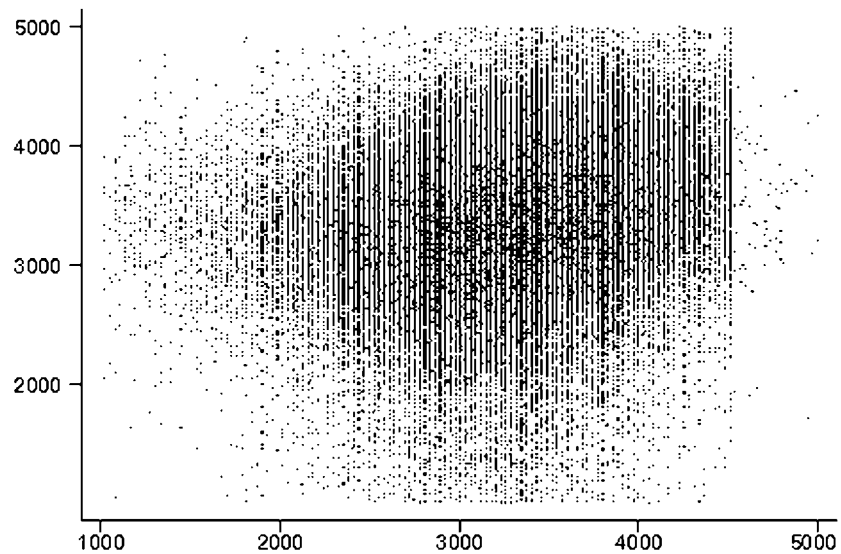
[8] We have used Census data to ask whether our matched data reproduce the actual structure of families in California over the relevant period. In our data, the distribution of numbers of children born between 1989 and 2001 to mothers who were born between 1970 and 1974 is: 51.9% have one child, 34.1% have two children, 10.8% have 3 children, and the rest have more. In the 2000 Census, mothers who were 26–30 years old and lived in California in 2000 had the following distribution of children 0–11 years old: 46.5% had one child, 36.5% had two children, 11.9% had three children. Hence, these distributions are quite similar, suggesting that we are doing a good job matching siblings in the 1989–2000 data. If we look at the match of mothers to grandmothers, we find that 70% of the time there is only one daughter matched, 15% of the time there are two daughters matched, and 6% of the time there are three daughters matched. If we use the 1980 Census to examine the number of children born between 1970 and 1974 to women born in California who were 12–45 years old in 1970, we find that 88% had only one daughter, 11.1% had two daughters, and few had more than two daughters born in that short time interval.

If grandmothers, mothers, and children are in our data set, we have two potential windows when we can measure the mother's status: the time of the mother's own birth and the time of her child's birth.

After 1989, the data include both the zip code of delivery and zip code of residence so that it is possible to investigate the correlations between income/poverty in the two locations. Appendix table A1 shows the results of this exercise. The correlations are strongly positive and statistically significant but around .5, indicating that conditions in the hospital zip code are a noisy proxy for conditions in the zip code of residence. In most of our regression models, we divide people by quartile of zip code income or poverty, so it is of interest to see whether there is any systematic tendency for women living in high poverty zip codes to deliver in lower poverty ones or vice versa. The second half of table A1 shows that there is no such tendency: 45% of mothers deliver in a zip code that has a poverty level similar to the poverty level in the area where they reside (i.e., they locate on the diagonal in the table); 28% deliver in a better place than they reside, and 27% deliver in a worse place.

Appendix table A2 shows how far the center of the zip code of residence is from the center of the zip code of the delivery. According to this measure, half the sample lives within 5.5 miles of the hospital, while 75% live within 10 miles. We have reestimated our models excluding people who lived more than 10 miles from the hospital of delivery and found that this did not substantively change our results.

The top panel of figure 1 plots the birth weights of 20% of the children born between 1989 and 2001 against the birth weights of their mothers. Only mother-child pairs where both weights are more than 1,000 grams and less than 5,000 grams are shown. The plot begins at 1,000 grams because there are virtually no mothers with birth weights less than 1,000 grams in our sample. The bottom panel is obtained by averaging child birth weight in each interval of mother's birth weight, by income level at the time of the mother's birth. The top line is for mothers born in high income areas; the bottom line is for mothers born in low income areas. There is a clear break at 2,500 grams, the threshold below which infants are considered to be "low birth weight." Among mothers who were over 2,500 grams at birth, there is a clear positive relationship between the birth weights of mothers and their children. Equally striking however, is that when we divide the sample into three parts according to the median income in the zip code where the mother was born, babies whose mothers were born into the highest income zip codes (line with circles) have higher birth weights than babies whose mothers were born into lowest income zip codes (line with triangles) regardless of their mother's initial birth weight. (The line for the middle-income group is in between the two lines, and it is not shown to make the graph easier to read.) The gap is relatively small in the group with mothers over 2,500 grams but quite large in the



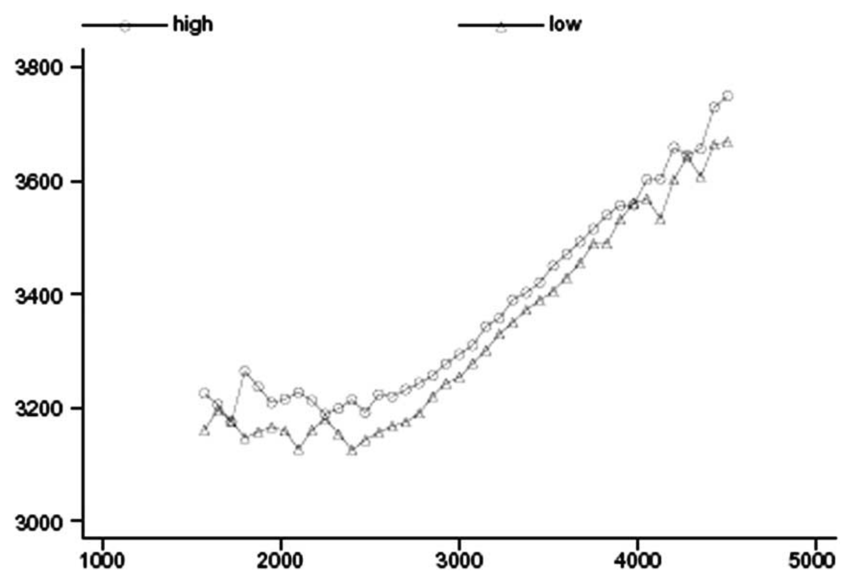


FIG. 1.—The relationship between mother birth weight and child birth weight. *Top*, the figure plots mother birth weight on the *X*-axis against child birth weight on the *Y*-axis. Each dot represents a mother-child pair. Only the mother-child pairs where both weights are more than 1,000 grams and less than 5,000 grams are shown. *Bottom*, the graph is obtained by averaging child birth weight in each interval of mother birth weight, by income level at the time of the mother's birth. The top line is for mothers born in high income areas (top income tercile); the bottom line is for mothers born in low income areas (bottom tercile).

group whose mothers were low birth weight. Hence, the graph suggests the possibility of an interactive effect between maternal poverty and maternal low birth weight in the production of child birth weight.

Table 1 shows summary statistics. The mean birth weight for mothers born between 1970 and 1974 is 3,268, while for children born between 1989 and 2001 it is 3,387. The probability of low birth weight declined only slightly, from 6.3% to 6%. If we divide the sample by race, blacks have lower average birth weights than whites, but this appears to be largely due to the much higher incidence of low birth weight among blacks. The probability of low birth weight is 12% for blacks in both the earlier cohort and in the later.

As expected, children born in poor neighborhoods have worse birth outcomes, but the relationship between SES and birth outcomes is nonlinear. While the first three quartiles of the poverty distribution appear to be roughly equivalent, the last quartile (highest poverty) has more births with low birth weight. For example, for mothers born between 1970 and 1974, the probability of low birth weight is about 6%–6.2% for the first three quartiles, and 7.2% (about 20% more) for the last quartile. Similarly, for children born between 1989 and 2001, the probability of low birth weight is about 5.6%–5.9% for the first three quartiles and 7.0% (about 25% more) for the last quartile.

IV. Methods

We regress measures of the child's birth weight on the mother's birth weight, starting with simple correlations and adding increasing numbers of controls. Thus, our model is essentially

$$\mathrm{BW}_2 = a\mathrm{BW}_1 + bX + e_2, \tag{1}$$

where BW is a measure of birth weight, the subscript 2 represents the second generation, the subscript 1 represents the first generation, X stands for the control variables, and e_2 is a random shock.

Evidently, we do not observe all of the characteristics of children and mothers (including the characteristics of the fathers they choose) that might be correlated with the child's birth weight. Hence, we first estimate (1) including only the mother's birth weight and controls for the infant's sex, the mother's race, dummy variables for the year of the child's birth to account for trends in birth weight over time, grandmother's age at the birth of the mother (in 3-year intervals), and interactions between the grandmother's county of residence at the time of the mother's birth and the mother's birth year. These variables may all be regarded as predetermined if not strictly exogenous.

We next estimate models including grandmother fixed effects. In these models, the effects of maternal low birth weight are identified by com-

Table 1
Summary Statistics

	Birth Weight (1)	Low Birth Weight (2)
Mothers born 1970–74:		
All	3,268	.063
White	3,295	.056
Black	3,077	.120
1st poverty quartile (low poverty)	3,272	.062
2nd poverty quartile (medium low poverty)	3,276	.060
3rd poverty quartile (medium high poverty)	3,274	.060
4th poverty quartile (high poverty)	3,238	.072
All children, 1989–2001:		
All	3,387	.060
White	3,420	.053
Black	3,143	.120
1st poverty quartile (low poverty)	3,410	.056
2nd poverty quartile (medium low poverty)	3,394	.059
3rd poverty quartile (medium high poverty)	3,399	.057
4th poverty quartile (high poverty)	3,344	.070

paring mothers who are sisters, and the effects of changes in maternal socioeconomic status at the time of the birth are identified by the fact that some grandmothers changed hospitals between births. Finally, we also estimate models including maternal characteristics at the time of the birth, such as the mother's age, education, and parity and interactions between county of residence and year. While these variables are not strictly exogenous and might be chosen jointly with the decision to give birth, it is interesting to see how their inclusion affects the estimated coefficients. If we could drive the correlation between mother and child's birth weight down significantly by adding measures of the mother's status at the time of the child's birth, this would suggest that it might be possible to intervene at this point to break the intergenerational cycle of low birth weight. Of course, even if our set of controls is quite rich, the controls are by no means perfect, and we cannot completely rule out the possibility of omitted variable bias.

A potentially important limitation of (1) is that it does not allow for an interaction between BW_1 and X. An interactive model will allow us to test more directly for the extent to which intergenerational transmission is mitigated by X variables. Hence we estimate

$$BW_2 = aBW_1 + bX + cBW_1 \times SES + e_2, \tag{2}$$

where SES is an indicator of the mother's socioeconomic status and the main effects of SES are captured by being included in the X vector.

We implement (2) in two ways. First, we use the grandmother's socioeconomic status at the time of the mother's birth as a measure of SES. This is measured using the median income or the poverty rate in the zip code of the hospital where the grandmother gave birth to the mother. This measure of SES is predetermined and not alterable by subsequent choices of the mother. Hence, we prefer this specification on conceptual grounds. However, because we only observe zip code of residence (which we believe is a better proxy for the income of the mother than zip code of the hospital of delivery) after 1989, we also estimate a second set of models using the mother's status at the time of the child's birth as our measure of SES. Maternal education is another contemporaneous measure of mother's SES that we can examine in this context.

V. Empirical Results

A. Intergenerational Correlations in Birth Weight

Table 2 presents estimates of the effects of maternal SES and maternal birth weight on the child's birth weight. We present estimates for three alternative models: a regression of an indicator equal to one if the child is low birth weight on an indicator equal to one if the mother is low birth weight (first row); a regression of child's birth weight on mother's birth weight (second row); and a regression of log of child's birth weight on log of mother's birth weight (third row). There may be nonlinearities in the effects of birth weight that lead low birth weight to have stronger effects than birth weight per se. Also, using the log of birth weight will allow for nonlinearities and tend to down weight very large birth weights. Hence, all three models are potentially interesting and capture different aspects of the intergenerational transmission of health.

The models in the table are estimated using the sample of children whose mothers could be linked to their grandmother's (i.e., whose mothers were born between 1970 and 1974).[9] In these and in all the other models, standard errors are clustered at the hospital-year level, where hospital is the hospital of child birth and year is the year of child birth.[10]

The first column shows estimates from models without controls. The probability that a child is low birth weight is 3.9 percentage points higher if her mother is also low birth weight. This is a large effect, given that the average probability of low birth weight is 6.0. In percentage terms, this effect is 63% of the baseline. The second column shows estimates conditional on the baby's gender, mother's race, year of birth effects, dummies for grandmother age at the time of mother birth, and the interaction of dummies for the county of residence of the grandmother at

[9] Models with grandmother fixed effects can only be estimated using this subsample, although estimates very similar to those of col. 1 of table 2 were obtained using a much larger sample of children linked to mothers born between 1960 and 1975 or between 1982 and 1985.

[10] Clustering at the family level or at the county-year level generated very similar standard errors.

Table 2
Effect of Mother's Birth Weight on Child Birth Weight

	(1)	(2)	(3)	(4)	(5)	(6)
A. Entire sample:						
1. Child's low birth weight on mother's low birth weight	.039	.033	.03	.03	.029	.029
	(.001)	(.001)	(.003)	(.003)	(.003)	(.003)
2. Child's birth weight on mother's birth weight	.226	.21	.201	.201	.201	.201
	(.001)	(.001)	(.003)	(.003)	(.003)	(.003)
3. Child's log birth weight on mother's log birth weight	.200	.182	.173	.173	.172	.172
	(.001)	(.001)	(.004)	(.004)	(.004)	(.004)
Sample size	638,497	636,099	636,099	619,966	615,808	570,102
B. Whites:						
1. Child's low birth weight on mother's low birth weight	.028	.028	.025	.026	.025	.025
	(.001)	(.001)	(.003)	(.003)	(.003)	(.003)
2. Child's birth weight on mother's birth weight	.208	.209	.202	.203	.202	.203
	(.001)	(.001)	(.003)	(.003)	(.003)	(.003)
3. Child's log birth weight on mother's log birth weight	.182	.182	.174	.175	.174	.174
	(.001)	(.001)	(.004)	(.004)	(.004)	(.004)
Sample size	546,355	544,958	544,958	529,991	527,668	490,021
C. Blacks:						
1. Child's low birth weight on mother's low birth weight	.054	.053	.031	.031	.031	.030
	(.004)	(.004)	(.009)	(.009)	(.009)	(.010)
2. Child's birth weight on mother's birth weight	.201	.2	.169	.167	.165	.165
	(.005)	(.005)	(.011)	(.012)	(.012)	(.013)
3. Child's log birth weight on mother's log birth weight	.169	.169	.129	.127	.127	.123
	(.006)	(.006)	(.014)	(.015)	(.015)	(.016)
Sample size	63,539	62,608	62,608	61,958	61,466	55,494
Child race, sex, and year of birth, GM age, GM county × year age, GM county × year		Y	Y	Y	Y	Y
Grandmother fixed effects			Y	Y	Y	Y
Poverty in mother's zip code birth				Y	Y	Y
Mother age, education, and parity					Y	Y
Mother county × year						Y

Note.—Standard errors clustered at the hospital and year level in parentheses. Each column of each panel is from a separate regression. In row 1 of each panel, the dependent variable is a dummy equal to 1 if the child was low birth weight. The coefficient reported is that on whether the mother was low birth weight. In row 2 of each panel, the dependent variable is the child's birth weight measured in kilograms and the coefficient reported is the coefficient on mother birth weight. In row 3 of each panel, the dependent variable is the log of child birth weight and the coefficient is the coefficient on the log of the mother's birth weight. "GM age" are dummies for the grandmother's age at the time that she gave birth to the mother. "GM county × year" are interactions of dummies for the grandmother's county of residence at the time of the mother's birth and the mother's year of birth.

the time of the mother's birth and the year of birth of the mother.[11] The coefficient drops to 3.3 percentage points. The drop is due mainly to controlling for race.

Column 3 shows models that condition on grandmother fixed effects. This specification uses within-family differences among siblings as the only source of variation and, therefore, controls for many permanent unobserved factors that might vary across families. Although the standard error triples, the point estimate on maternal low birth weight declines only marginally to 2.9 percentage points and remains highly significant. In percentage terms, this effect is 46% of the average probability of low birth weight. Ideally, one would like to control for at least some of the time-varying factors that may have contributed to low birth weight status in one of the sisters but not in the other. In column 4, we include a proxy for socioeconomic status at the time of the mother's birth as measured by poverty in her hospital of birth zip code, but this has little effect on the point estimate.

For completeness, the two remaining columns show the effects of controlling for some mother characteristics. In column 5, we add controls for maternal age, education, and parity; and in column 6 we add the interaction of dummies for maternal county of residence at the time of the child's birth and the year of the child's birth. The interpretation of the estimates in columns 5 and 6 requires caution, because mother age, education, parity, and location are all potentially endogenous variables. But the point estimates in columns 5 and 6 do not change significantly relative to column 4. We have also estimated models that condition on the mother's current zip code of residence. These models generated estimates very similar to the one in column 6.[12]

A qualitatively similar pattern emerges when we look at birth weight and log of birth weight in rows 2 and 3. In these models, adding grandmother fixed effects has a smaller impact on the point estimates on mother's birth weight. Row 2 of column 3 indicates that a 100-gram increase in mother's birth weight results in a 20-gram increase in child's birth weight, after controlling for grandmother fixed effects. Row 3 indicates that this amounts to an elasticity of 17%.

Table 2 shows that the correlation between mother and child birth weights (or in the incidence of low birth weight) is remarkably stable once we control for grandmother fixed effects. Of course, it is certainly possible that omitted factors are driving our results. However, the stability

[11] For computational ease, we group grandmother's age in 3-year intervals. We also group the five smallest counties together.

[12] We were unable to estimate grandmother fixed effects models that control for the interaction of current zip code of maternal residence and year of child birth because of the large number of variables involved.

of the coefficients as we move from column 3 to column 6 lends some credibility to the idea that maternal birth weight actually affects child birth weight and that the estimates in the table do not reflect only omitted factors. In other words, having a mother who is low birth weight appears to have an impact on the probability that the child is low birth weight independent of those genetic factors controlled for by the grandmother fixed effects or other permanent indicators of the background of the mother. This is consistent with the fetal programming hypothesis discussed above.

In the middle and bottom panels of table 2, we present estimates for whites and blacks separately. The middle panel shows that for whites, adding grandmother fixed effects reduces the estimated effect of low birth weight of the mother on low birth weight of the child from 2.8 percentage points to 2.5 percentage points, but the addition of other covariates has little effect. For blacks, the inclusion of grandmother fixed effects results in a larger decline in the estimated intergenerational transmission of health: the coefficient for the low birth weight model falls from 5.3 percentage points to 3.1 percentage points. Given the larger baseline incidence of low birth weight for blacks, both estimates imply a roughly 20%–25% decline in the estimated coefficient when grandmother fixed effects are added.

The low birth weight models indicate that the coefficient on maternal low birth weight is twice as large for blacks as for whites, indicating that the intergenerational transmission of low birth weight is much stronger for blacks than for whites. Specifically, in models that control for grandmother fixed effects, a white child with a mother who is low birth weight is 2% more likely to be low birth weight, while for blacks the equivalent figure is 3%. In contrast, the effect of a continuous measure of maternal birth weight on child birth weight is more similar for blacks and whites, and if anything, it is slightly lower for blacks. For each 10-gram increase in maternal birth weight, child birth weight rises by 2 grams for whites and 1.6 grams for blacks. The fact that intergenerational correlations in low birth weight are more sensitive to an indicator of SES (in this case race) than intergenerational correlations in birth weight is a pattern that we find throughout our study, and it suggests that we might find significant interactions between low birth weight and more direct measures of SES, a question we investigate in the next section.

One concern is that our sibling comparisons are polluted by omitted variables that change between the birth of the siblings. Arguably, a better estimate of the extent of intergenerational transmission of birth weight is provided by twins, because twin comparison controls for many unobservables. On the other hand, twin comparisons are informative only about differences in birth weight that are not associated with differences in gestational age, and most cases of low birth weight are the result of preterm birth rather than interuterine growth retardation. In any case, Royer (2005) uses a larger sample of the California birth records and shows that models based on twin comparisons generate results that are qualitatively similar to our estimates based on sibling comparisons.

Finally, we have also estimated models with alternative outcomes. For example, we ask whether infants of mothers who are born low birth weight are more likely than other children to die in their first year. We find little evidence that this is the case. We have also tested whether mothers who are born with congenital malformations are more likely to have children who have congenital malformations. Again, we do not find a statistically significant effect.

B. Do Intergenerational Correlations in Birth Weight Vary by Socioeconomic Status?

Tables 3 and 4 ask whether the intergenerational transmission of birth weight uncovered in table 2 is stronger for mothers of lower socioeconomic status. As discussed above, there are two points in time when it is possible to measure the mother's SES. The first measure, at the time the mother was born, is the income or poverty level in the zip code of the hospital where she was delivered. The second, at the time of the child's birth, is the mother's own years of education or the income or poverty level in the mother's zip code of residence.

Table 3 shows models estimated using SES measured at the time of the mother's birth, while table 4 shows models estimated using SES measured at the time of the child's birth. For the zip code level measures, we focus on whether the mother was in the highest poverty or lowest income quartile of the distribution. Indicators for being in one of these quartiles are interacted with maternal birth weight in order to see whether intergenerational correlations in birth weight differ with SES. Education is the mother's self-reported education from the birth certificate. We define a mother as having low education if she has a high school degree or less and having high education if she has some college or more.

Models in columns 1 and 4 include the SES main effects as well as controls for the child's race, sex, year of birth, dummies for grandmother age at the time of the mother's birth, and the interaction of dummies for the county of residence of the grandmother at the time of the mother's birth and the year of birth of the mother. Models in columns 2 and 5 also include grandmother fixed effects and are the preferred specifications. For completeness, models in columns 3 and 6 include maternal age, parity, and the interaction of dummies for maternal county of residence at the time of the child's birth and the child's birth year. As mentioned above, these maternal characteristics are potentially endogenous, and the interpretation of these estimates requires caution.

The main effects shown in table 3 indicate that, as expected, socioeco-

Table 3
Variations in the Effect of Mother's Birth Weight on Child Birth Weight by SES at Mother's Birth

	Low Birth Weight on Low Birth Weight			Birth Weight on Birth Weight		
	1	2	3	4	5	6
Model 1: mother's poverty:						
Low poverty × Mother's birth weight	.0322	.0305	.028	.212	.201	.201
	(.0020)	(.0035)	(.0036)	(.002)	(.008)	(.004)
High poverty × Mother's birth weight	.0382	.0316	.028	.215	.208	.209
	(.0037)	(.0061)	(.0060)	(.003)	(.006)	(.006)
High poverty	.0042	.0038	.0033	−27.25	−33.82	−32.82
	(.0009)	(.0018)	(.0019)	(12.6)	(24.54)	(26.54)
p-value Low education × Mother's birth weight = High education × Mother's birth weight	.12	.87	.97	.46	.35	.37
Sample size	532,182	532,182	490,416	532,182	532,182	490,416
Model 2: mother's income:						
Low income × Mother's birth weight	.029	.024	.021	.205	.195	.197
	(.0042)	(.0007)	(.0007)	(.004)	(.008)	(.008)
High income × Mother's birth weight	.034	.031	.029	.215	.204	.205
	(.0018)	(.0067)	(.0034)	(.001)	(.003)	(.003)
High income	−.0013	−.0003	−.0009	−24	−32.9	−27.5
	(.0011)	(.0021)	(.0022)	(15.1)	(29.8)	(30.3)
p-value Low income × Mother's birth weight = High income × Mother's birth weight	.27	.36	.37	.27	.31	.42
Sample size	548,611	548,611	502,863	548,611	548,611	502,863
Child race, sex, and year birth, GM age, GM county × year	Y	Y	Y	Y	Y	Y
Grandmother fixed effects		Y	Y		Y	Y
Mother age, education, parity, county × year			Y			Y

Note.—Standard errors clustered by hospital and year in parentheses. Each column of each model is from a different regression. In cols. 1–3, the dependent variable is a dummy equal to one if a child is low birth weight. The coefficients reported are those on the interaction between a dummy equal to one if the mother is low birth weight and indicators for her SES, as well as the main effect of her SES. In cols. 4–6, the dependent variable is birth weight and the coefficients reported are those on the interaction between mother's birth weight and indicators for her SES. "GM age" are dummies for the grandmother's age at the time of the mother's birth. "GM county × year" are interactions of dummies for the grandmother's county of residence at the time of the mother's birth and the mother's birth year.

nomic status is correlated with birth weight. For example, conditional on grandmother fixed effects, the incidence of child low birth weight is about a 0.4 percentage points higher if the mother was born into a high poverty zip code (col. 2). This difference represents a large increase given that the baseline incidence of low birth weight is only 6%. In contrast, average birth weight is only 33 grams lower if the mother is born in a high poverty zip code, and this estimate is not statistically significant. Compare this

Table 4
Variations in the Effect of Mother's Birth Weight on Child Birth Weight by SES at Child's Birth

	Low Birth Weight on Low Birth Weight			Birth Weight on Birth Weight		
	1	2	3	4	5	6
Model 1: mother's education:						
Low education × Mother's birth weight	.035	.031	.029	.21	.201	.2
	(.002)	(.003)	(.003)	(.001)	(.003)	(.003)
High education × Mother's birth weight	.026	.024	.022	.214	.204	.207
	(.002)	(.004)	(.004)	(.002)	(.004)	(.004)
High education	−.008	−.006	−.005	29.5	25.2	1.86
	(.0007)	(.001)	(.0007)	(10.28)	(16.57)	(17.1)
p-value Low education × Mother's birth weight = High education × Mother's birth weight	.005	.15	.18	.21	.61	.22
Sample size	641,614	641,614	593,801	641,614	641,614	593,801
Model 2: mother's income:						
Low income × Mother's birth weight	.039	.033	.03	.206	.197	.197
	(.0030)	(.004)	(.0004)	(.00)	(.005)	(.005)
High income × Mother's birth weight	.029	.026	.024	.213	.204	.204
	(.0018)	(.0030)	(.0031)	(.002)	(.003)	(.003)
High income	−.0072	−.0051	−.0047	8	−1	−8
	(.0009)	(.0012)	(.0013)	(11)	(16)	(17)
p-value Low income × Mother's birth weight = High income × Mother's birth weight	.002	.17	.26	.02	.16	.19
Sample size	629,314	629,314	578,667	629,314	629,314	578,667
Model 3: mother's poverty:						
Low poverty × Mother's birth weight	.0285	.0242	.0224	.212	.202	.202
	(.0018)	(.0029)	(.0031)	(.002)	(.003)	(.003)
High poverty × Mother's birth weight	.041	.0404	.0375	.21	.202	.201
	(.0030)	(.0047)	(.0049)	(.003)	(.0048)	(.0051)
High poverty	.007	.0045	.0039	−27	−26	−13
	(.0009)	(.0012)	(.0013)	(11)	(16)	(17)
p-value Low poverty × Mother's birth weight = High poverty × Mother's birth weight	.0001	.001	.005	.55	.91	.9
Sample size	627,422	627,422	576,821	627,422	627,422	576,821
Child race, sex, and year birth, GM age, GM county × year	Y	Y	Y	Y	Y	Y
Grandmother fixed effects		Y	Y		Y	Y
Mother age, education, parity, county × year			Y			Y

Note.—Standard errors clustered by hospital and year are in parentheses. Each column of each model represents a different regression. In cols. 1–3, the dependent variable is a dummy equal to one if the child is low birth weight; the coefficients reported are the coefficients on an interaction between a dummy equal to one if the mother is low birth weight and indicators for her SES as well as the main effect of her SES. In cols. 4–6, the dependent variable is birth weight, and interactions between birth weight and maternal SES are shown in addition to the main effect of SES. "GM age" are dummies for the grandmother's age when she gives birth to the mother. GM county × year is the interaction of dummies for the county where the grandmother resided at the time of the mother's birth and dummies for the year of birth of the mother.

with the baseline, which is 3,268 grams.[13] This finding is interesting for two reasons. First, it confirms that our measure of SES at the time of the mother's birth has some signal, even if it is a noisy proxy for income in the mother's zip code of residence. Second, it suggests that low birth weight is more sensitive to SES than birth weight above some cutoff, which is consistent with the Turkheimer et al. (2003) model discussed above (that SES matters more at low levels of SES). The same is true if we look at log birth weight (not shown).

Turning to the interactions, column 1 suggests that there might be an interaction between maternal SES at birth and maternal birth weight in models of low birth weight, although our estimates are not precise. Children born to a low birth weight mother are more likely to be low birth weight themselves (as we saw in table 2), and the point estimate indicates that the effect is larger if the mother was also born into a high poverty zip code. A similar result is obtained if we look at the income interaction in the bottom panel. But column 2 shows that these results are not robust to the inclusion of grandmother fixed effects. Overall, we cannot reject the hypothesis that the effect of maternal low birth weight is the same across SES groups when SES is measured at the time of the mother's own birth.

One problem with table 3 is that the variation in SES at birth among siblings is rather limited, given that the mothers are constrained to have been born 4 years apart. A second problem is that income in the zip code of residence at the time of the mother's own birth is less accurately measured than income in the zip code of residence at the time of the child's birth because, as discussed above, we did not know the zip code of residence in the early years of the vital statistics data and we proxy for it using the zip code of the hospital of delivery.

Table 4 shows similar models estimated using maternal education as well as poverty and income in the mother's zip code of residence, all measured at the time of the child's birth. These are measures of her current economic status, though they are correlated with her past status. These measures show more between-sibling variation than the longer-term measure of status used in table 3. And unlike the zip code level measures of SES, which of course vary only at the zip code level, maternal education is measured at the individual level.

Table 4 is organized in the same way as table 3. Estimates using low birth weight as the dependent variable appear in columns 1–3. In the case of education, when grandmother fixed effects are not included, the coefficient on the interaction between low education and low birth weight

[13] The coefficients on the main effect for income (lower panel) are quantitatively smaller, although the difference between low birth weight and birth weight remains.

is 3.1 percentage points, and the coefficient on the interaction between high education and low birth weight is 2.6 percentage points. The two coefficients are statistically significant. When grandmother fixed effects are included (col. 2), the coefficient on the interaction between low education and low birth weight is slightly lower (3.1 percentage points), and the coefficient on the interaction between high education and low birth weight is also slightly lower (2.4 percentage points). Although the distance between the two point estimates has remained virtually unchanged, the two coefficients are now not statistically significantly different from each other. This is due to the decline in the precision of the estimates, more than to changes in the point estimates. The loss of precision is due to the fact that the inclusion of the grandmother fixed effects absorbs much of useful variation in the independent variables of interest. A similar pattern arises when we measure SES using income in the middle panel (model 2).

In contrast, the estimates using poverty in the current zip code of residence (model 3) show a sharp gradient in the interaction terms, and the difference in the effect of low birth weight between high and low poverty groups remains statistically significant even after the introduction of grandmother fixed effects. In terms of magnitudes, the estimates suggest that children born in poor households are .040 percentage points more likely to be low birth weight if their mothers were low birth weight. Among nonpoor households the comparable estimate is .022. Hence, poverty raises the probability that low birth weight is transmitted by 88%.

One possible interpretation of the contrast between the results for poverty in tables 3 and 4 is that measures of the mother's SES at the time of the child's birth are more relevant to predicting whether or not the child will be low birth weight than measures taken at the time of the mother's birth. An alternative interpretation is that the results are stronger because income in the zip code of residence is more accurately measured at the time of delivery, and there simply is more variation in poverty at delivery than in poverty at birth once grandmother fixed effects are included in the model.

Using SES measured at the time of the child's birth also allowed us to replicate Dalton and Conley's model by including mother fixed effects. Models with mother fixed effects focus on short-term changes in the economic status of the mother between the births of her children and ignore differences in the SES of mothers who are siblings. We have estimated these models and find that there is no significant interaction between maternal low birth weight and maternal poverty (or income) when mother fixed effects are included. That is, in mother fixed effects models, the effect of maternal low birth weight is the same whether the child was born in a low poverty or a high poverty area. (Alternatively, the effect of income is the same whether or not the parent is low birth weight.)

Hence, we find little evidence that very short-term variations in a mother's income have an impact on the birth weight of her children. It seems then that it is the difference in the current SES of mothers who are sisters that identifies the interactive effects of poverty in table 4.

C. Long-Run Effects of Birth Weight on Later Socioeconomic Status

In the preceding tables, we showed that low birth weight is transmitted across generations, that poverty has an independent effect on the incidence of low birth weight, and that poverty and low birth weight interact to produce low birth weight in the next generation. An important remaining question is whether low birth weight, in turn, affects future SES. In addressing this question, we also explore one possible channel that might explain the correlations uncovered in table 2. In previous work we argue that the SES of the mother affects the child's birth weight (Currie and Moretti 2003). If it turns out that being born low birth weight affects a mother's SES later in life, this would suggest that intergenerational correlations in health status were related to the intergenerational transmission of poverty.

This question is addressed in table 5, which shows models using the three available measures of mother's socioeconomic status at the time of the child's birth as the dependent variable: income in the zip code of residence, as measured by the median family income in the mother's zip code of residence as of the 1990 Census (converted to real $1970); an indicator equal to one if the mother's zip code of residence is a high poverty (top poverty quartile) zip code in the 1990 Census; and maternal education. These SES measures are regressed on the mother's own birth weight as well as on a measure of maternal SES at the time of her own birth (i.e., the grandmother's SES). To measure grandmother SES we use the median family income in the hospital where the mother was born, as of the 1970 Census.

Table 5 shows that there is a strong correlation between SES at the time of the mother's own birth and her SES at the time of her child's birth. But the mother's birth weight or low birth weight has an independent predictive effect (col. 1). Column 2 shows that the addition of grandmother fixed effects causes the effect of low birth weight to be reduced but that it remains highly statistically significant. That is, of two sisters born in the same type of neighborhood, the one with lower birth weight is more likely to live in a lower income zip code when she gives birth to her own child many years later. The magnitude of the effect is nontrivial. For example, column 2 indicates that being low birth weight is associated with a loss of $110 in future income, on average, on a baseline income of 10,096 (in $1970), for a loss of 1%. Hence, these models show that low birth weight is a significant predictor of future status in our

Table 5
Effect of Mother Birth Weight and Income at Mother's Birth on Mother's Socioeconomic Status at Child's Birth

	All			White			Black		
	1	2	3	4	5	6	7	8	9
A. Outcome = Income in zip code of residence at child's birth (10,000 $1970):									
1. Birth income (10,000 $1970)	.075	.055	.049	.077	.054	.051	.054	.061	.049
	(.002)	(.003)	(.003)	(.003)	(.003)	(.003)	(.005)	(.011)	(.012)
Low birth weight	−.021	−.011	−.019	−.021	−.009	−.011	−.024	−.011	−.009
	(.0002)	(.0005)	(.0005)	(.0002)	(.0005)	(.0005)	(.003)	(.005)	(.003)
Sample size	526,517	526,517	482,540	447,126	447,126	412,125	55,842	55,842	49,927
2. Birth income (10,000 $1970)	.075	.055	.049	.077	.054	.05	.054	.063	.05
	(.002)	(.002)	(.003)	(.002)	(.002)	(.003)	(.005)	(.011)	(.012)
Birth weight (kg)	.085	.027	.026	.089	.016	.023	.014	.007	.005
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.002)	(.003)	(.003)
Sample size	526,517	526,517	482,540	447,126	447,126	412,125	55,842	55,842	49,927
B. Outcome = Zip code of residence at child's birth is high poverty:									
1. Birth income (10,000 $1970)	−.02	−.015	−.0134	−.019	−.014	−.0131	−.022	−.02	−.014
	(.0006)	(.0008)	(.0008)	(.0006)	(.0008)	(.0008)	(.002)	(.004)	(.002)
Low birth weight	.0065	.003	.0025	.005	.005	.001	.01	.004	.003
	(.0005)	(.0006)	(.0006)	(.0005)	(.0006)	(.0006)	(.001)	(.001)	(.001)
Sample size	526,517	526,517	482,540	447,126	447,126	412,125	55,842	55,842	49,927
C. Outcome = Mother's education at child's birth:									
1. Birth income (10,000 $1970)	.265	.167	.13	.286	.168	.126	.213	.226	.199
	(.011)	(.018)	(.017)	(.011)	(.019)	(.019)	(.027)	(.058)	(.061)
Low birth weight	−.192	−.099	−.079	−.182	−.082	−.077	−.233	−.092	−.052
	(.012)	(.014)	(.014)	(.014)	(.015)	(.016)	(.023)	(.027)	(.030)
Sample size	536,077	536,077	494,630	457,312	457,312	423,306	56,003	56,003	50,451
Child race, sex, year birth GM age, GM county × yr	Y	Y	Y	Y	Y	Y	Y	Y	Y
Grandmother fixed effects		Y	Y		Y	Y		Y	Y
Mother age, parity, county × year			Y			Y			Y

Note.—Standard errors clustered by hospital and year are in parentheses. "GM age" are dummies for the grandmother's age at the time she gave birth to the mother. "GM county × year" are interactions between dummies for the grandmother's county of residence at the time of the mother's birth and dummies for the year of birth of the mother. Birth income is measured using median family income in the zip code of birth of the mother from the 1970 Census. The median birth income is $10,096. Models for blacks in cols. 8 and 9 include county and year dummies, but not the interactions.

models, even conditional on the inclusion of grandmother fixed effects. This result is consistent with Smith (2005), who finds that an adult retrospective report of poor health in childhood is a significant predictor of adult outcomes even in sibling fixed effects models. Birth weight can be viewed as a much narrower, but more accurately measured, indicator of health.

The models in table 5 can also be interpreted as typical "Solon" regressions of child income on parent's income, except that income is measured at the zip code rather than at the individual level, income is measured at the time of birth for both parent and child, and income is not measured in quite the same way for mother and child (see, e.g., Solon 1999). It is interesting to compare the coefficient on parent's income from these models to those that have appeared in the literature. The coefficient of .055 is likely to be an underestimate of the coefficient we would obtain if we had income in the zip code of residence for both mother and child: recall that the correlation between income in the hospital of delivery and income in the hospital of residence is about .5. This suggests that the coefficient we would obtain using zip code of residence for both would be about .11, which is lower but not orders of magnitude different from many previous estimates of intergenerational correlations in income in the United States. The results are similar if we look at blacks and whites separately (cols. 4–9).

The remaining sections of table 5 explore the impact of birth income and birth weight on two other indicators of mother's SES at the time of her child's birth, her education and her residence in a high poverty neighborhood. As mentioned above, education is particularly interesting because, unlike the other outcome variables in the table, it is an individual-level measure. The grandmother fixed effects estimates suggest that being low birth weight increases the probability of living in a high poverty neighborhood (defined as one in the highest quartile of poverty rates) by about 3% relative to baseline and that it reduces future educational attainment by about a tenth of a year.

We have also estimated models with alternative outcomes. For example, we have looked at whether women who are born low birth weight have worse marriage market outcomes. We find that in specifications similar to the one in column 2 of table 5, there is a negative correlation between low birth weight and the probability of being married at the time of the child's birth and between low birth weight and the father's education (if father education is reported). Women born low birth weight are 3.4 percentage points less likely to be observed married when giving birth, conditional on grandmother fixed effects and controls for SES at birth. Similarly, women born low birth weight have partners with 0.08 fewer years of schooling on average. Both estimates are statistically significant.[14] Overall, we conclude that whether we use individual level measures of SES such education, or zip code level measures of poverty and income, our findings indicate that being born low birth weight has a nontrivial effect on socioeconomic status later in life.

D. Do Long-Run Effects of Birth Weight on Later Socioeconomic Status Vary by Initial Socioeconomic Status?

Table 5 indicates that being born low birth weight has a long-run effect on later SES. But does this effect vary across SES groups? Are the poor at double jeopardy? In table 6 we present estimates of models similar to the ones in table 5, where we have added interactions between low birth weight (or birth weight) and indicators for low and high SES. We measure the mother's SES at the time of her own birth using the median 1970 income in the zip code of the hospital where she was born. We classify the mother as high income if the zip code was in the top quartile of income. We measure the mother's socioeconomic status later in life using income in her zip code of residence divided by $10,000 (cols. 1–3) and her years of schooling (cols. 4–6).

The interaction terms in columns 1–3 indicate that being born low birth weight has an overall negative effect, but the negative effect is larger for women who were born in poor areas. Column 1 indicates that women who were low birth weight and were from poor or middle income areas experience an average income loss of about $290 ($1970), while women who were born low birth weight and were from rich areas experienced an average income loss of about $190. This difference is statistically significant, as shown by the test in row 4. These estimates fall to $260 and $70, respectively, when we include grandmother fixed effects in column 2.[15] The estimate of $260 is equivalent to about $1,308 in $2005. Estimates in column 3 are reported mainly for completeness, because they include controls that are potentially endogenous.

Similar results obtain when we look at the interaction between birth weight (measured in kilograms) and SES in the lower panel. One additional gram in birth weight is associated with an average increase in income of $1.38 for women born in the low SES group, and $.7 for women born in the high SES group (col. 1). The difference remains statistically significant in column 2, when we include grandmother fixed effects.

When we examine interactions in models of education, we find generally similar results in models that include grandmother fixed effects (col. 5).

[14] Royer (2005) finds an effect of birth weight on the probability that the mother is married and on the father's education, although these effects largely disappear when she controls for twin pair fixed effects.

[15] The gap appears larger for blacks than for whites (not shown).

Table 6
Variation in Effect of Mother's Birth Weight on Mother's Income and Education at Time of Child's Birth, by SES at Mother's Birth

	Dependent Variable Is Income			Dependent Variable Is Education		
	1	2	3	4	5	6
Model 1: interaction with low birth weight:						
[Low birth weight] × [Birth income is low]	−.029	−.026	−.022	−.211	−.148	−.121
	(.004)	(.005)	(.005)	(.026)	(.031)	(.032)
[Low birth weight] × [Birth income is high]	−.019	−.007	−.007	−.189	−.088	−.071
	(.002)	(.002)	(.002)	(.013)	(.015)	(.015)
Birth income is high	.071	.049	.037	.269	.169	.122
	(.002)	(.002)	(.002)	(.010)	(.015)	(.015)
F-test: group 1 = group 2, *p*-value	.04	.001	.007	.45	.08	.15
Sample size	526,517	526,517	482,540	536,077	536,077	494,630
Model 2: interaction with birth weight:						
[Birth weight] × [Birth income is low]	.138	.113	.075	.099	.069	.07
	(.020)	(.022)	(.023)	(.011)	(.014)	(.014)
[Birth weight] × [Birth income is high]	.076	.089	.017	.096	.036	.051
	(.010)	(.011)	(.010)	(.005)	(.006)	(.006)
Birth income is high	.093	.085	.058	.281	.286	.189
	(.007)	(.009)	(.009)	(.043)	(.055)	(.055)
F-test: group 1 = group 2, *p*-value	.03	.001	.02	.79	.02	.21
Sample size	526,517	526,517	482,540	536,077	536,077	494,630
Child race, sex, year birth, GM age, GM county × year	Y	Y	Y	Y	Y	Y
Grandmother fixed effects		Y	Y		Y	Y
Mother age, parity, county × year			Y			Y

Note.—Standard errors clustered by hospital and year are in parentheses. The dependent variable in cols. 1–3 is income in the mother's zip code of residence at the time of the child's birth (i.e., the zip code median income in the 1970 Census, in units of $10,000). The dependent variable in cols. 4–6 is the mother's own years of education at the time of the child's birth as reported on the birth certificate. Model 2 uses the continuous birth weight measure in kilograms. "GM age" are dummies for the grandmother's age at the time she gave birth to the mother. "GM county × year" are interactions between dummies for the grandmother's county of residence at the time of the mother's birth and dummies for the year of birth of the mother.

Women who are born low birth weight and are from poor or middle income areas experience a loss of years of schooling equal to 0.14, while women who are born low birth weight and are from rich areas experience a loss of years of schooling of only 0.09. This difference is statistically significant in column 2 (at the 90% level of confidence) but is perhaps less striking than the differences in income/poverty.

Consistent with table 5, the main effects of birth income are all large and significant. For example, the estimates in columns 1 indicate that being born in a high income zip code is associated with a median income in zip code of residence that is $710 higher. Since this effect is measured in 1970 dollars and represents about 8% of the average income in the sample, it is a large effect. Similarly, being born in a high income zip code is associated with a quarter of a year of additional schooling, on average.

We have also estimated models pushing our specification further and allowing for four SES groups (defined using quartiles). The main effects are monotonically increasing in SES. For example, in models that include grandmother fixed effects, the average future incomes of mothers born in the second, third, and fourth quartiles of income are $605, $958, $1,493 higher, respectively, than the average income of mothers born in the first income quartile. This is consistent with what Solon has shown regarding the intergenerational transmission of income. The interactions also show a monotonic pattern, with the strongest effects for the interaction of maternal low birth weight and the dummy for the lowest income quartile, and weaker effect for the highest income quartile, but these effects (and the differences between them) are not statistically significant.

E. Limitations

Our results are subject to several limitations given the crudeness of our measures of SES and the lack of data on several important determinants of child birth weight. One of the most important problems is that because of data limitations, we measure the mother's SES at the time of her own birth using the zip code of the hospital of delivery rather than the zip code of residence, which we view as a more accurate proxy for individual income. (As we have shown in appendix tables A1 and A2, the two measures are highly but not perfectly correlated in the years in which both measures are available.)

A second issue is that we are measuring SES at the zip code rather than at the individual level. However, this may actually be an advantage. As Solon (1999) demonstrates, point-in-time measures of SES may be misleading, since there is a great deal of transitory variation in these measures. In contrast, place of residence is a less fleeting measure of status and so may be more relevant for our investigation. To the extent that neighborhoods have their own effects on individuals, characteristics of zip code of residence may be regarded as measures of status that are of interest in their own right, as well as proxies for individual status. It is worth noting that in addition to median income and poverty in the zip code, we investigated additional SES measures, including median property values and the fraction of adults who were high school dropouts or college graduates in a zip code. These alternatives yielded estimates similar to those described above.

A third source of potential bias is that we observe mother's birth weight but have little information about the father. As discussed above, the inclusion of fixed effects for the mother's current zip code of residence might be expected to partially mitigate this problem (if current zip code of residence is highly correlated with the father's birth weight and socioeconomic status). And we found that the addition of controls for zip code of residence had little impact on our estimates.

However, given reasonable assumptions, we may also be able to bound the extent of potential bias from this source. Suppose we modify equation (1) as follows (and ignore the other X's since we showed above that they have relatively little impact on the estimated coefficient on mother's birth weight):

$$BW_2 = a_1 BW_{Mother} + a_2 BW_{Father} + e, \tag{1'}$$

and suppose further that

$$BW_{Father} = cBW_{Mother} + u. \tag{3}$$

If $a_1 = a_2$, then the extent of the bias from omitting father birth weight depends on the parameter c. If $c = 1$ and we omit BW_{Father} from (1′) then the estimated coefficient on BW_{Mother} will equal $2 \times a_1$. If $c = 0$, then the estimated coefficient on BW_{Mother} will be unbiased. Positive assortative mating suggests that $0 > c > 1$ so that the coefficient on BW_{Mother} captures some of the effect of the omitted father's birth weight. In fact, Cole (2000) finds that the correlation between mother's and father's heights is about .8. If the relationship between parents' birth weights is similar, then dividing the estimated coefficient on mother's birth weight by two provides a lower bound on the true effect of mother's birth weight on child birth weight independent of father's birth weight. On the other hand, if what we are interested in is the effect of the parent's endowments on the endowments of the children, then the fact that the mother's coefficient captures much of the effect of the father is perhaps an advantage of our procedures.

Along similar lines, some models of parental behavior suggest that compensatory resources will be directed to infants who are "weak" (or, in this context, those who are low birth weight). If this is the case, then the true effects of low birth weight will be understated (see Grossman 2000).

One final concern has to do with nonrandom selection. The women whom we include as giving birth in our California data are a subset of all the women born in California. Women who were born in California but who die, or never become mothers, or who give birth outside California, are not included in our analysis. The concern is of course that a woman's health at birth determines the probability that she appears in the sample. Royer (2005) shows that birth weight is positively related to the probability of being observed to give birth in our data, but that the effect is negligible. In particular, an increase in birth weight of 200 grams is associated with an increase in the probability of giving birth in California by 0.5 percentage points.[16] Royer concludes that this effect is small and likely to be inconsequential. Estimates of bounds that allow for nonrandom selection appear to confirm that selection is unlikely to introduce significant bias.

VI. Conclusions

We show that there is a strong intergenerational correlation in birth weight that does not seem to be due to omitted variables—women whose mothers were low birth weight are 50% more likely to be low birth weight themselves. This correlation persists when a rich set of controls including grandmother fixed effects and measures of income at the time of the mother's birth are added to the model. There is an interaction between maternal low birth weight and proxies for poverty in the production of low birth weight in the child: the intergenerational transmission of low birth weight is stronger for poor mothers than for other mothers.

We also find that mothers who were low birth weight are more likely to live in a high poverty zip code and have less education at the time of their own child's birth many years later. Again, these effects are stronger for mothers who come from more disadvantaged backgrounds and are weaker for mothers with higher socioeconomic status.

Together these findings suggest that intergenerational correlations in health could play a role in the intergenerational transmission of income. Proxies for parent's poverty affect child health at birth, and health at birth affects future poverty, income, and education. Although the estimated effects of low birth weight on future education and proxies for future income and poverty are modest, it is important to note that low birth weight is only a crude measure of health at birth and that poor children tend to accumulate health insults as they age at a faster rate than rich children. Moreover, to the extent that parents engage in compensatory behavior that is unobserved, we will underestimate the negative effects of low birth weight and other health shocks on future outcomes. Thus, the overall effect of health in childhood could be large.

[16] The effect appears nonlinear. It is only for mothers whose birth weights fell within the range of 1,500–3,000 grams that the probability of observation is an increasing function of birth weight.

Appendix

Table A1
Relationship between SES in Zip Code of Residence and SES in Zip Code of Hospital: Data for 1989–2001

	Correlations		Regression Coefficients Dependent Variable Is	
	Poverty in Zip Code of Hospital (1)	Income in Zip Code of Residence (2)	Poverty in Zip Code of Hospital (3)	Income in Zip Code of Hospital (4)
All:				
Poverty in zip code of residence	.475		.46 (.019)	
Income in zip code of residence		.549		.50
Whites:				
Poverty in zip code of residence	.471		.485 (.023)	
Residence income		.557		.497 (.019)
Blacks:				
Poverty in zip code of residence	.386		.385 (.026)	
Residence income		.374		.395 (.028)
Controls			Y	Y

	Poverty Quartile of Zip Code of Residence, 4 = Highest				
	1	2	3	4	Total
Zip code of hospital lowest poverty quartile	182,074	74,935	61,688	39,683	358,380
Zip code of hospital 2nd lowest poverty quartile	97,270	136,231	83,743	47,357	364,601
Zip code of hospital 3rd highest poverty quartile	46,296	91,462	134,805	77,787	350,350
Zip code of hospital highest poverty quartile	31,796	55,287	80,976	191,668	359,727
Total	357,436	357,915	361,212	356,495	433,058

Note.—Standard errors are in parentheses.

Table A2
Distribution of Distance between Zip Code of Residence and Zip Code of Hospital Based on 1989–2001 Data

	All (1)	Whites (2)	Blacks (3)
10th percentile	0	0	0
25th percentile	2.7	2.7	1.4
50th percentile	5.4	5.5	5
75th percentile	10.3	10.6	8.4
90th percentile	17.9	18.6	12.9

Note.—The unit of measurement is miles.

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