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“ The Returns to Increasing Body Weight ”

by

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The Returns to Increasing Body Weight

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Two major health-related policy objectives in most developed countries are to increase the birthweights of children in low-birthweight populations and to reduce weight or body mass among most adults. The impact of weight -- at birth and in adulthood -- as well as other physical attributes such as height on human capital investments and wages has also been the concern of a recent economics literature and of much bigger literatures in other disciplines.¹ Many low-birthweight infants who survive infancy, for example, are claimed to suffer cognitive and neurological impairment that limits the returns to human capital investments in them, their productivities and their earnings as adults, and that, for females, increases the probability of having low birth weight babies. Being overweight or obese, on the other hand, is claimed to reduce schooling and wages at least for white women in the United States, which some interpret to reflect discrimination.²

¹ ACC/SCN (2000), for example, cite 198 references in their survey on the determinants of and the impact of low birth weight. A number of other studies have focused on the effects of low birthweight have appeared in both the epidemiological and social science literatures (e.g., Alexander and Korenbrot 1995; Chomitz, Cheung and Liebermann 1995; Conley and Dalton 2000; Richards, *et al.* 2001, Shiono and Behrman 1995; Strauss 2000). One important indicator of longer-run nutrition that is claimed to be determined substantially by nutrition in the womb and in the early years of life is adult height, which has been used widely by economic historians as a measure of health, nutrition and standard of living (e.g., Fogel 1994, Steckel 1995). There also is a large literature on the negative effects of being overweight and or obese, particularly in the U.S. and other developed economies (e.g., Adamitis 2000, Everett 1990, Flegal, *et al.* 1998, Fraser 1994, Korn 1997, Larkin and Pines 1979, Mokdad, *et al.* 1999, Power and Parsons 2000, Rissanen 1996, Roehling 1999, Sarlio-Lahteenkorva and Lahelma 1999, Seidell 1998, Sobal and Stunkard 1989, Wolf and Colditz 1998), a subset of which has investigated the impact of weight on human resource investments and wages (e.g., Averett and Korenman 1996, 1999, Cawley 2000, Haskins and Ransford 1999, Gortmaker *et al.* 1993, Loh 1993, Págan and Dávila 1997, Register and Williams 1990, Sargent and Blanchflower 1994 -- as well as related literatures that consider the impact of height (e.g., *The Economist* 1996, Loh 1993, Margo and Steckel 1982, Sargent and Blanchflower) on wages, productivity, earnings, and the market value of slaves.

² Averett and Korenman (1996), Págan and Dávila (1997) and Roehling (1999), for example, note that the estimates in the literature may be due to weight discrimination, a possibility

There have been a number of studies that have identified the determinants of birthweight within the context of models that incorporate both heterogeneity and optimizing behavior and evaluated major policy changes in terms of their impact on weight at birth (Rosenzweig and Schultz 1983; Grossman and Joyce 1990; Rosenzweig and Wolpin 1994,1995; Currie and Gruber 1996; Currie and Hyson 1999). However, the literatures concerned with the consequences of weight gain at birth or in adulthood generally do not provide a clear interpretation of the observed linkages between physical characteristics, adult human capital investments and adult earnings. A problem with almost all prior studies of the consequences of birthweight variation, for example, is that the policy-relevant effects of increasing the nutrition received by a fetus and possible genetic influences on fetal development are not distinguished. It is possible that infants with genetically-determined low weights at birth also have genetic endowments that make them less healthy as adults, and that increasing their weights at birth would have little lasting effect beyond infant survival on adult life achievements. What are of policy interest are the effects of increasing the birthweight of a child or the body mass of an adult with given genetic endowments. Conventional cross-sectional and longitudinal data sets cannot answer that question unambiguously.

Generally researchers are inattentive to estimation problems that arise from endowment heterogeneity in assessing the effects of anthropometrics on adult human capital. Three recent

that also is discussed in the legal literature (Adamitis 2000, Korn 1997, Roehling 1999). Alternative, though not necessarily exclusive possibilities for an inverse impact of over weight or obesity on wages might be more work loss to greater illness and early retirement (e.g., Rissanen 1996, Seidell 1998, Wolf and Colditz 1998) or less productivity when working (e.g., Rissanen 1996, Seidell 1998). Finally, as explored in this paper, over weight may have no causal impact on wages but just be correlated with other attributes that are rewarded in labor markets.

exceptions to this generalization use data on relatives.³ Conley and Bennett (2000), using sibling data from the PSID, find that conventional estimates understate by 50% the negative impact of low birthweight on the probability of timely high school graduation.⁴ Averett and Korenman (1996), using the 1988 NLSY, find that the negative contemporaneous relationship between the Body Mass Index (BMI) and hourly wage rates for white and Hispanic women in the cross-section is higher in absolute value compared with the estimates obtained using sibling differences. Cawley (2000) also uses the NLSY to estimate the impact of BMI (as well as of weight and height separately) on the ln wages of women using the weight of a child as an instrument for the weight of the mother.

While these three studies recognize some aspects of the estimation problems that plague the previous literature, their resolutions of these estimation problems are incomplete. For example, the sibling-based studies ignore the responsiveness of resource allocations in the family to endowment differences. In particular, such estimates must assume that individual-specific endowment differences do not affect schooling and wages, contrary to the twins-based findings in Behrman, Rosenzweig and Taubman (1994), and that pre-natal input differences between siblings

³ Pagán and Dávila (1997) also recognize the possible endogeneity problem in their estimates of wage relations based on the NLSY (1989 wave) in which they find significantly negative coefficient estimates for BMI for both females and males. They conduct a Hausman test for endogeneity using as instruments health limitations, self-esteem, family poverty level in 1998, education, experience, race, ethnic group, marital status, school enrollment, region and occupation. This test failed to reject the null hypothesis of BMI's exogeneity. However this test is not persuasive because, given heterogeneity in earnings endowments, many of the instruments used would be correlated with the unobserved determinants of wages that are in the error term for the wage relation.

⁴ They also present individual level (i.e., not sibling) estimates that suggest a substantial and significant positive intergenerational birthweight link with both parents.

are orthogonal to endowment differences, contrary to the evidence in Rosenzweig and Wolpin (1995). Moreover, there are numerous claims that low income or poverty causes overweight or obesity particularly for women in societies such as the U.S. (e.g., Power and Parsons 2000, Sobal and Stunkard 1989, Stunkard 1996), so the negative coefficients between adult incomes and adult body mass reported in the second study may reflect reverse causality. Finally, no studies have linked increases in weight gain at birth to adult weight gain net of endowments. Indeed, the use of a child's weight as an instrument for maternal adult weight must assume that genetic endowments that are a component of body mass are uncorrelated with endowments related to ability and earnings.

In this paper we obtain improved estimates of the impacts of anthropometrics at birth and in adulthood on critical outcomes over the life cycle within a context in which individuals are born with health and earnings endowments that may be correlated with each other and across generations and optimally invest in health and earnings capacity. We construct a simple three-period optimizing model determining investments in human capital and physical characteristics that incorporates endowment heterogeneity. The model has two purposes: (i) to illustrate the difficulties in identifying the effects of at-birth and adult physical characteristics in the labor market and (ii) to show how both the distinct roles of endowments and of early health investments can be identified. We show in particular that with information on the birthweights of genetically identical twins it is possible, with fewer assumptions than are needed to identify schooling returns to earnings based on twins estimators (Ashenfelter and Krueger 1994; Behrman *et al.* 1994), to identify the causal effect of increasing birthweight on adult anthropometrics, schooling and earnings in the presence of endowment heterogeneity. Using the same assumptions employed in

studies of earnings determinants using twins-based data it is also possible to identify the presence of bias in the cross-sectional contemporaneous relationship between adult physical characteristics such as body mass and adult earnings that arises when optimizing behavior creates a correlation between human capital investments and endowments.

In our empirical work we use new survey data on female twins collected by the authors from a sample from the Minnesota Twins Registry, the largest birth-certificate-based twins registry in the United States. We focus on women in this paper because of the suggestion in most previous studies that the negative effect of adult weight gain in the labor market is largest for women and lack of sufficient weight for women at birth is claimed to cross generations (Averett and Korenman 1996, Gortmaker, et al. 1993, Haskins and Ransford 1999, Sarlio-Lahteenkorva and Lahelma 1999). In particular we look at the effects of increasing birthweight on schooling attainment, adult body mass, adult height and adult earnings, comparing estimates that control for endowment effects with those that do not to assess the confounding role of genetic influences. We also estimate (i) the extent to which the intergenerational relationship between birthweight is due to the heritability of body mass and (ii) the relationships between adult body mass and adult height and adult earnings net of the influence of endowment effects and compare these estimates to those obtained in the literature to assess the extent of bias. The estimates thus permit a reassessment of the true effects of efforts to increase birthweight among low-birthweight populations and to reduce obesity on labor market returns.

Our estimates provide a number of clear results. First, they indicate that increasing fetal growth, for given endowments, has a significant positive effect on subsequent schooling attainment, with our preferred estimate indicating that augmenting a child's birthweight by a

pound increases schooling attainment by about a third of a year. The effect of increasing birthweight on schooling, moreover, is underestimated by 50% if there is no control for genetic endowments as is the case for cross-sectional estimates. This suggests that either nutrient consumption is negatively correlated with genetic endowments or that health and ability endowments are negatively correlated. Second, our estimates indicate that intrauterine nutrient consumption does not have effects that persist to affect significantly adult BMI - increasing birthweight is not a cause of adult obesity. Third, the estimates indicate that the genetic birthweight endowment also is the component of birthweight that plays the dominant role in the intergenerational correlation of birthweights. Fourth, the estimates indicate that, in contrast, intrauterine nutrient consumption plays the dominant role in determining adult height, consistent with the literature that makes use of height statistics to gauge childhood nutritional investments over time and across countries (Fogel 1994, Schultz 1999, Steckel 1995, Strauss and Thomas 1998). Fifth, our estimates indicate that the significant inverse association between adult BMI and wages found in cross-sectional estimates solely reflects a correlation between unmeasured earnings endowments and BMI, and disappears with control for endowments common to monozygotic (MZ) twins. Sixth, the significant positive association between adult height and wages found in cross-sectional estimates is increased substantially with control for endowments. There is thus evidence that augmenting birthweight in low-birthweight populations, which evidently increases both adult schooling attainment and height, has real labor-market payoffs, while the returns to controlling adult body mass in high-income settings may be illusory, at least in terms of labor market consequences for adults of prime labor-force age.

1. Identification of the Returns to Weight Gain

a. A behavioral model

We construct a simple three-period optimizing model determining investments in human capital and physical characteristics that incorporates correlated endowments for earnings and physical traits. The first period corresponds to pre-school in which nutrients that affect physical attributes are allocated. In the second period schooling and nutrient resources are allocated, and in the third period the individual also chooses nutrient levels and is in the labor market, where both schooling and possibly physical attributes have payoffs. There are three *correlated* endowments in the model - a persistent physical endowment B_0 , an earnings endowment μ (earnings ability), and income I that is determined, for example, by one's parents. The model has two purposes: (i) to illustrate the difficulties in identifying the effects of adult physical characteristics in the labor market and (ii) to show how both the roles of endowments and of early health investments can be identified.

We assume that, for each individual, the function (1) is maximized:

$$(1) \quad E(V) = U(C_1, X_1, B_1) + \delta U(C_2, X_2, B_2) + \delta^2 EU(C_3, X_3, B_3),$$

where C_i = nutrient consumption in period i , X_i =other consumption, B_i =the individual's physical attribute (body weight, height) in period i , and δ is the discount rate. The physical attribute in each period depends on contemporaneous consumption and the value of the physical attribute in the previous period, as given by the function

$$(2) \quad B_i = b(B_{i-1}, C_i), i=1,2,3,$$

where B_0 is the physical attribute endowment.

In the second period, the individual may allocate resources H to investment in schooling S , which has a payoff in the third period. The schooling function is given by

$$(3) \quad S = s(B_2, C_2, H, \mu),$$

where we assume that nutrient consumption, physical attributes and the earnings endowment may also contribute to schooling.⁵

The wage function in the third period is

$$(4) \quad \ln W_3 = \beta S + \gamma B_3 + \mu + v,$$

where β is the return to schooling, γ is the effect of the physical attribute and v is an exogenous, stochastic earnings shock that is not known to the individual in the first two periods and whose realizations are orthogonal to the endowments. If resources can be transferred between periods two and three only through schooling investments, the budget constraints are thus

$$(5) \quad I = C_1 + C_2 + p_H H + p_x (X_1 + X_2)$$

$$(6) \quad W_3 = C_3 + p_x X_3,$$

where p_H is the per-unit price of the effective schooling resource and p_x is the price of the X good

The solution to the maximization problem yields a set of period-specific decision rules expressing the choice variables as functions of the exogenous variables known to the decision-maker inclusive of endowments:

$$(7) \quad Z_i = Z_i(p_H, p_x, I, B_0, \mu), i=1,2$$

$$(8) \quad Z_3 = Z_3(p_H, p_x, I, B_0, \mu, v),$$

where $Z_i = C_1, C_2, X_1, X_2, B_1, B_2, H, S$, and $Z_3 = C_3, X_3, B_3, W_3$.

b. Identifying pre-birth nutrient intake effects and endowment influences on adult outcomes

⁵We can allow independent shocks to physical attributes and schooling in (2) and (3) without altering conclusions. We suppress them to reduce notational clutter.,

We now show it is possible using information on the birthweights of MZ twins to identify (i) the effects of an exogenous increase in early (intrauterine or first-period) nutrient consumption on schooling, adult (second-period) physical characteristics or adult wages and (ii) the existence of confounding endowment effects on these variables that renders the identification of the effect on the adult wage of variation in adult physical characteristics seemingly impossible, as in the model here. The key identifying assumption is that while the average of the nutrient intakes for the twins may be correlated with their common endowment, the birthweight difference within an MZ twin-pair reflects purely random differences in nutrient intakes, broadly defined - twin-specific intakes that are expressed in birthweight differences are orthogonal to their identical endowments. Consider function (2) the time of birth in the first period linearized and expanded to distinguish between common and specific nutrient intakes for each twin in a pair, where B_{1jk} is birthweight for twin j in twin-pair k :

$$(9) \quad B_{1jk} = C_{1jk} + C_{1k} + B_{0k}.$$

The model suggests that $\text{cov}(C_{1k}, B_{0k})$ is non-zero due to optimizing behavior as long as mothers, who can choose the average or common level of inputs, either know B_{0k} or know μ_k and μ_k and B_{0k} are correlated. However, differences in the twin-specific intakes C_{1jk} cannot be functions of the B_{0k} 's.

To illustrate the identification problem and the solution using twins, consider a linear representation of the log wage function (4) for twin j in pair or family k in which B_3 , H and thus S are solved out in terms of its determinants, given by (3) and (7), and using (9):

$$(10) \quad \ln W_{3jk} = \alpha_1(C_{1jk} + C_{1k}) + \alpha_2 B_{0k} + \alpha_3 I_k + \alpha_4 \mu_k + \alpha_5 p_H + \alpha_6 p_x + v_{jk},$$

where the α 's are coefficients and v_{jk} is a random, twin-specific error. Now, neither the nutrient

inputs nor the endowments are observed in (9) and (10), only birthweights. However, if we substitute for the unobserved inputs in (10) observed birthweight using (9) and difference across the twins, thus eliminating all of the common terms in (9) and (10), we get the simple difference regression

$$(11) \quad \Delta \ln W_{3jk} = \alpha_1 \Delta B_{1jk} + \Delta v_{jk},$$

where Δ is the twin difference operator. Another way of showing that the effect of nutrient consumption on schooling is identified using MZ twin pairs is to examine the observed moments expressed in terms of the unknown variables and coefficients. In particular, the regression coefficient in (11) is $\text{cov}(\ln \Delta W_{3jk}, \Delta B_{1jk}) / \sigma^2(\Delta B_{1jk})$, where

$$(12) \quad \text{cov}(\Delta \ln W_{3jk}, \Delta B_{1jk}) = \alpha_1 \sigma^2(\Delta C_{1jk}) \text{ and}$$

$$(13) \quad \sigma^2(\Delta B_{1jk}) = 2\sigma^2(\Delta C_{1jk}),$$

which can be solved for α_1 .⁶

In contrast, the coefficient obtained from a cross-sectional regression of the log wage on birthweight across non-identical individuals or siblings neither identifies the effect of variation in nutrient intake nor provides insights into the roles of endowments in input choices. To see this, note that the regression coefficient in this case is $\text{cov}(\ln W_{3jk}, B_{1jk}) / \sigma^2(B_{1jk})$, which is given by

$$(14) \quad [\alpha_1(\sigma^2(C_{1jk}) + \sigma^2(C_{1k}) + \text{cov}(C_{1k}, B_{0k})) + \alpha_2(\sigma^2(B_{0k}) + \text{cov}(C_{1k}, B_{0k})) + \alpha_3(\alpha_1 \text{cov}(B_{0k}, \mu_k) + \text{cov}(C_{1k}, \mu_k))] / [\sigma^2(C_{1jk}) + \sigma^2(C_{1k}) + \text{cov}(C_{1k}, B_{0k}) + \sigma^2(B_{0k})].⁷$$

It is clear from (14) that a regression of wages on birthweight does not identify the effect α_1 of

⁶Note that we have made use of the assumption that first-period choices are made in ignorance of adult wage shocks v .

⁷For simplicity, we have dropped the price and income terms from (14), which are presumably observables.

increasing nutrient intake on wages, and indeed, depending on covariances between endowments and the response of inputs to endowments, the sign of the regression coefficient could be opposite that for α_1 .

The contrast between the cross-sectional relationship between birthweight and the wage, given by (14), and the effect obtained using the within-MZ estimator, which provides α_1 , can provide some information on the existence of *genetic* endowment effects. This is because if there were no genetic influences - no effect of variation in B_0 - the cross-sectional and within-MZ estimates would be identical, as seen in (9). Two comparisons of the cross-sectional and within-MZ estimators are of particular interest. First, one may find from the within-MZ estimator that α_1 is positive while the cross-sectional birthweight effect (14) is zero. In that case it must be true that, assuming that both the birthweight and earnings endowments positively contribute to earnings ($\alpha_2, \alpha_3 > 0$), either the birthweight and earnings endowments are negatively correlated or nutrient intakes are provided less to those with higher endowments, or both. A second polar case is when α_1 is zero, such as in expression (2) for the adult period. In that case the cross-sectional birthweight relationship solely arises from endowment-allocation effects and covariances.

c. Adult wages and adult physical characteristics

Identification of the effects of adult physical characteristics on wages, given heterogeneity in endowments, is also difficult even with twins data. To highlight the potential spurious contemporaneous relationships between physical characteristics and earnings assume that the physical characteristic B_3 does not have a direct effect on second-period earnings - employers do not care about physical traits - so that $\gamma=0$. Nevertheless, W_3 and B_3 will be correlated across individuals or siblings who do not have identical genetic endowments, even “controlling for”

schooling. There are three reasons. First, a positive shock to wages increases third-period consumption, from (6) which, from (2), increases B_3 . This is the reverse causation discussed by Cawley (2000). Second, the endowment component B_0 of the physical characteristic may be correlated with the earnings endowment μ . The sign of this correlation is unknown - individuals who are inherently more attractive may have higher or lower endowed ability, and those with a propensity for greater heft may also be more or less able. Third, as can be seen by substituting (8), for $Z=C$, into (2) both B_3 and the wage are functions of the unobserved earnings endowment μ . As noted also by Cawley, therefore, differencing (4) across sisters, as in Averett and Korenman (1996), neither eliminates completely the endowments, and thus their joint influence on B_3 , S and W_3 , nor deals with the problem of reverse causation.

Does the model suggest any instruments that could be used to identify the true effects of both schooling and the physical characteristic on the wage in the absence of direct measures of the endowments? It might appear that first- or second-period nutrient consumption is a valid instrument, because consumption prior to the third period is not affected by the wage shock - exogenous changes in the third period wage do not affect C_1 or C_2 - and the third-period physical characteristic is a function of lagged consumption in (2). However, the correlation between C_1 , C_2 and B_3 is also due to the fact that all are correlated with the endowments B_0 and μ . Similarly, the first-period physical characteristic B_1 will not be a valid instrument, although it will “predict” B_3 , because it depends on C_1 which is correlated with B_0 and ability μ . Income I will also not be a valid instrument if that endowment is correlated with the earnings endowment. For example, we can think of I as representing parental income and μ the “child’s” ability. If ability is heritable and affects schooling, then parental income (or their schooling) will not be a valid instrument for the

outcomes S or B_2 in (4). Conversely, using a child's traits (e.g., B_0) as an instrument for his/her parent's outcomes, as in Cawley (2000), has the same problem as an instrument if endowments are heritable and correlated.

Differences between MZ twins have been used to identify schooling effects in the presence of unmeasured ability. Indeed, we have constructed the model so that a within-MZ twin estimator would deliver a consistent estimate of β . This is because in the model the wage shock v is unknown at the time the schooling decision is made, so that the only potential source of bias in β is due to the fact that schooling depends on the earnings endowment, which is swept out using the within-twin (but not the within-sister) estimator. If the physical characteristics were also unaffected by contemporaneous wage shocks, then within-MZ estimates of γ would also be unbiased. One example is adult height, which for prime-age adults is not sensitive to contemporaneous consumption; i.e., for height $\partial B_3 / \partial C_3 = 0$ in (2). If, however, as for weight or body mass, B_3 depends contemporaneously on consumption, even a within-identical twin estimator would yield a biased estimate of γ net and gross of schooling if consumption is responsive to income. With endowments swept out by the within-MZ estimator, however, it is possible to use lagged consumption or the lagged physical characteristics as an instrument. In the model, for example, B_3 depends structurally on C_2 and C_1 (or B_2 and B_1) net of endowments and none of these variables is affected by the wage shock, which is unknown at the time of the allocation decisions.

2. Data

To explore the relationships between physical characteristics, schooling and earnings with particular attention to the roles of endowments and input choices, we use information from a

recent survey of twins. The twins data were obtained by resurveying a subset of the twins from the Minnesota Twin Registry (MTR) based on a survey instrument designed by us in collaboration with the Temple University Institute of Survey Research. The MTR is the largest birth-record-based twins registry in the United States, assembled between 1983 and 1990 starting with birth records on all twins (both monozygotic, MZ, and dizygotic, DZ) born in Minnesota in 1936-55. Details of the sample and its characteristics are in Lykken, *et al.* (1990). The MTR staff obtained from the Minnesota State Health Department all birth certificates reporting multiple births. These birth certificates provide information on both the birthweights and the gestation of the twins. The MTR staff located over 80% of the twins and sent them a four-page Biographical Questionnaire (BQ) in the mid 1980's with an introductory Newsletter describing the project and a letter signed by Minnesota's governor urging participation.⁸ 80% of the individuals contacted, 71% of concordant pairs, supplied information for the BQ.

Our survey instrument was mailed out in May 1994 to the 5862 members of same-sex pairs who had filled out the BQ and for whom the MTR had current addresses. An additional 776 members of same-sex pairs for whom updated addresses had been located between May and September 1994 were sent questionnaires in November 1994. 3682 twins returned a completed questionnaire, for a response rate of surviving twins of over 60%. Information obtained included the height and weight of the twins at the time of the survey, their schooling attainment, their work experience and wages on the last job, a retrospective history of smoking and alcohol

⁸ Among the first six birth cohorts studied (birth years of 1936, 1937, 1938, 1949, 1954, and 1955) 27% of the same-sex pairs identified through birth certificates are known to have been broken by the death of at least one of the members prior to our survey.

consumption, and the birthweights for their first four children.⁹ The estimates in this paper are based principally on the returned questionnaires from (i) all women (MZ and non-MZ twins) and women in MZ twin pairs for which the key birthweight, gestation, and self-reported height, weight and earnings variables are available, totaling 1518 and 808 women, respectively.¹⁰ In addition, we look at the birthweights of the first-born children of the twin mothers and make use of the self-reported information on height and weight from the BQ as instruments.

As discussed, by comparing the cross-sectional and within-MZ estimates of the relationship between weight at birth and adult outcomes, we can identify the effects of health inputs on and the role of endowments in determining adult earnings. Such estimates thus help understand the complex relationship between adult physical characteristics and adult earnings. There are two features of the data that are particularly relevant to the analysis of birthweight effects on adult outcomes. First, the birthweight information is based on measures from birth certificates, and thus the birthweights for the twins are not subject to recall error. Moreover, because the birthweights of twins are assessed at the same time and by the same measurer, most of the measurement error will be common to the twins and thus will be eliminated using within-twins estimators. The second feature of the sample, and of twins in general, relevant to the

⁹ The item response on returned questionnaires is very high, exceeding that on recent Current Population Surveys and the 1990 Census. For example, only 9% of ever employed workers in our sample did not answer the questions on earnings or self employment income; on the CPS more than 20% do not.

¹⁰ It is possible that this twins sample is not representative of all United States' females belonging to the same birth cohorts. Clearly there may be selectivity associated with being born in Minnesota, both siblings reporting all relevant data, or being a MZ twin. However, in Behrman and Rosenzweig (2000) we show using 1990 census data that the comparable schooling and earnings characteristics of the intact MZ twin pairs and the population of individuals residing in Minnesota in 1990 are quite similar.

identification of birthweight effects is that there is substantial variation in birthweight between genetically-identical twins, variation that is not correlated with their common environment (the womb) or genes. In our sample, the average absolute value of the difference in birthweights within pairs of MZ twins is 10.5 ounces.¹¹ The corresponding figure for same-sex non-identical twin pairs is 11.2 ounces. Thus there is ample within-twin variation to obtain precise estimates of birthweight input effects using twin difference methods.

For each twin we have constructed a measure of fetal growth based on the birth certificate information - birthweight divided by gestation. We will use this measure rather than birthweight in obtaining our estimates for two reasons. First, the literature has suggested that this measure better reflects the healthiness of a child, as the leading proximate cause of low birthweight in the United States and other developed countries is pre-term births (ACC/SCN 2000, Strauss 2000). In our sample, 20.5% of the twins were, by the standard definition (less than 37 weeks of gestation), “pre-term” births. Second, while within-twin differences in birthweight are by definition for the same gestation, variation in birthweight across non-twin births also reflects variation in gestation. Normalizing birthweight by gestation makes the two estimates comparable.¹²

To identify the contemporaneous effects of weight and height on earnings using within-twin methods requires that there also be significant differences between twins in anthropometrics.

¹¹Having a greater birthweight in a twin pair is not correlated with being first-born. The average difference between first- and second-born twins in our sample is a statistically insignificant .5 ounces.

¹²We could make the cross-sectional and within-twin estimates of birthweight comparable by also including gestation in the cross-sectional specifications, but the birthweight coefficient would then in any case reflect fetal growth. Estimates of the effects of variation in birthweight in which gestation is included as a separate variable do not differ importantly from the fetal growth estimates reported here.

Such differences also appear to be significant - the average absolute values of the differences in adult height and weight between MZ twins in a twin pair are 1.45 inches and 20 pounds, respectively. Some of these differences may reflect measurement error, however. Unlike for birthweight, schooling, height and weight information is derived from self-reports rather than from direct measurement or independent records. The measurement error in these reports would induce bias in the estimates even if anthropometrics and schooling were uncorrelated with endowments, particularly for estimates based on within-twin pair differences (Bishop 1976, Griliches 1979). However, as in the twins data sets used by Ashenfelter and Krueger (1994), the Minnesota twins survey provides information on respondent schooling from two sources - the respondent and the respondent's twin. There are also two respondent contemporaneous self-reports for height and weight separated by an interval of 8-10 years - from the 1994 survey and from the BQ. The twin cross-reports on schooling and the time-lagged BQ self-reports on height and weight can be used as instruments to eliminate the bias due to measurement errors in the self-reported 1994 schooling and anthropometric variables, as well as to eliminate the reverse causation bias in weight or BMI given the absence of strong degree of persistence in the wage shocks net of endowments.¹³

Another important feature of the survey is that, to maximize the size of the sample of female twins that could be used for analysis, in recognition of the intermittent labor-force

¹³We rely also on the assumption, as in classical errors-in-variables models, that the own and lagged report errors are independent. Note that if there is a permanent component to the measurement errors that is common to the twins, the within-MZ estimators eliminates this source of intertemporal measurement error correlation. The classical assumptions are thus more likely to hold for within-MZ estimators, although the consequences of them not holding are more severe compared with OLS.

participation of women, the earnings on the last job was elicited rather than only earnings in the year prior to the survey. A well-known problem in analyzing the wages of women is that at any given survey date many women may not be in the labor force, resulting in a selective sample of female earners (Gronau 1974, Heckman 1974). Only 82% of the women in the sample, for example, worked in 1993, the survey reference year. But 97% of the sample members worked at some point in their lives, 91% in the five years preceding the survey. Finally, to take into account the variability in work time during the year in which earnings are reported, the wage, earnings and time-worked information was used to construct full-time annual earnings based on either earnings in 1993 or on the last job, inflated in the latter case by the relevant CPI.

Table 1 reports descriptive statistics for the two samples of female twins. As seen in Table 1, the twins have considerably lower average birthweight (5 pounds and 10 ounces) compared to the general population (7 pounds and 6 ounces). By the standard definition of low birthweight - below 5 pounds and 8 ounces (2.5 kgm) - almost half of the twins were low birthweight. This appears to be the result of twinning rather than the selectivity of mothers who produce twins. Figure 1 displays the average birthweights of the twins who are mothers, the birthweights of their first-born children (almost none of whom are twins themselves) and the average birthweights of the first-borns of white mothers in the 1998 NLS. As can be seen, the average birthweight of the children of the twins, 7 pounds and 6 ounces, is the same as that of the children of non-twin mothers in the general population.¹⁴ Moreover, the adult body mass index (BMI) of the twins themselves is also comparable to that of the general population in the United States. Indeed, like

¹⁴This is not because the twins who are mothers had higher birthweights than the twins who did not have any children. Indeed, the mean birthweight of the twin mothers was 3 ounces less than that of the total sample of female twins.

that population, the group is on average “overweight”. The international standard for being overweight is for the BMI, expressed using the metric system, to be 25 or higher (Sarlio-Lahteenkorva and Lahelma 1999, Flegal *et al.* 1998). 42.8% of the female twins exceed this threshold, and 16.6% would be considered by these standards to be “obese”, the standard for obesity being a BMI 30 or higher.

3. Estimates

a. Fetal Nutrient Intake Effects on Human Capital, Physical Attributes and Earnings

Table 2 reports OLS and within-MZ estimates of the relationships between fetal growth and, in the order of the table, subsequent adult schooling attainment, adult BMI, adult height, and the log wage based on equation (10) for the four dependent variables.¹⁵ The estimates for schooling in the first two columns indicate that, whatever the estimation procedure, a child’s fetal growth and his or her subsequent schooling attainment is significantly and positively related. However, the OLS estimate understates α_1 for schooling attainment by more than 50%. This suggests that in the population either human capital inputs tend to be negatively correlated with health endowments or that health and ability endowments are negatively correlated. The within-MZ point estimate of α_1 indicates that efforts taken by a mother to increase fetal growth such that birthweight is increased by one pound at birth (an increase in fetal growth of .4 ounces per week)

¹⁵Appendix Table A reports within-MZ estimates of the effects of “low” birthweight as conventionally defined and as employed in many studies of birthweight consequences, on the same set of dependent variables with the fetal growth measure included and excluded. These estimates suggest that the continuous birthweight specification dominates - in no case was the coefficient on the indicator of low birthweight statistically significant when fetal growth was also included in the specification. Richards *et al.* 2001 also find that birthweight is positively correlated with adult outcomes above the low birthweight threshold, although these results are based on cross-sectional estimates.

result in almost a third of a year more of schooling.

The results for BMI suggest clearly that genetics play a role in BMI. The within-MZ estimate of α_1 for body mass is essentially zero - fetal inputs that increase birthweight (and schooling attainment) do not result in additional body fat later in life. Thus the sole reason for the positive association between fetal growth and adult BMI is evidently the influence of genetic endowments, as indicated by expression (14).¹⁶ This suggests that increasing birthweight, for given genetic endowments, does not result in obesity for the child later in life. However, increasing birthweight does result in increased adult height. The within-MZ point estimate, which is not different from the OLS estimate, suggests that a one-pound increase in birthweight brought about by increased womb nutrients would increase adult height by .6 inches. Finally, the within-MZ point estimate of the reduced-form effect of fetal growth on the wage indicates that augmenting a child's birthweight by a pound increases her adult earnings by over 7%. That increasing fetal growth and birthweight increases earnings is not surprising given the estimates suggesting that increasing birthweight increases schooling. However, the OLS estimate of the fetal growth-earnings relationship indicates the absence of any correlation between fetal growth and the wage. This is also consistent with the results in the first column suggesting a general negative correlation between the genetic component of birthweight and ability endowments or inputs. These relationships and variation in endowments in the population evidently obscure the fact that increasing fetal growth augments human capital and earnings.

b. Identifying the Genetic Component of the Intergenerational Correlation in Birthweight

¹⁶This result is consistent with the findings in the literature on the heritability of adult BMI based on adoptions, MZ twins reared apart and comparisons of MZ and DZ twins (Vogler, *et al.*, 1995; Allison *et al.*, 1996; and Herskind *et al.*, 1996).

Another way of assessing the importance of the genetic component of physical characteristics and their heritability is to examine the association between a mother's weight at birth and her children's birthweight, controlling for inputs that affect birthweight. The reduced-form correlation between maternal and child birthweight reflects both the heritability of endowments and the fact that the mother's birthweight may affect her choices of inputs that affect her child's birthweight. For example, we have seen that higher birthweight is associated with higher schooling levels. If more educated mothers make different investments in fetal development (in part because they marry more educated husbands), then this will be reflected in the intergenerational birthweight correlation. Thus, to isolate the genetic correlation we need to control for inputs. Indeed, one way to test whether most if not all variables affecting birth outcomes are accounted for is by estimating the intergenerational effect of birthweight across mother's who are identical twins. What remains in the maternal birthweight difference, as we have discussed, is only that part of birthweight that reflects different inputs, which are not heritable. These can only affect the children's birth outcomes by either influencing input choices made by the mother while she is pregnant or by influencing the heritable endowment of the father via the marriage market (e.g., through the schooling effect). To the extent that assortative mating by endowments is strong, this latter effect will be negligible.

We have three variables that have been proposed as possible behavioral determinants of birthweight - smoking by the mother while pregnant, alcohol consumption by the mother while pregnant, and having a child as a teen. Only the first variable appears to be robust to estimation procedures that have been employed in the prior literature, but we include all three variables to assess the robustness of our results. As indicated in the model, and has been emphasized in the

literature on birthweight determination (e.g., Rosenzweig and Schultz 1983, Grossman and Joyce 1990, Rosenzweig and Wolpin 1994), input choices may be correlated with endowments. The within-MZ estimator eliminates the role of the mother's endowment, but the cross-sectional-based estimates do not. To assess to what extent our inferences about the intergenerational relationship between maternal and child birthweights are sensitive to the treatment of input effects we employ OLS, two-stage least squares (2SLS) and the within-MZ estimation procedures. We use as instruments for the smoking and alcoholic drink variables the prices of cigarettes and the state beer tax in the states of residence of the twin mother when she was aged 25, 30 and 35 based on the annual time-series, by state, of cigarette prices and beer taxes used in Becker, Grossman and Murphy (1994) and Grossman, Chaloupka and Sirtalan (1998).¹⁷

Table 3 reports the OLS, 2SLS and within-MZ estimates of the effects of the mother's fetal growth on her first child's birthweight, controlling for a key determinant of birthweight - maternal smoking while pregnant - and also her alcohol consumption while pregnant and whether or not the mother was a teenager. Both the OLS and 2SLS estimates indicate that net of the mother's smoking behavior and her alcohol consumption while pregnant, her own fetal growth and her child's birthweight are significantly and positively associated. The point estimates suggest that a one pound increase in the mother's birthweight is associated with a 2.3 to 2.8 ounce increase in her (first) child's birthweight. Differencing out the common genetic and input components of birthweight for the two twin mothers, however, completely eliminates the

¹⁷Note that we do not use parental earnings or schooling as instruments. If endowments are heritable and schooling and earnings are correlated with endowments, as in the model, then these are not valid instruments. Maternal schooling and income were used as key instruments by Rosenzweig and Schultz (1983) in their study of birthweight determination.

relationship between the mother's birthweight and her child's birthweight. This result is consistent with the hypothesis that the intergenerational correlation in birthweight is genetic in origin and the lack of importance of any omitted birthweight inputs correlated with differences in the twin mother's weight at birth induced by greater inputs by her mother. Note that the coefficient of the smoking input does not change in magnitude and is still measured precisely despite the reduction in degrees of freedom using the within-MZ estimator. This latter result suggests that smoking behavior during pregnancies is not strongly correlated with the mother's birthweight endowment.

c. Do Employers care about BMI and Height?

The preceding results suggest that (i) early nutrient intakes, for given endowments, induce subsequent human capital investments and result in higher adult earnings and (ii) the genetic component of birthweight, which strongly predicts both an adult's body mass and her children's birthweight, is negatively associated with either human capital investments or with ability. The latter finding suggests that the relationships between adult body mass and height, attributes of adult physical appearance, and human capital or wages may also reflect the role of correlated endowments and optimal input responses to endowments rather than employer direct valuations of body mass or height. To investigate whether employers directly reward or punish weight and height, net of observed human capital attributes and unmeasured endowments and net of the possible effects of income on weight, we estimate a log wage equation including body mass and height using OLS, within-MZ and within-MZ with instruments estimation procedures.

The first column of Table 4 reports the OLS log wage estimates including only the adult anthropometric variables. These estimates conform to those found in the literature - BMI is negatively correlated with the wage - women with a larger body mass are paid less - while women

who are taller are paid more. The OLS point estimate for BMI (-.006), moreover, is almost exactly the same as that found by Cawley (2000) using OLS (selectivity-corrected) based on women in the NLSY (-.005). When the observable human capital variables schooling and full-time actual work experience are also included in the wage regression as in column two, however, the coefficient estimates for both BMI and height are reduced by over 50% - evidently taller and lighter women have more accumulated measurable human capital.

The within-MZ estimates reported in column three, which remove the influences of permanent but unmeasured earnings endowments, indicate that height still commands a labor-market premium but that BMI has a statistically insignificant *positive* effect on the wage. These results as well as those in Table 2 suggest that the endowed or genetic component of weight, measured at birth or in adulthood, is also negatively associated with earnings (ability) endowments. However, it is possible that BMI is higher among high-wage earners with the same endowments and accumulated human capital because increased wages induce more consumption. Moreover, as noted measurement error in height, weight and schooling self-reports may also bias the within-estimates. The fourth column of Table 4 reports the within-MZ estimates that employ the twin cross-reports of schooling and the lagged BQ weight and height self-reports as instruments.¹⁸ In this specification, height has a statistically significant and strong effect on wages. However, the estimates imply that the effect of increasing body mass on wages is essentially zero. There is thus no credible evidence that employers directly penalize workers who have greater body mass but who have the same productivity endowments.

4. Conclusion

¹⁸Table B in the Appendix reports the first-stage within-MZ estimates.

In this paper we have used data on female twins to estimate the relationships among fetal growth, adult physical characteristics and adult schooling and wages. We developed a simple model of life-cycle resource allocations incorporating endowment heterogeneity to show in particular the difficulties in identifying the effects of adult physical characteristics on labor market outcomes. However, we also demonstrated that difference in birthweights between identical twins can be used to identify the life-cycle consequences on physical attributes, schooling and earnings of increasing fetal nutrient intake, for given endowments. Our empirical results contain five main findings. First, we find that there are real payoffs to increasing body weight at birth. Increasing birthweight increases adult schooling attainment, adult height and earnings. Second, increasing birthweight does not, however, lead to increased adult body mass or obesity. Third, correlations between birthweight or adult body mass and adult outcomes that do not account for endowment heterogeneity (i) understate considerably the beneficial returns to early interventions that increase fetal growth, (ii) overstate the consequences of higher birthweight for adult obesity, and (iii) overstate the negative consequences of increased adult body mass on earnings. These biases arise evidently because the genetic and family environmental factors associated with body mass are negatively correlated with both human capital investments and with endowments that augment earnings and human capital. Fourth, in contrast, correlations between adult height and adult wages that do not account for endowment heterogeneity understate the positive effect of increased adult height on earnings. Finally, we find that birthweight has a significant heritable component that is reflected in an adult's body mass and in the birthweight of her children.

Our estimates have some important implications for policy. The significantly positive effects of fetal growth on schooling and adult height support programs that serve to increase

weight at birth, such as Medicaid (Currie and Gruber 1996), and the use of public resources to do so from an efficiency perspective if schooling has positive externalities as usually is assumed. In particular, the discouragement of smoking while pregnant would have real benefits for children that extend beyond survival chances - our estimates suggest, for example, that a mother who smokes one pack of cigarettes per day reduces the lifetime earnings of her child by over 10%. Moreover efforts to increase birthweight, to the extent they have been successful, are not the cause of the increased incidence of obesity among adults. However, our findings do not indicate any support for policies increasing fetal growth on the grounds of intergenerational nutritional links between mothers and their children.

Our estimates of the relationships between adult anthropometrics and wages suggest that alleged inverse effects of overweight and obesity are an artifact of the estimation procedures that have been used in previous studies. While BMI by itself may signal to employers about other productivity-related characteristics such as endowed ability, once there is control for earnings endowments, height, schooling and work experience, there is not evidence that employers discriminate against overweight or obese individuals. Moreover, our finding that a person's height, net of the influence of genetic endowments and family factors that increase earnings and net of body mass, schooling and work experience, is positively associated with earnings does not imply that employers favor height *per se*. Our estimates suggest that increased adult height, unlike increased adult body mass, reflects greater childhood nutritional intakes, so that among observationally identical individuals, even among those sharing the same set of genes and family background, those who are taller may be more productive workers.

Finally, the incidence of twin births is growing with the increased use of medical

procedures that augment fertility among older women. Our findings suggest that such procedures to the extent that they increase multiple births impose non-trivial costs on children's subsequent development. On average twins have 28 ounces less birthweight than singletons, which our estimates indicate translates into a reduction in lifetime earnings for such children of over 12%.

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Figure 1
Average Birthweights (oz.):
Twins, their First-Borns and White NLSY79 Mothers' First-borns

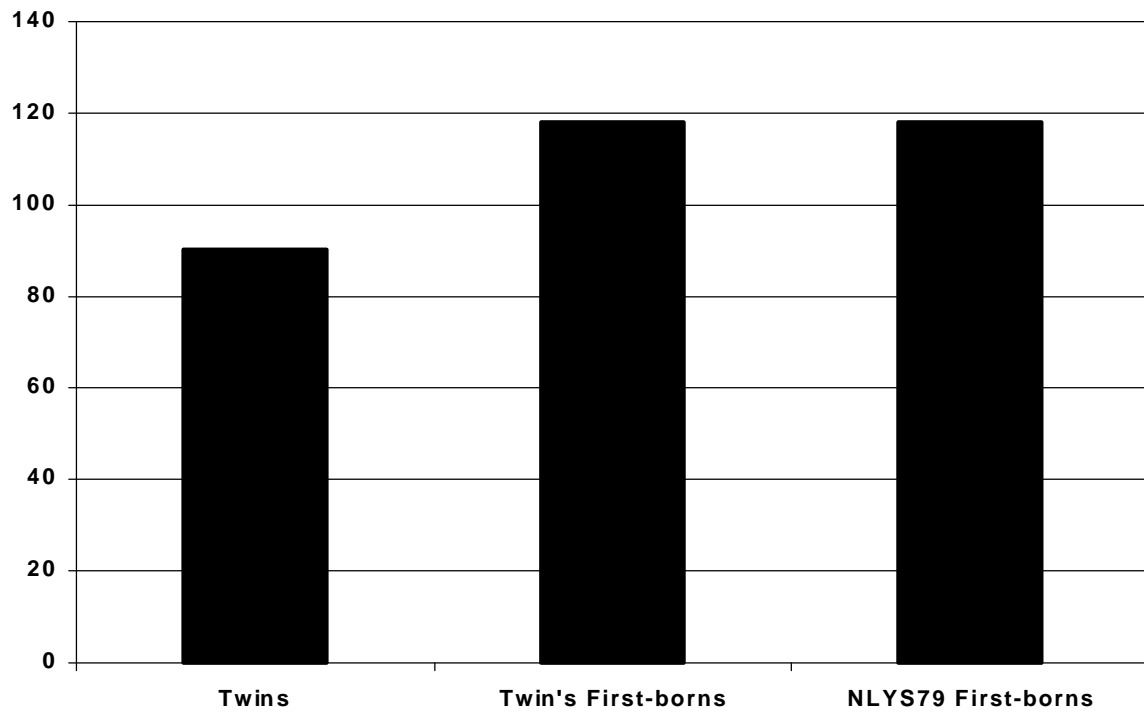


Table 1
Means and Standard Deviations

	Mean	Standard deviation
All female twins (N=1518)		
Fetal growth: ounces per week of pregnancy	2.34	.420
Birthweight (ounces)	90.2	17.9
BMI: pounds per square inch	.0361	.00739
BMI: kilograms per meter squared	25.4	5.20
Height (inches)	64.6	2.70
Weight (pounds)	150.9	33.0
Schooling (years)	13.8	2.20
Hourly wage (1993 \$)	11.45	7.20
Age	45.6	5.46
Female twins with at least one child (N=1201)		
Birthweight of first child (ounces)	118.1	19.7
Packs of cigarettes mother smoked per week while pregnant	.337	.590
Number of days per week alcoholic drinks were consumed while pregnant	.901	1.28
Mother was a teen at first birth	.109	.312

Table 2
OLS and Within-MZ Twin Estimates of Fetal Growth on Own Schooling Attainment, BMI, Height and the LnWage

Variable	Schooling		BMI		Height		LnWage	
Estimation procedure	OLS	Within-MZ	OLS	Within-MZ	OLS	Within-MZ	OLS	Within-MZ
Fetal growth	.309 (2.09) ^a	.786 (3.29) ^b	.00110 (2.16) ^a	.000109 (0.13) ^b	1.49 (7.66)	1.48 (6.04)	.0437 (1.51) ^a	.178 (2.37) ^b
Age	-.0471 (4.02)	-	.000125 (3.26)	-	.0216 (1.51)	-	-.00328 (1.40)	-
Constant	15.2 (23.3)	-	.0278 (12.9)	-	60.2 (74.2)	-	2.36 (17.5)	-
N	1518	808	1518	808	1518	808	1518	808

^aAbsolute value of robust t-statistic with clustering by individuals.

^bAbsolute value of robust t-statistic.

Table 3
OLS, 2SLS and Within-MZ Twin Mother Estimates:
The Intergenerational Effect of Mother's Fetal Growth on Birthweight

	OLS	OLS	2SLS ^c	Within-MZ	Within-MZ
Mother's fetal growth	6.96 (4.89) ^a	7.10 (4.94) ^a	5.66 (2.85) ^a	-.155 (0.04) ^b	-.0436 (0.10) ^b
Number of packs per week mother smoked during the pregnancy	-4.48 (4.68)	-4.30 (4.27)	-16.2 (1.16)	-4.64 (2.00)	-4.01 (1.65)
Number of days per week alcohol was consumed during the pregnancy	-	-.370 (0.86)	.905 (1.79)	-	.513 (0.43)
Mother a teenager at time of birth	-	-.300 (0.16)	2.30 (0.67)	-	-4.73 (1.18)
Constant	103.4 (30.9)	103.5 (30.7)	101.9 (16.9)	-	-
N	1201	1201	1201	420	420

^aAbsolute value of robust t-statistic with clustering by individuals.

^bAbsolute value of robust t-statistic.

^cInstruments for smoking and drinking while pregnant include the prices per pack of cigarettes and beer taxes when the mother was age 25 and age 30 and year of birth.

Table 4
OLS and Within-MZ Twin Estimates of the Effect of BMI and Height on Log Wages

	OLS	OLS	Within-MZ	IV Within-MZ ^c
BMI (metric)	-.00623 (2.76) ^a	-.00311 (1.59) ^a	.00413 (0.64) ^b	.00197 (0.19) ^b
Height (inches)	.0165 (3.42)	.00809 (1.94)	.0354 (1.61)	.0552 (1.94)
Schooling	-	.0898 (18.56)	.0924 (5.69)	.104 (4.38)
Work experience	-	.0116 (11.2)	.00630 (2.88)	.00589 (2.66)
Age	-.00323 (1.55)	-.00321 (1.71)	-	-
Constant	1.56 (4.54)	.589 (1.95)	-	-
N	1518	1518	808	808

^aAbsolute value of robust t-statistic with clustering by individuals.

^bAbsolute value of robust t-statistic.

^cBMI, height and schooling instrumented. Instruments are birthweight and height and weight from the BQ. See Appendix Table B.

Table A

Within-MZ Twin Estimates of “Low Birthweight” and Fetal Growth on Own Schooling Attainment, BMI, Height and the LnWage

Variable	Schooling		BMI		Height		LnWage	
Low birthweight	-.305 (1.62)	.0251 (0.11)	-.000313 (0.45)	.000114 (0.15)	-.696 (4.25)	-.144 (0.65)	-.0309 (0.52)	.0822 (1.10)
Fetal growth	-	.749 (2.55)	-	.000964 (0.96)	-	1.24 (4.98)	-	.259 (2.52)
N	808	808	808	808	808	808	808	808

^aAbsolute value of robust t-statistic with clustering by individuals.^bAbsolute value of robust t-statistic.

Table B
First-Stage Within-MZ Twin Estimates: Schooling, BMI and Height

	Schooling	BMI	Height
Twin's report of schooling	.678 (17.9) ^a	.000184 (1.43)	-.0188 (0.64)
Height reported in BQ	.0244 (0.54)	-.000588 (3.82)	.582 (16.5)
Weight reported in BQ	.00735 (2.22)	.000196 (17.5)	.00225 (0.88)
Birthweight	.00720 (1.61)	.000005 (0.33)	.0161 (4.68)
Work experience	.00483 (0.98)	-.000022 (1.32)	.00125 (0.33)
R ²	.457	.437	.491
N	808	808	808

^aAbsolute value of robust t-statistic.