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ABSTRACT

This research note combines two national Taiwanese datasets to investigate the relationship between low birth weight (LBW) babies, their family background and their future academic outcomes. We find that LBW is negatively correlated with the probability of such children attending university at the age of 18; however, when both parents are college or senior high school graduates, such negative effects may be partially offset. We also show that discrimination against daughters does occur, but only in those cases where the daughters were LBW babies. Moreover, high parental education (HPE) can only buffer the LBW shock among moderately-LBW children (as compared to very-LBW children) and full term-LBW children (as compared to preterm-LBW children).

Ming-Jen Lin
Dept. of Economics
National Taiwan University
21 Hsu-Chow Road, Taipei (100)
Taiwan
mjlin@ntu.edu.tw

Jin-Tan Liu
Department of Economics
National Taiwan University
21 Hsu-Chow Road
Taipei (100), TAIWAN
and NBER
liujt@ccms.ntu.edu.tw

Shin-Yi Chou
Department of Economics
College of Business and Economics
Lehigh University
621 Taylor Street
Bethlehem, PA 18015-3117
and NBER
syc2@lehigh.edu

1. INTRODUCTION

In their studies of the short-term consequences of low birth weight (LBW), Perlman (2001) and Hack et al. (2002) demonstrated that LBW infants were at greater risk of suffering later developmental difficulties, arguing that they were more likely to suffer, for example, from brain dysfunction or neuro-sensory impairment. Almond et al. (2005) also found that higher infant mortality rates and higher hospital costs were further consequences of LBW.

Although subject to the 'stringent longitudinal linkage between information at birth and many years later' (Boardman et al., 2002), there has been rapid growth over recent years in studies on the long-term developmental outcomes of LBW babies. Examples include McCormick et al. (1992), Breslau et al. (1994) and Hack et al. (2002), who found that LBW children had lower IQs, health and behavioral problems, and Conley and Bennett (2000) who found a negative association between LBW and timely high school graduation. Low test scores have also been found to be associated with LBW (Hack et al., 2002; and Boardman et al., 2002), while Bonjour et al (2003) suggested that families with low average birth weight had low average schooling. Finally, Behrman and Rosenzweig (2004) found that augmented birth weight had significant effects on height, schooling and wages. In summary, viewing birth weight as an 'input' into the production function (or the initial endowment of human capita), the prior studies have generally established a negative association between LBW and subsequent outcomes.

In this paper, we are particularly interested in the interactive effects of parental education and LBW on the academic outcomes of children, a channel rarely discussed within the literature. Previously, Currie and Hyson (1999) found that although the 'high social economic status' of parents could buffer the negative effects

of LBW on self-reported female health conditions, it could not buffer test scores and wages. However, Kandel and Mednick (1991), Raine et al. (1994) and Tibbetts and Piquero (1999) all found that the interactions between LBW and parental rejection (or inferior family background) were associated with higher probability of being arrested and committing violent crime.

As to the interaction effect between LBW and parental education, Currie and Hyson (1999) provided two hypotheses on the subject. The first was that if parents were faced with credit constraints, the LBW children of those parents who were designated as having low parental education (LPE) [1]would receive less human capital investment than their LBW-HPE (high parental education) counterparts. Their second hypothesis was that if HPE and LPE parents differed in terms of their tastes – which decide both their investment in pregnancy and hence, the probability of LBW – and their subsequent investment in their children, then the underinvestment in the human capital of a LBW child would be greatest within an LPE environment.

The major concern with regard to these hypotheses is that they can only explain why parental investment might rise with HPE; they cannot explain why such an increase should benefit LBW children more than NBW children.[2] Whether the LBW children benefit more from HPE depends on parental investment and the exact shapes of the production function.[3] Thus, the interactive effect between LBW and parental education must be determined empirically.

Finally, LBW and LPE may be proxies for an unobserved variable, such as

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[1] In our paper, LPE refer to low parental education,, including elementary and junior high school education, and HPE refers to high parental education, including college and senior high school.

[2] We would like to express our appreciation to the anonymous referee who raised this valuable point.

[3] For example, if parents invest equally in their LBW and NBW children, and LBW children have a lower marginal return to parental investment, the gap between LBW and NBW children will rise as HPE rises. On the other hand, if LBW children have lower marginal returns to investment, but their parents have strong preferences for equality of outcomes, and hence devote more resources to their LBW children than their NBW children, the gap could also decrease with HPE.

genetic factor, that is causing low health endowments and children's lower academic performance. In such a case, the association between LBW, parental education and subsequent academic outcome is not causal; all variables are merely indicators of the underlying genetic endowment. In this paper, we do not attempt to sort out these causal relationships. Rather we intend to provide descriptive information on whether high parental education is a potential mechanism to mediate the negative impact of LBW.

Another interesting issue is parental attitudes towards differences in gender. Becker (1981) suggested that parents may discriminate against daughters if the returns from investing in sons are higher. Using data from Taiwan, Greenhalgh (1985) argued that the secondary status of women, as measured by schooling, occupation and income level, was caused by the interaction between economic institutions and patriarchal family institutions, which is essentially rooted in the different types of inter-generational contracts and expectations of mutual obligations in raising sons and daughters.[4]

Parish and Willis (1993) found that investment in children in Taiwanese families was often frustrated by credit constraints, with earlier born female children doing particularly poorly because of the need for them to start work at an early age to support their younger siblings. Finally, Yu and Su (2006) found that firstborn males in Taiwan had additional leverage in the sibling competition for family resources; however, the privilege for firstborns did not extend to daughters. Using Japan as an illustrative case, Brinton (1988, 1993) also argued that it was the structure of the Japanese employment system and the implicit intra-familial contract that shaped the human capital development system and encouraged the maintenance of different roles for men and women, with such gender stratification being the systematic result of a

[4] In Taiwan, parents basically rely upon their sons to look after them in their old age, while daughters generally contribute resources to the extended family of the husband.

sequence of choices made across the life cycle.

In the present study, we combine two national population datasets from Taiwan, with a total of 1.3 million observations. In doing so, we extend the literature in several ways. First, the large sample size and the high quality of our datasets enable us to overcome the problems of measurement error and lack of statistical power, especially for LBW children. Second, we also explore the relationship between LBW, parental education and academic outcome by gender. Finally, we account for the heterogeneity within the group of LBW children by using the detailed information on gestational age and birth weight.

2. DATASETS

The first dataset used was the birth certificate records, which contain information on birth weight, gestational age, birth county, gender, and the age and education of both parents at the time of the birth, for all children born between September 1978 and August 1982, a period during which there were over 300,000 births per year in Taiwan. Following the normal path, those born between September 1978 and August 1979 would take the college entrance examinations held in 1997; hence, we matched these birth certificate records against the College Entrance Examination files from 1997 to 2000, which allowed us to identify who had entered college from our sample cohort. The summary statistics of the variables are provided in Appendix Table A-1.

After dropping observations for those who had died before the age of 18 and those with missing values on the explanatory variables, the linkage between the two national datasets yielded a sample of 1,296,308. Table 1 presents detail on university attendance, by birth weight and by the mother's educational attainment, with senior high school and

above being referred to as 'HPE' and the remainder being designated as 'LPE'.[5] Consistent with the prior literature, educational achievements are strongly correlated with parental education. Students with HPE mothers had a much higher probability of attending university (32.1 percent vs. 10.7 percent) than those with LPE mothers.

<Table 1 is inserted about here>

On the other hand, LBW students had lower test outcomes than normal birth weight (NBW) students; for example, the proportion of the sample attending any university was 32.4 (10.8) percent for NBW with HPE (LPE), while for their LBW counterparts, this figure was only 26.6 (7.7) percent. In summary, parental education is positively and LBW is negatively associated with academic achievement...

3. MAIN RESULTS

In order to estimate the interaction effects of LBW and parental education on educational attainment, we regress the following logit model:

$$Y_{ijt} = \alpha + \beta_1 \mathrm{LBW} + \beta_2 HPEF + \beta_3 HPEM + \gamma_1 LBW \times HPEF + \gamma_2 LBW \times HPEM + \delta X_{ijt} + \mu_j + \nu_t + \varepsilon_{ijt}. \quad (1)$$

where Y_{ijt} is the university attendance of individual *i* born in county/city *j* in year *t*.

The regressors included a LBW dummy, mother's education (HPEM = 1 if mother's education is senior high school or above), father's education (HPEF = 1 if father's education is senior high school or above) and their interaction terms. Other explanatory variables (X) included gender (male = 1), twin dummy, birth order dummies, mothers' age dummies, birth county (μ_j) and birth year (ν_t) dummies (all of these are available from the birth certificate records), family income (in log), and

[5] We also divided parental education into five categories; the results (not shown in this note) are similar to those shown in Tables 1 and 2.

government-employed household.[6] ε_{ijt} represents the disturbance term.

Equation (1) indicates that the marginal effect of LBW on university attendance depends upon LBW (β_1) itself (which should be negative) and its interaction with parental education (γ_1 and γ_2). Hence, the marginal effect of LBW is $\beta_1 + \gamma_1$* HPE Father + γ_2 * HPE Mother. Positive measures of γ_1 and γ_2 (mean parental education) can 'buffer' the negative effect of LBW for a child. The logit estimations and marginal effects are reported in Table 2, for both the whole sample and by gender.

<Table 2 is inserted about here>

Our results suggest that for those students with parents designated as LPE, the probability of attending any university is 4.5 percent lower for those with LBW; however, since a college or senior high school-educated father (mother) can buffer the LBW shock by raising the probability of attending university by 0.7 (1.0) percent, the marginal effect of LBW for those who have HPE parents is only –2.6 percent but is statistically significant. This implies that a HPE father and mother can together offset around 40 percent (1.7/4.5) of the negative effect of LBW. Furthermore, Table 2 also suggests that parental education, family income, government-employed households are all positively correlated, and birth order is negatively correlated, with the probability of attending university.

As to gender effect, Table 2 would seem to indicate that the coefficient of gender is small and insignificant at first glance. Furthermore, differences in the estimations between the male and female regressions are small and not always in favor of boys; nevertheless, the coefficients of the interaction between LBW and an HPE mother were larger in the male regression (1.49 percent, significant) than in the female

[6] Income and parental occupations data were obtained from the Government Employee Insurance files, Labor Insurance files and Farmers Insurance files. The monthly wages of the insured parents were then aggregated to obtain the household income.

regression (0.6 percent, insignificant). It therefore seems clear that HPE mothers still discriminate against daughters with lower health endowments.

4. SENSITIVITY TESTS

McCormick et al (1992), Boardman et al (2002) and Hack et al (2002) found that adverse birth outcomes were more profound within the 'very low birth weight' (VLBW) group than in the 'moderately low birth weight' (MLBW) group (1,500gm-2,500gm). Table 3-1 explores this issue by using VLBW, MLBW and their interactions with parental education as the independent variables. We find that VLBW can reduce the probability of attending university by 11 percent, while MLBW reduces this probability by only 4.7 percent. Furthermore, the negative effect of VLBW is not buffered at all by HPE parents. Clearly, therefore, VLBW represents an index of high risk.

<Table 3-1 is inserted about here>

Gestational age also provides useful information for predicting problems in newborn babies. For example, babies whose gestation period lasted the full 40 weeks are less likely to develop negative syndromes than premature-term babies. We can therefore categorize LBW babies into two groups, full-term (gestation age >38weeks) or preterm (<38 weeks). Full-term LBW babies are defined here as those likely to experience intra-uterine growth retardation.[7] As Table 3-2 shows, as compared to a NBW baby, the likelihood of a 'preterm low birth weight' (PLBW) baby attending university is 4.8 percent lower, while the likelihood of a full-term LBW (FLBW) baby attending university is 4.6 percent lower. A parent designated as HPE can buffer the negative effect of a FLBW by 0.8 to 1.2 percent; however, neither the father nor the mother can buffer the negative effect of LBW for PLBW babies.

[7] We are grateful to the editors for providing this perspective.

<Table 3-2 is inserted about here>

The final sensitivity test checks whether the strong correlation between parental education levels would affect our results using three different model specifications: father's education only, mother's education only, and either parent with senior high school education (or above) as the independent variables. Table 3-3 shows that the marginal effect of LBW and its interaction terms, with different parental education variables, remains at -4.4 percent to -4.6 percent, and 1.2 percent to 1.4 percent, respectively. These results are similar to those obtained from Table 2. Hence the potential problem of multi-colinearity does not jeopardize our previous estimations.

<Table 3-3 is inserted about here>

5. CONCLUSION

This study has combined two unique national Taiwanese datasets to present evidence on the ways in which LBW and parental education are associated with academic outcomes. Our results suggest that LBW is significantly and negatively associated with university attendance which is consistent with previous literature; however, having HPE parents can offset the LBW shock by as much as 40 percent. Furthermore, the buffering effects are only significant for sons, not for daughters, which suggest that HPE parents discriminate against LBW daughters. Finally, parents with high levels of education can only buffer the LBW shock among moderately-LBW children (as compared to very-LBW children) and full term-LBW children (as compared to preterm-LBW children). These results suggest the importance to consider the heterogeneity within LBW children. VLBW and preterm-LBW children may face very different developmental process than do MLBW and full-term-LBW children

The next step is to bring in more structured and detailed data to the analysis of the problem -- either from a standpoint of the production function of health on future outcomes, or on the ways in which parents allocate resources within the household – to help us to gain a better understanding of the mechanisms involved in this bio-social link. For example, an implicit assumption through our research is that LBW, or VLBW with preterm status are risk factors because they make the children less likely to benefit from parental investment. However, it is also likely that parents invest less in children with these risk factors because they anticipate not getting high return. In addition, for our finding that gender is also a risk factor, the latter mechanism seems to be more plausible. In order to investigate these complex mechanisms, we need to know more about the production function that can transform parental investment into outcomes, the preferences of parents that govern the intra-household distribution of resources, and the ways in which these factors interact with parental education. Unfortunately, our dataset contains no detailed information that would allow us to identify either the different investments in LBW and NBW children, or their preferences with regard to intra-household resource distribution. The strong buffering effect found in this study does, however, point to a potentially intriguing research direction if appropriate data can be obtained to identify these mechanisms.

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Table 1 University attendance, by birth weight and mother's education

Mother's Education [a]	University Attendance [b]					
	Whole Sample		NBW (>2,500g)		LBW (≤2,500g)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
HPE Mother	0.3210	0.4669	0.3238	0.4679	0.2660	0.4419
No. of Observations	289,976		276,081		13,895	
LPE Mother	0.1068	0.3088	0.1084	0.3108	0.0768	0.2663
No. of Observations	997,973		947,247		50,726	

Notes:

[a] HPE refers to college or senior high school education; LPE refers to junior high school education or below.

[b] NBW refers to normal birth weight; LBW refers to low birth weight

Table 2 Logit results of university entrance [a]

Variables	Whole Sample			Male			Female		
	Coefficient	S.E.	Marginal Effects	Coefficient	S.E.	Marginal Effects	Coefficient	S.E.	Marginal Effects
LBW [e]	−0.4067***	0.0197	−0.0450	−0.4388***	0.0293	−0.0487	−0.3785***	0.0266	−0.0417
HPE Father [b]	0.6296***	0.0066	0.0696	0.6463***	0.0091	0.0717	0.6119***	0.0095	0.0673
LBW with HPE Father	0.0596*	0.0316	0.0066	0.0526	0.0467	0.0058	0.0684	0.0429	0.0075
HPE Mother [b]	0.4895***	0.0069	0.0541	0.4625***	0.0096	0.0513	0.5194***	0.0100	0.0572
LBW with HPE Mother	0.0929***	0.0321	0.0103	0.1339***	0.0473	0.0149	0.0505	0.0436	0.0056
Family Income	0.0101***	0.0001	0.0011	0.0103***	0.0002	0.0011	0.0098***	0.0002	0.0011
Government Employee	0.5164***	0.0084	0.0571	0.4968***	0.0117	0.0551	0.5380***	0.0122	0.0592
First Child	0.9432***	0.0185	0.1043	0.9341***	0.0257	0.1037	0.9528***	0.0266	0.1049
Second Child	0.6067***	0.0182	0.0671	0.6103***	0.0254	0.0677	0.6026***	0.0263	0.0663
Third or Fourth Child	0.3648***	0.0179	0.0403	0.3740***	0.0249	0.0415	0.3546***	0.0258	0.0390
Gender	0.0076	0.0052	0.0008	–	–	–	–	–	–
No. of Observations		1,287,949			666,754			621,195	
LR Chi^2		119527.53			60565.91			59167.80	
Pseudo R^2		0.1141			0.1112			0.1179	

Notes:

[a] *** indicates significance at the 1 percent level; ** indicates significance at the 5per cent level; and * indicates significance at the 10 percent level. Other regressors include eight mother age dummies (ages 20-22, 23-25, 26-28, 29-31,32-34, 35- 37, 38-40 and above 40), twin, county and birth year dummies.

[b] LBW refers to low birth weight; and HPE refers to high parental education, including college and senior -high school.

Table 3-1 Sensitivity test of the interaction between university attendance, very low birth weight, moderately low birth weight and parental education

Variables [a]	Whole Sample		
	Coefficient [b]	S.E.	Marginal Effects
VLBW [d]	−0.9986***	0.1686	−0.1105
MLBW [d]	−0.4266***	0.0239	−0.0472
HPE Father [d]	0.6310***	0.0065	0.0698
HPE Mother [d]	0.4911***	0.0069	0.0543
VLBW with HPE Father	−0.1516	0.2557	−0.0168
VLBW with HPE Mother	0.1357	0.2521	0.0150
MLBW with HPE Father	0.0528	0.0383	0.0058
MLBW with HPE Mother	0.0944**	0.0387	0.0104
Family Income	0.0101***	0.0001	0.0011
Government Employee	0.5167***	0.0084	0.0571
No. of Observations		1,287,949	
LR Chi^2		119521.47	
Pseudo R^2		0.1141	

Notes:

[a] Other explanatory variables include male, birth order dummies, mother age dummies, twin, county and birth year dummies.

[b] Logit estimation: *** indicates significance at the 1 percent level; and ** indicates significance at the 5 percent level.

[c] VLBW refers to ‘very low birth weight’ of <1,500gm; MLBW refers to ‘moderately low birth weight’ of >1,500 gm but <2,500 gm; and HPE refers to ‘high parental education’, including college and senior high school.

Table 3-2 Sensitivity test of the interaction between university attendance, preterm low birth weight, full-term low birth weight and parental education

Variables [a]	Whole Sample		
	Coefficient [b]	S.E.	Marginal Effects
PLBW [c]	−0.4180***	0.0347	−0.0463
FLBW [c]	−0.4030***	0.0237	−0.0446
HPE Father [c]	0.6285***	0.0066	0.0696
HPE Mother [c]	0.4898***	0.0069	0.0542
PLBW with HPE Father	0.0389	0.0534	0.0043
PLBW with HPE Mother	0.0740	0.0529	0.0082
FLBW with HPE Father	0.0743**	0.0387	0.0082
FLBW with HPE Mother	0.1107***	0.0400	0.0123
No. of Observations		1,287,949	
Pseudo R^2		0.1142	

Notes:

[a] Other explanatory variables include male, log family income, governmental employee, birth order dummies, mother age dummies, twin, county and birth year dummies.

[b] Logit estimation: *** indicates significance at the 1 percent level; and ** indicates significance at the 5 percent level.

[c] PLBW refers to 'preterm low birth weight' of <2500gm with a gestation period of <38 weeks; FLBW refers to 'full-term low birth weight' of <2500gm with a gestation period of >38 weeks; and HPE refers to 'high parental education', including college and senior high school.

Table 3-3 Sensitivity test of the interaction between university attendance, low birth weight and education of either father, mother, or HEP w/ either parent

Variables [a]	(1)			(2)			(3)		
	Coefficient [b]	S.E.	Marginal Effects	Coefficient [b]	S.E.	Marginal Effects	Coefficient [b]	S.E.	Marginal Effects
LBW [c]	–0.3982***	0.0193	–0.0441	–0.3973***	0.0172	–0.0448	–0.4206***	0.0213	–0.0463
HPE Father [c]	0.8058***	0.0060	0.0893	–	–	–	–	–	–
LBW with HPE Father	0.1071***	0.0263	0.0119	–	–	–	–	–	–
HPE Mother	–	–	–	0.7579***	0.0063	0.0854	–	–	–
LBW with HPE Mother	–	–	–	0.1190***	0.0267	0.0134	–	–	–
HPE either Parent	–	–	–	–	–	–	0.8567***	0.0060	0.0944
LBW with HPE w/either Parent	–	–	–	–	–	–	0.1301***	0.0271	0.0143
No. of Observations	1,287,949			1,287,949			1,287,949		
LR Chi^2	112212.56			110499.29			111197.08		
Pseudo R^2	0.1092			0.1053			0.1112		

Notes:

[a] Other explanatory variables include male, log family income, governmental employee, birth order dummies, mother age dummies, twin, county and birth year dummies.

[b] Logit estimation: *** indicates significance at the 1 percent level.

[c] LBW refers to low birth weight; and HPE refers to high parental education, including college and senior high school.

Appendix

Table A-1 Basic summary statistics of variables *

Variables	Mean	S.D.
University Attendance-All Sample	0.155	0.362
Gestational Age (weeks)	39.74	1.197
Birth Weight (grams)	3287.3	467.1
Low Birth Weight	0.051	0.022
Twins	0.010	0.097
Male	0.517	0.500
Family Income (in log)	3.008	2.241
Father's Education		
College	0.054	0.226
Junior College	0.052	0.221
High School	0.217	0.421
Junior High School	0.172	0.378
Elementary School	0.505	0.499
Mother's Education		
College	0.022	0.147
Junior College	0.029	0.168
High School	0.174	0.379
Junior High School	0.178	0.382
Elementary School	0.596	0.491
Mother's Age		
20-22	0.136	0.343
23-25	0.304	0.460
26-28	0.267	0.443
29-31	0.131	0.337
32-34	0.041	0.198
35-37	0.014	0.117
38-40	0.005	0.068
>40	0.005	0.068
Government Employee	0.076	0.265
First Child	0.367	0.482
Second Child	0.314	0.464
Third or Fourth Child	0.280	0.450

Note: * No. of observation = 1,287,949.