行政院國家科學委員會專題研究計畫 成果報告

新生兒出生體重的長期影響
研究成果報告(精簡版)

計 畫 類 別 ：個別型
計 畫 編 號 ：NSC 95-2415-H-002-005-
執 行 期 間 ：95 年 08 月 01 日至 96 年 10 月 31 日
執 行 單 位 ：國立臺灣大學經濟學系暨研究所

計 畫 主 持 人：劉錦添

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報 告 附 件 ：出席國際會議研究心得報告及發表論文

處 理 方 式 ：本計畫可公開查詢

中 華 民 國 96 年 11 月 30 日

Available online at www.sciencedirect.com
ScienceDirect
Economics of Education Review 25 (2006) 647–658
Economics of Education Review
www.elsevier.com/locate/econedurev

Asymmetries in progression in higher education in Taiwan: Parental education and income effects

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Received 1 September 2002; accepted 24 July 2005

Abstract

A unique data set on Taiwan was employed to investigate the socioeconomic family backgrounds of students attending universities. Our empirical study found that individuals attending university are more likely to come from better-educated families than are those who do not attend university. Students attending public universities, which receive higher government subsidies, tend to come from wealthier families. Furthermore, our results show that the relationship between the size of the government subsidies and family background is not purely progressive. Students attending normal universities/teacher training colleges received the highest subsidies but tended to come from the least-educated families. Students attending the top five public universities come from the most affluent families of Taiwanese society.

JEL classification: I1; L1

Keywords: Subsidies; Higher education; Family background; Taiwan

1. Introduction

Education is invariably heavily subsidized by governments in many countries around the world, with the government's involvement often being justified on the basis of market imperfections and income distribution considerations. Within the market for education, market imperfections can take on a variety of forms, the most commonly cited being the presence of positive externalities from schooling, and the constraints of the capital markets (in terms of restricting borrowing against future human capital). Although various appeals to market imperfections have provided support for intensive educational policies, these are clearly not the only rationale for government education programs, since education also provides a mechanism for the redistribution of societal income and the welfare of its citizens (Fernandez and Rogerson, 1995).

This paper set out to empirically examine the characteristics of the beneficiaries of public expenditure on higher education in Taiwan, along with an

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doi:10.1016/j.econedurev.2005.07.002

evaluation of the distributional consequences of government spending. In common with many countries around the world, higher education in Taiwan is heavily subsidized by the government. In the 1998 fiscal year, government spending on higher education accounted for 0.56% of the island's GDP; this figure is comparable to the average percentage spent by 28 OECD countries (1%) and that spent by 17 non-OECD countries (0.9%).[1]

In Taiwan, subsidies for higher education generally come in the form of government-financed low-tuition public universities. Depending on the score achieved in the Joint Entrance Examinations, a student is assigned to major in a particular field, at a specific university or college in Taiwan. In general, public universities are more prestigious, and hence, more favored by students. If the likelihood of students from low-income families attending public universities were to be greater than the likelihood of those from higher-income families attending the same universities, then public support for higher education would prove to be an effective transfer of resources from higher-income individuals to lower-income individuals.

Our study differs from a recent study carried out in Argentina (Rozada & Menendez, 2002) in four respects. First, our study used nationally based data combining annual birth certificate records with the national joint entrance examination files, whilst the social and economic status of families was represented by the parents' educational attainment and income levels. Second, we employed a two-part model to estimate the conditional probability of entering public university and the conditional probability of entering different types of public universities. Third, while socioeconomic variables were the major concerns of this study, we also controlled for individual characteristics and year and city/county fixed effects, which are confounding factors in individual educational attainment. Fourth, and the most important of all, we were able to distinguish among the different types of public universities that students attended and further establish the relationship between the level of government subsidies and family background.

Several results of our empirical study stand out. First, college students are more likely to come from better-educated families. Second, compared to students attended private universities, students attending public universities tend to come from the wealthier families of Taiwanese society. Among the public universities, students attending normal universities (teacher training institutions) received the greatest subsidies from the government, followed by the students at the top five public universities, and then by the students at the other lower-tier public universities. We found that students at the top five public universities come from the best-educated families, followed by the students at the other lower-tier public universities. Students at normal universities (teacher training institutions) tend to come from poorer families. Taking all of these results together, the findings of this study suggest that public spending on higher education tends to subsidize the wealthier families in Taiwan. The only exception to this is that students who choose to attend normal universities in order to benefit from heavy government subsidies are generally from poorer families.

This paper is organized as follows: the next section provides the background to the system of higher education in Taiwan, followed, in the subsequent sections, by a brief literature review and a description of the data set. The penultimate section provides the empirical estimation results, followed in the final section by the conclusions drawn from this study.

2. Higher education in Taiwan

In Taiwan, all college and university students must pass the fiercely competitive College and University Joint Entrance Examination. Around 120,000 students have enrolled to take the examination each year between 1991 and 1997. Prior to 1995, the overall admission rate to colleges and universities was around 44%, but this subsequently jumped to 49% in 1996, and 60% in 1997. Typically, following the examination, students list and rank both their preferred major and their preferred choice of institution. Depending on their examination scores, students are then assigned to major in a particular field at a specific institution.

In contrast to the educational system in the US, public universities or colleges, in general, are regarded as being much more prestigious than their private counterparts in Taiwan, and indeed, represent the primary choice for Taiwanese students. In 2001, there were a total of 57 universities (27 public and 30 private) and 78 colleges (23 public and 55 private) in Taiwan, and of these, the private universities and colleges accounted for almost

[1] http://www.oecd.org/dataaoecd (10/2003).

71% of the island's 677,171 undergraduate students.[2] From this point on, for brevity, we use the word "university" to mean "university and college", unless we explicitly note them separately. For example, when we use the term "public universities", it also includes "public colleges".

The government has long assumed a primary role in the distribution of educational resources in Taiwan, which has resulted in considerable discrepancies between public and private institutions, both in terms of the level of tuition fees and the amount of government subsidies provided. In 1996, government expenditure on education, covering all universities in Taiwan, came to around NT$134,124 per student; however, when broken down to expenditure on public versus private universities, the figures were NT$181,378 for public universities and NT$99,993 for private universities.[3] Clearly, the educational expenditure per student in public universities is almost double that in the private universities. Tuition fees for each academic year in public universities range between NT$26,680 and NT$35,940, whereas in private universities, the range is between NT$67,680 and NT$93,860, demonstrating that tuition fees in private universities are almost 2.5 times as high as those in public universities.[4] These tuition fees are regulated and approved by the Ministry of Education each year.

Government subsidies among the public universities also vary. We categorized the public universities into three groups in terms of the size of the subsidies they receive from the government: normal universities/teacher training colleges receive the most, followed by the top five public universities, and then by the other low-tier public universities, which receive the least. Both normal universities and teacher training colleges receive the greatest subsidies from the government. Normal universities are responsible for training teachers for high school and junior high school teaching positions, whilst teacher training colleges are designed to train them for kindergarten and primary school level positions. In order to attract better quality students, the government waives all tuition fees for students in both normal universities and teacher training colleges, whilst also providing a living stipend subsidy each month.

On average, the top five public universities receive more government subsidies than the lower-tier public universities.[5] For example, in 1996, the total government budget for the top five public universities was NT$1,253 million, whereas, for the five lower-tier public universities included in this comparison, the budget amounted to NT$928 million. In terms of government expenditure per student, the figure was NT$217,206 for the top five public universities, and NT$207,011 for the lower-tier public universities.[6]

It is also worth noting that if either the father or the mother works in the public sector, a family can receive an annual educational subsidy from the government, which amounts to around NT$13,600 per child for public universities, and NT$35,800 per child for private universities. The subsidy covers around 70% of the university tuition fees. It follows, therefore, that educational costs for government-employed families are lower than are those for privately employed families.

3. Data sources

The data in this study were assembled from two major sources: (1) annual birth certificate records from 1978 to 1982, complied by the Ministry of Interior Affairs; and (2) the College and University Joint Entrance Examination files, covering the years from 1996 to 1999, compiled by the College and University Entrance Examination Center, at the Ministry of Education. These two sources are national data sets. The birth certificates contain information on birth weight, gestational age, place of birth, gender, parity, the mother's marital status, age and schooling, and the father's age and schooling. The joint entrance examination files include test scores as well as details of the university and college and the name of the department attended by the students. We used the personal ID code to merge these two files and restrict the ages of all individuals

[2] http://www2.edu.tw/statistics/index.htm (5/2002).

[3] The exchange rates was 1 US$ = 27.49 New Taiwan Dollars (NT$) in 1996.

[4] http://www.high.edu.tw/05/05.htm (5/2002).

[5] The top five public universities include National Taiwan University, National Chengchi University, National Tsinghua University, National Chiao Tung University, and National Yang-Ming University. For comparison, we select five universities from the lower or second-tier public universities: National Central University, National Sun Yat-Sen University, National Taiwan Ocean University, National Chung Cheng University and National Cheng Kung University.

[6] Details on the government budgets for public universities are provided at http://www.high.edu.tw/12/12.htm and details on the numbers of students within each university are available at http://www.edu.tw/statistics/index.htm.

Table 1
Summary statistics by university attendance

	Attending university		Not attending university	
	Mean	Std. dev.	Mean	Std. dev.
Father's education (d.v.)				
College (or university) and over	0.153	0.360	0.032	0.176
College without a bachelor's degree	0.120	0.325	0.040	0.196
High school	0.311	0.463	0.185	0.388
Junior high school	0.145	0.352	0.165	0.371
Mother's education (d.v.)				
College (or university) and over	0.069	0.253	0.012	0.107
College without a bachelor's degree	0.085	0.279	0.019	0.136
High school	0.306	0.461	0.134	0.341
Junior high school	0.169	0.375	0.166	0.372
Parent's occupation in public sector (d.v.)	0.209	0.407	0.047	0.211
Parent's monthly income ('00,000)[a]	0.459	0.204	0.365	0.165
First-born son (d.v.)	0.235	0.424	0.179	0.383
First-born daughter (d.v.)	0.221	0.415	0.167	0.373
Male	0.518	0.500	0.517	0.500
Low birth weight (d.v.)	0.054	0.227	0.083	0.276
Twin (d.v.)	0.008	0.088	0.010	0.100
Mother's age at birth (d.v.)				
20–29	0.807	0.395	0.808	0.394
30–39	0.169	0.375	0.120	0.325
40 and over	0.004	0.060	0.006	0.077
Location (d.v.)				
Taipei city	0.157	0.364	0.099	0.299
Taipei county	0.150	0.357	0.133	0.340
Sample size	257,068		1,339,258	

[a]Dummy variable is denoted as d.v.

to the range of 18–21 years for the period 1996–1999. The sample for analysis was 1,596,326 individuals; of these, 257,068 (16.1%) attended universities and 1,339,258 (83.9%) did not.[7] Table 1 summarizes the basic statistics applying to the whole sample.

The explanatory variables of primary interest to us were the educational attainment, occupation and income levels of the child's parents. Education was divided into five categories: illiteracy to primary school attainment (6 years), junior high school level (9 years), high school level (12 years), college level without a bachelor's degree (15 years), and college and university and beyond with a bachelor's degree or higher (16 years), with illiteracy to primary school being the omitted category in all regressions. Information on the parents' educational attainment was obtained from the child's birth certificate.

The parents of those individuals who had gained access to universities generally had a higher educational background. A similar pattern is also apparent with regard to the mother's education. The mothers of those who had attended universities were more highly educated. However, when comparing the two samples (attended vs. not attended universities), there was a smaller difference between the mother's educational attainments in the two samples than there was between the father's educational attainments.

If one of the parents was an employee in the government sector (defined here as a government-employed family), then the family would qualify to receive an educational subsidy from the government on the child's entry into university. In this study, we included a dummy variable to distinguish a government-employed family from a non-government employed family. Since information on the occupation of the parents is often incomplete in the birth

[7]The out-of-wedlock birth child was excluded from the sample.

certificate records, we obtained this information from the Government Employees Insurance file, administered by the Department of Public Insurance, identifying the parents' employment sector for the period 1996–1999. Of those attending universities, 21% were from government-employed families, a figure which was significantly higher than the 4.7% of those not attending universities. Details on parental income were unavailable from either the birth certificate records or the university entrance examination files, therefore, the data were subsequently merged with those from the Government Employee Insurance files and the Labor Insurance and Farmer Insurance files (since the Department of Public Insurance and Bureau of Labor Insurance maintain detailed information on the wages of all insured parties).

We then aggregated the monthly wages of the insured parents to create a variable for household income; however, it should be noted that since family income is recorded for only 1 year, the family income variable represents only a crude proxy for the economic resources available to a child.[8] Table 1 provides details of parental income, from which it is clear that those who had attended universities came from wealthier families.

We also controlled for the characteristics of the child and the mother, city/county dummies and year dummies for all regressions. As a result of family budgetary constraints, birth order and the number of siblings may have a significant impact on the educational opportunities available to a child (Parish & Willis, 1993). Many prior studies have also documented the long-term negative effects of being a low birth weight baby (Corman & Chaikind, 1998; Currie & Hyson, 1999). Child characteristics in this study, therefore, included dummy variables indicating a first-born son or daughter, gender, low birth weight and whether the child was one of a pair of twins.

The child's birth order (defining the first-born son or daughter) was determined from the birth certificate records, and low birth weight was defined as birth weight of less than 2500 g. We also controlled for the mother's age at the time of the child's birth; in order to allow for the nonlinear effect of the mother's age, we recoded age as a set of splines with cutoff points of 19, 29 and 39 years.

In addition to examining the socioeconomic characteristics of all university students, we were also interested in the characteristics of those attending public universities. Compared to private universities, public universities not only charge low tuition and fees, but also receive higher government subsidies. In Table 2, of the 257,068 students attending universities, 87,214 (32.9%) attended public universities and 169,854 (67.1%) attended private universities. Furthermore, compared to those attending private universities, the parents of public university students were more likely to have a college degree or above.

In order to further examine the association between government subsidies on higher education and students' family background, we sorted the public universities into three categories in order of the size of the subsidies received from the government, from highest to lowest, as follows: normal universities/teacher training colleges, top five public universities and lower-tier public universities. Sample statistics of students at normal universities/teacher training colleges, top five public universities and other lower-tier public universities are presented in Table 2.

Of the 87,214 students attending public universities, 25,978 (29.8%) elected to attend normal universities/teacher training colleges, 28,050 (32.1%) had gained access to one of the top five public universities and 33,186 (38.1%) attended lower-tier public universities. For the three subcategories of public universities, students attending normal universities/teacher training colleges tended to come from poorer families where parents had lower educational achievements. Those attending the top five public universities tended to have parents who are well educated, or came from families with a wealthier background. We controlled all of the explanatory variables described above and fit logit or multinomial logit regressions, as presented in the next section.

4. Empirical results

We present our estimates based on a two-part model which has frequently been used in numerous applied studies (i.e., Duan, Manning, Morris, & Newhouse, 1983). The first equation of the model is a logit equation for the probability that a student will attend college or university. The second

[8] We discarded all zero income observations since those parents were more likely to be out of labor force or be self-employed, and have neither Labor nor Government Employees' Insurance. Self-employed workers can join labor insurance, but only if they are members of an occupational union.

Table 2
Summary statistics by public University, top five public university and normal university attendance

	Attending public university		Attending private university		Attending normal university		Attending top 5 public university		Attending other public university	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Father's education (d.v.)										
College (or university) and over	0.192	0.394	0.133	0.339	0.113	0.317	0.289	0.453	0.173	0.378
College without a bachelor's degree	0.129	0.335	0.115	0.319	0.130	0.337	0.137	0.344	0.122	0.327
High school	0.305	0.460	0.315	0.464	0.320	0.467	0.286	0.452	0.309	0.462
Junior high school	0.131	0.338	0.152	0.359	0.145	0.352	0.112	0.315	0.138	0.344
Mother's education (d.v.)										
College (or university) and over	0.097	0.296	0.054	0.226	0.049	0.216	0.163	0.369	0.079	0.270
College without a bachelor's degree	0.102	0.302	0.076	0.266	0.084	0.278	0.134	0.340	0.089	0.284
High school	0.313	0.464	0.303	0.459	0.287	0.453	0.331	0.471	0.317	0.465
Junior high school	0.156	0.363	0.175	0.380	0.176	0.381	0.128	0.335	0.164	0.370
Parent's occupation in public sector (d.v.)	0.251	0.434	0.188	0.391	0.230	0.421	0.313	0.464	0.215	0.411
First-born son (d.v.)	0.237	0.425	0.234	0.423	0.149	0.356	0.259	0.438	0.287	0.452
First-born daughter (d.v.)	0.225	0.417	0.220	0.414	0.295	0.456	0.233	0.422	0.163	0.369
Male	0.518	0.500	0.518	0.500	0.340	0.474	0.536	0.499	0.643	0.479
Low birth weight (d.v.)	0.052	0.222	0.056	0.230	0.057	0.232	0.048	0.214	0.051	0.219
Twin (d.v.)	0.008	0.086	0.008	0.088	0.008	0.087	0.007	0.085	0.008	0.088
Mother's age at birth (d.v.)										
20–29	0.803	0.398	0.809	0.393	0.829	0.377	0.778	0.415	0.803	0.398
30–39	0.178	0.382	0.165	0.371	0.147	0.354	0.207	0.405	0.177	0.381
40 and over	0.003	0.057	0.004	0.062	0.003	0.052	0.004	0.061	0.003	0.056
Location (d.v.)										
Taipei City	0.158	0.365	0.156	0.363	0.069	0.253	0.247	0.431	0.153	0.360
Taipei County	0.146	0.353	0.152	0.359	0.090	0.287	0.189	0.392	0.154	0.361
Sample size (without income)	87214		169854		25978		28050		33186	
Parent's monthly income ('00,000)	0.476	0.213	0.450	0.199	0.453	0.205	0.511	0.224	0.463	0.205
Sample size (with income)	75,201		145,004		22,044		23,515		28,491	

equation is a logit equation for the conditional probability that a potential college student will attend a public university; or a multinomial logit equation for the conditional probability of attending a normal university/teacher training college, one of the top five public universities or a lower-tier public university, where the omitted category is the private university.

There are two reasons why we used a two-part model that omits the inverse Mills' ratio (which is usually reported along with Heckman's two-step estimates) in the second part. First, students make their decision about which type of university/college to attend only after receiving the card reporting their scores on the Joint Entrance Exams. Consequently, decisions about university/college attendance and the type of university/college to attend can be modeled as two different stochastic processes. Second, since we do not have good exclusion restrictions, we decided that the two-part model would outperform the selection model (Leung & Yu, 1996). Nevertheless, we also estimated the sample selection model, which included the inverse Mills' ratio in the second stage, and it yielded results similar to the two-part model.

Each model included three sets of explanatory variables, the first of which aimed to capture the socioeconomic background of the family (this set of variables included dummy variables for the parents' education levels, the parents' occupation in the public sector, and the parents' monthly incomes). The second set of explanatory variables aimed to describe the characteristics of the individual (this set included dummy variables for male, first-born son or daughter, twin, low birth weight and the mother's age at the time of the child's birth). The third set provided dummies for the year of entry into university (1996–1999) and for the 21 city/county locations. In order to reduce the amount of space taken up by the location element of the study, we report only the dummy variables for Taipei City and Taipei County.

First, we analyzed those factors which affect the decision to attend university (see Table 3 for the results). The educational levels of parents significantly affect the likelihood of a child attending university; in both specifications in Table 3. There is a significant gradient between each parent's education level and the educational attainment of the child. The father's educational level has a stronger association with the child's university attendance than the mother's educational level. As compared to children whose parents had only a primary school education, children whose fathers had a bachelor's degree or higher were 14% more likely to attend university; those whose mothers had a bachelor's degree or higher were 11% more likely to attend university.

Since higher education is not compulsory education, only those who attend university can benefit from government subsidies. Given this fact, our results suggest that government spending on higher education actually subsidizes wealthier families. This implication is further supported by the regression results where the family income variable was included. In specification (2), we included a proxy for monthly household income, the coefficient of which was positive and statistically significant, suggesting that children from wealthier families are more likely to attend university.

Since the government heavily finances public universities, we undertook a further investigation to determine which groups benefit the most from government subsidies by examining the impact of family background on the likelihood of entering public university. From the logit estimations, which are presented in Table 4, we found that a strong relationship exists between parental education levels and the likelihood of the child attending a public university. This finding contradicts that of Rozada and Menendez (2002) that, in Argentina, no socioeconomic variables are statistically significant in determining public university attendance. In our study, mother's education level had a stronger association with the probability of entering public universities than that of the father. As compared to children whose parents had only a primary school education, children whose mothers had a bachelor's degree or higher were 12% more likely to attend a public university; those whose fathers had a bachelor's degree or higher were 5% more likely to attend a public university. In a review of the existing studies on human capital, Haveman and Wolfe (1995) and Behrman (1999) similarly found that the mother's educational achievement had positive effects on the education of the child, with these effects tending to be more significant than those based on the educational achievement of the father. Furthermore, in our study, the family income variable was positive and significant, again indicating that students from wealthier families are more likely to attend public universities (see Table 4, Specification (2)).

Table 3
Regression results on university attendance

	Dependent variable = 1 if attending university					
	Specification (1)			Specification (2)		
	Coeff.	Std. err.	ME	Coeff.	Std. err.	ME
Father's education (d.v.)						
College (or university) and over	1.223[a]	(0.011)	[0.139]	1.210[a]	(0.012)	[0.127]
College without a bachelor's degree	1.063[a]	(0.010)	[0.121]	1.006[a]	(0.011)	[0.105]
High school	0.817[a]	(0.007)	[0.093]	0.751[a]	(0.007)	[0.078]
Junior high school	0.482[a]	(0.007)	[0.055]	0.442[a]	(0.008)	[0.046]
Mother's education (d.v.)						
College (or university) and over	1.009[a]	(0.014)	[0.111]	1.036[a]	(0.016)	[0.108]
College without a bachelor's degree	0.908[a]	(0.012)	[0.103]	0.888[a]	(0.013)	[0.093]
High school	0.659[a]	(0.007)	[0.075]	0.616[a]	(0.007)	[0.064]
Junior high school	0.300[a]	(0.007)	[0.034]	0.272[a]	(0.007)	[0.028]
Parent's occupation in public sector (d.v.)	0.690[a]	(0.007)	[0.078]	0.468[a]	(0.008)	[0.049]
Parent's income (in log)				0.398[a]	(0.006)	[0.047]
First-born son (d.v.)	0.256[a]	(0.007)	[0.029]	0.263[a]	(0.007)	[0.027]
First-born daughter (d.v.)	0.288[a]	(0.007)	[0.032]	0.289[a]	(0.008)	[0.030]
Male	0.016[a]	(0.006)	[0.001]	0.014[b]	(0.007)	[0.001]
Low birth weight (d.v.)	−0.352[a]	(0.010)	[−0.040]	−0.316[a]	(0.011)	[−0.033]
Twin (d.v.)	−0.169[a]	(0.026)	[−0.019]	−0.195[a]	(0.029)	[−0.020]
Mother's age at birth (d.v.)						
20–29	0.898[a]	(0.015)	[0.102]	0.815[a]	(0.017)	[0.085]
30–39	1.171[a]	(0.016)	[0.133]	1.104[a]	(0.018)	[0.115]
40 and over	0.991[a]	(0.039)	[0.113]	1.014[a]	(0.066)	[0.106]
Location (d.v.)						
Taipei City	0.035[a]	(0.034)	[0.003]	0.078[a]	(0.036)	[0.008]
Taipei County	0.098[a]	(0.034)	[0.011]	0.096[a]	(0.035)	[0.010]
Intercept	−3.432[a]	(0.037)		−7.386[a]	(0.072)	
Pseudo-R^2	0.121			0.130		
Log likelihood	−619,110			−501,578		
Sample size	1,596,326			1,222,902		

Notes: Standard errors are in parentheses and marginal effects are in brackets.
Control variables also include year and city/county dummies.
[a]Statistically significant at the 1% level.
[b]Statistically significant at the 5% level.

According to the above findings, students attending public universities tend to come from wealthier families, who can more easily afford to pay for the costs of their children's higher education; nevertheless, this is also the group which pays the lowest tuition fees and which tends to receive the greatest amount of subsidies from the government. If viewed from a different perspective, however, it may be argued that over a longer period of time, this group of students would eventually pay substantially higher amounts of tax to the government, given that their better level of education is likely to lead to substantially higher income levels.[9] Whether the amount expected to be repaid is sufficient to offset the subsidies received is open to debate, and is clearly an issue worthy of further research in the future. Another argument worth considering is that these public school students may subsequently go on to generate substantial positive externalities, such as the development of new technologies, thus

[9]Liu, Hammitt and Lin (2000) have shown that the wage function in Taiwan is convex and so returns to schooling increase with the level of education.

Table 4
Regression results on public university attendance

	Dependent variable = 1 if attending public university					
	Specification (1)			Specification (2)		
	Coeff.	Std. err.	ME	Coeff.	Std. err.	ME
Father's education (d.v.)						
College (or university) and over	0.217[a]	(0.017)	[0.048]	0.225[a]	(0.018)	[0.050]
College without a bachelor's degree	0.095[a]	(0.016)	[0.021]	0.105[a]	(0.018)	[0.023]
High school	0.043[a]	(0.012)	[0.009]	0.049[a]	(0.013)	[0.011]
Junior high school	0.001	(0.014)	[0.0003]	−0.002	(0.015)	[−0.0003]
Mother's education (d.v.)						
College (or university) and over	0.523[a]	(0.021)	[0.116]	0.519[a]	(0.022)	[0.116]
College without a bachelor's degree	0.270[a]	(0.018)	[0.060]	0.271[a]	(0.020)	[0.060]
High school	0.117[a]	(0.012)	[0.026]	0.111[a]	(0.013)	[0.024]
Junior high school	0.029[a]	(0.013)	[0.006]	0.032[b]	(0.014)	[0.007]
Parent's occupation in public sector (d.v.)	0.153[a]	(0.011)	[0.034]	0.014[a]	(0.012)	[0.031]
Parent's income (in log)				0.025[b]	(0.010)	[0.005]
First-born son (d.v.)	−0.017	(0.012)	[−0.004]	−0.018	(0.013)	[−0.004]
First-born daughter (d.v.)	−0.002	(0.012)	[−0.0005]	0.009	(0.013)	[0.002]
Male	0.006	(0.011)	[0.001]	0.010	(0.012)	[0.002]
Low birth weight (d.v.)	−0.076[b]	(0.019)	[−0.017]	−0.078[a]	(0.020)	[−0.017]
Twin (d.v.)	−0.041	(0.048)	[−0.009]	−0.063	(0.052)	[−0.014]
Mother's age at birth (d.v.)						
20–29	0.115[a]	(0.032)	[0.025]	0.130[a]	(0.036)	[0.029]
30–39	0.111[a]	(0.033)	[0.024]	0.115[a]	(0.038)	[0.025]
40 and over	0.045	(0.078)	[0.010]	−0.047	(0.124)	[−0.010]
Location (d.v.)						
Taipei City	0.090	(0.064)	[0.021]	0.099	(0.066)	[0.022]
Taipei County	0.139[b]	(0.064)	[0.031]	0.143[a]	(0.066)	[0.032]
Intercept	−1.121[a]	(0.071)		−1.416[a]	(0.133)	
Pseudo-R^2	0.012			0.013		
Log likelihood	−162,619			−139,484		
Sample size	257,068			220,205		

Notes: Standard errors are in parentheses and marginal effects are in brackets.
Control variables also include year and city/county dummies.
[a]Statistically significant at the 1% level.
[b]Statistically significant at the 5% level.

benefiting the whole of society, including those from poorer families. There are, however, inherent difficulties in undertaking an evaluation of whether the value of the positive externalities would exceed the amount of subsidies.

Since there is also a disparity in government subsidies within public universities, we further examined the progression effect of parental education on the choice of different public universities. As Table 5 shows, students attending normal universities are more likely to come from less-educated families. Students whose fathers hold a bachelor's degree or higher is 2.6% less likely to attend a normal university; the likelihood of attending a normal university is also reduced by 1.6% if the mothers hold a bachelor's degree or higher.

Students attending the top five public universities come from the most affluent families of Taiwanese society. The parents' educational achievements play a strong role in increasing the likelihood of their children entering the top ranking public universities, with the mother's schooling beyond high school having a stronger impact on a child's educational attainment. Compared to children whose parents with only a primary school education, having mothers whose educational achievements are at the level of bachelor's degree or higher raises the likelihood of a child attending one of the top five

Table 5
Regression results on university attendance MNL model (Specification 1)

	Top 5 university/private			Normal university/private			Other public university/private		
	Coeff.	Std. err.	ME	Coeff.	Std. err.	ME	Coeff.	Std. err.	ME
Father's education (d.v.)									
College (or university) and over	0.496[a]	(0.074)	[0.049]	−0.238[a]	(0.030)	[−0.026]	0.190[a]	(0.027)	[0.016]
College without a bachelor's degree	0.199[a]	(0.067)	[0.021]	0.015	(0.026)	[−0.001]	0.051[b]	(0.024)	[0.002]
High school	0.118[b]	(0.052)	[0.014]	−0.035[c]	(0.019)	[−0.004]	0.024	(0.018)	[0.001]
Junior high school	0.085[b]	(0.037)	[0.010]	−0.072[a]	(0.022)	[−0.006]	−0.012	(0.020)	[−0.001]
Mother's education (d.v.)									
College (or university) and over	0.941[a]	(0.063)	[0.084]	−0.041	(0.038)	[−0.016]	0.358[a]	(0.030)	[0.027]
College without a bachelor's degree	0.556[a]	(0.059)	[0.051]	0.039	(0.031)	[−0.004]	0.164[a]	(0.027)	[0.010]
High school	0.292[a]	(0.043)	[0.028]	−0.082[a]	(0.019)	[−0.010]	0.108[c]	(0.017)	[0.008]
Junior high school	0.067[b]	(0.028)	[0.007]	−0.030	(0.020)	[−0.003]	0.031	(0.018)	[0.002]
Parent's occupation in public sector (d.v.)	0.128[a]	(0.041)	[0.011]	0.335[a]	(0.019)	[0.025]	0.005	(0.017)	[−0.005]
Parent's income (in log)									
First-born son (d.v.)	0.012	(0.023)	[0.002]	−0.047[b]	(0.023)	[−0.003]	−0.046[a]	(0.016)	[−0.004]
First-born daughter (d.v.)	0.061[b]	(0.025)	[0.007]	−0.029[c]	(0.017)	[−0.002]	−0.028	(0.020)	[−0.003]
Male	0.133[a]	(0.018)	[0.012]	−0.756[a]	(0.018)	[−0.068]	0.527[a]	(0.016)	[0.066]
Low birth weight (d.v.)	−0.119[a]	(0.036)	[−0.011]	−0.016	(0.029)	[0.001]	−0.062[b]	(0.027)	[−0.005]
Twin (d.v.)	−0.094	(0.078)	[−0.008]	−0.027	(0.078)	[−0.001]	−0.017	(0.069)	[−0.001]
Mother's age at birth (d.v.)									
20–29	0.227[a]	(0.079)	[0.022]	0.042	(0.046)	[−0.001]	0.126[a]	(0.046)	[0.010]
30–39	0.275[a]	(0.090)	[0.028]	−0.081	(0.050)	[−0.010]	0.138[a]	(0.049)	[0.012]
40 and over	0.440[a]	(0.134)	[0.046]	−0.335[a]	(0.135)	[−0.031]	0.009	(0.115)	[−0.001]
Location (d.v.)									
Taipei City	0.471[a]	(0.019)	[0.052]	−1.025[a]	(0.026)	[−0.087]	−0.025	(0.017)	[0.002]
Taipei County	0.451[a]	(0.021)	[0.047]	−0.736[a]	(0.023)	[−0.064]	0.062[a]	(0.017)	[0.009]
Intercept	−2.542[a]	(0.311)		−1.348[a]	(0.049)		−2.226[a]	(0.050)	
Log likelihood	−250,184								
Chi-squared	18,394[a]								
Sample size	257,068								

Notes: Standard errors are in parentheses and marginal effects are in brackets.
Control variables also include year dummies which are not reported here.
[a]Statistically significant at the 1% level.
[b]Statistically significant at the 5% level.
[c]Statistically significant at the 10% level.

public universities by 8.4%, whereas a similar educational achievement by the father raises the likelihood by only 4.9%. The significantly positive coefficient of family income in Table 6 also leads us to the same conclusion.

According to the multinomial logit results in Tables 5 and 6, the relationship between government education subsidies and family background is not truly monotonic. Students from poor families tend to attend normal universities, which receive the highest subsides among the universities. Students from the wealthiest families tend to attend one of the top five public universities, which receive the second highest subsidies.

We continue by briefly discussing here the remaining variables in Table 3, 5 and 6 that are of interest to us. We found that children from government-employed households are more likely to attend university, either one of the top five public universities or normal universities, a result which confirms that government-employed households are a special group enjoying greater subsidies for higher education. The significantly positive coefficients of the first-born son and daughter indicate that household resources are usually allocated toward the oldest child, and consequently that he/she will have better opportunities for educational achievement. This finding is, however, inconsistent with that of Parish and Willis (1993) who

Table 6
Regression results on university attendance MNL model (Specification 2)

	Top 5 university/private			Normal university/private			Other public university/private		
	Coeff.	Std. err.	ME	Coeff.	Std. err.	ME	Coeff.	Std. err.	ME
Father's education (d.v.)									
College (or university) and over	0.540[a]	(0.028)	[0.048]	−0.231[a]	(0.032)	[−0.026]	0.220[a]	(0.027)	[0.020]
College without a bachelor's degree	0.240[a]	(0.029)	[0.020]	0.031	(0.029)	[−0.001]	0.074[a]	(0.026)	[0.004]
High school	0.142[b]	(0.023)	[0.012]	−0.023	(0.021)	[−0.003]	0.042[a]	(0.019)	[0.003]
Junior high school	0.094[b]	(0.027)	[0.009]	−0.083[a]	(0.024)	[−0.007]	−0.007	(0.022)	[−0.001]
Mother's education (d.v.)									
College (or university) and over	0.973[a]	(0.031)	[0.085]	−0.024	(0.040)	[−0.014]	0.359[a]	(0.032)	[0.027]
College without a bachelor's degree	0.595[a]	(0.029)	[0.052]	0.056[c]	(0.033)	[−0.002]	0.166[a]	(0.029)	[0.010]
High school	0.323[a]	(0.022)	[0.029]	−0.081[a]	(0.021)	[−0.010]	0.098[a]	(0.019)	[0.007]
Junior high school	0.085[b]	(0.024)	[0.007]	−0.025	(0.022)	[−0.003]	0.035	(0.020)	[0.003]
Parent's occupation in public sector (d.v.)	0.130[a]	(0.018)	[0.008]	0.349[a]	(0.020)	[0.027]	−0.002	(0.018)	[−0.006]
Parent's income (in log)	0.098[a]	(0.016)	[0.009]	−0.029[c]	(0.016)	[−0.003]	−0.004	(0.015)	[−0.001]
First-born son (d.v.)	0.029	(0.019)	[0.003]	−0.061[b]	(0.025)	[−0.004]	−0.045[a]	(0.017)	[−0.004]
First-born daughter (d.v.)	0.084	(0.021)	[0.008]	−0.018	(0.019)	[−0.002]	−0.018	(0.021)	[−0.003]
Male	0.131[a]	(0.019)	[0.011]	−0.748[a]	(0.020)	[−0.067]	0.526[a]	(0.018)	[0.065]
Low birth weight (d.v.)	−0.125[a]	(0.032)	[−0.010]	−0.018	(0.032)	[0.001]	−0.074[a]	(0.030)	[−0.006]
Twin (d.v.)	−0.153	(0.084)	[−0.013]	−0.055	(0.086)	[−0.002]	−0.015	(0.074)	[0.001]
Mother's age at birth (d.v.)									
20–29	0.242[a]	(0.067)	[0.019]	0.081	(0.053)	[0.002]	0.138[a]	(0.052)	[0.011]
30–39	0.286[a]	(0.070)	[0.024]	−0.060	(0.057)	[−0.009]	0.147[a]	(0.055)	[0.013]
40 and over	0.372[a]	(0.182)	[0.040]	−0.597[b]	(0.246)	[−0.051]	−0.037	(0.179)	[−0.002]
Location (d.v.)									
Taipei City	0.484[a]	(0.018)	[0.054]	−1.023[a]	(0.027)	[−0.086]	−0.019	(0.019)	[0.003]
Taipei County	0.456[a]	(0.019)	[0.047]	−0.715[a]	(0.024)	[−0.062]	0.062[a]	(0.018)	[0.009]
Intercept	−3.795[a]	(0.186)		−1.105[a]	(0.184)		−2.197[a]	(0.165)	
Log likelihood	−215,447								
Chi-squared	16,259[a]								
Sample size	220,205								

Notes: Standard errors are in parentheses and marginal effects are in brackets.
Control variables also include year dummies which are not reported here.
[a]Statistically significant at the 1% level.
[b]Statistically significant at the 5% level.
[c]Statistically significant at the 10% level.

found that first-born children received less education. Low birth weight significantly reduces the likelihood of attendance at universities, or at a public university, or at one of the top five public universities. These results suggest that poor infant health has a long-term negative effect on the subsequent educational achievement of a child and are consistent with those of Currie and Hyson (1999) and Corman and Chaikind (1998).

5. Conclusions

In this paper, we have extensively examined the relationship between family background, individual characteristics and educational achievement in Taiwan. The results of our study suggest that family background has an important impact on the educational achievements of children. The education levels attained by parents also positively affect the likelihood of a child attending a university or a public university. Furthermore, completion of a university education (i.e., a bachelor's degree) by the parents is found to have a greater impact on university attendance by a child than any additional years of parental schooling beyond that level. The household income variable has a positive association with the educational attainment of the child,

with this variable being statistically significant in all cases. The results of this study are consistent with those of Rozada and Menendez (2002), who used data from Argentina. The empirical evidence from this study and the Argentinean study both support the contention that government spending on higher education actually subsidizes richer families, not poorer families. Thus, for considerations of equity, there may a need to review, in the near future, the low tuition fees currently adopted by public universities.

Acknowledgements

This study was partially supported by a grant from the National Health Research Institute, Taiwan (NHRI-EX-93-9226PI).

References

Behrman, J. (1999). Labor markets in developing countries. In O. Ashenfelter, & D. Card (Eds.), *Handbook of labor economics*. Amsterdam: North-Holland.

Corman, H., & Chaikind, S. (1998). The effect of low birthweight on the school performance and behavior of school-aged children. *Economics of Education Review*, *17*, 307–316.

Currie, J., & Hyson, R. (1999). Is the impact of health shocks cushioned by socioeconomic status? The case of low birthweight? *American Economic Review*, *89*, 245–250.

Duan, N., Manning, W., Morris, C., & Newhouse, J. (1983). A comparison of alternative models for the demand for medical care. *Journal of Business and Economic Statistics*, *1*, 115–126.

Fernandez, R., & Rogerson, R. (1995). On the political economy of education subsidies. *Review of Economic Studies*, *62*, 249–262.

Haveman, R., & Wolfe, B. (1995). The determinants of children's attainments: A review of methods and findings. *Journal of Economic Literature*, *33*, 1829–1878.

Liu, J.-T., Hammitt, J., & Lin, C. J. (2000). Family background and returns to schooling in Taiwan. *Economics of Education Review*, *19*, 113–125.

Leung, S. F., & Yu, S. (1996). On the choice between sample selection and two-part models. *Journal of Econometrics*, *72*, 197–229.

Parish, W., & Willis, R. (1993). Daughters, education, and family budgets: Taiwan experience. *Journal of Human Resources*, *20*, 583–604.

Rozada, M. G., & Menendez, A. (2002). Public university in Argentina: Subsidizing the rich? *Economics of Education Review*, *21*, 341–351.

AS LOW BIRTH WEIGHT BABIES GROW, CAN WELL-EDUCATED PARENTS BUFFER THIS ADVERSE FACTOR? A RESEARCH NOTE*

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This research note combines two national Taiwanese data sets to investigate the relationships among low birth weight (LBW) babies, their parents' educational levels, and their future academic outcomes. We find that LBW is negatively correlated with the probability of such children attending college at age 18; however, when both parents are college or high school graduates, such negative effects may be partially offset. We also show that discrimination against daughters occurs, but only for daughters who were LBW babies. Moreover, high parental education can buffer the LBW shock only among moderately LBW children (as compared with very LBW children) and full-term LBW children (as compared with preterm LBW children).

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, such as brain dysfunction or neurosensory impairment. Almond, Chay, and Lee (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. 2002:353), studies on the long-term developmental outcomes of LBW babies have grown rapidly in number in recent years. For example, McCormick et al. (1992), Breslau et al. (1994), and Hack et al. (2002) found that LBW children had lower IQs and health and behavioral problems, and Conley and Bennett (2000) found a negative association between LBW and timely high school graduation. Low test scores have also been found to be associated with LBW (Boardman et al. 2002; Hack et al. 2002), and 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 capital), prior studies have generally established a negative association between LBW and subsequent outcomes.

In this article, we are particularly interested in the interactive effects of parental education and LBW on the academic outcomes of children, a channel rarely discussed in the literature. Currie and Hyson (1999) found that although the high socioeconomic status of parents could buffer the negative effects of LBW on self-reported female health conditions, it could not buffer the negative effects on test scores and wages. However, Kandel and Mednick (1991), Raine, Brennan, and Mednick (1994), and Tibbetts and Piquero (1999) found that the interactions between LBW and parental rejection (or inferior family background) were associated with a higher probability of being arrested and committing a violent crime.

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Currie and Hyson (1999) provided two hypotheses regarding the interaction between LBW and parental education. The first was that if parents were faced with credit constraints, the LBW children of parents who were designated as having low parental education (elementary and junior high school education) would receive less human capital investment than their LBW counterparts with high-education (senior high school and college education) parents. Their second hypothesis was that if high-education and low-education parents differed in terms of their tastes—which decide 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 among parents with low levels of education.

The major concern with regard to these hypotheses is that they can explain only why parental investment might rise with higher levels of parental education; they cannot explain why such an increase should benefit LBW children more than normal birth weight (NBW) children.[1] Whether the LBW children benefit more from high parental education depends on parental investment and the exact shape of the production function.[2] Thus, the interactive effect between LBW and parental education must be determined empirically.

Finally, LBW and low levels of parental education may be proxies for an unobserved variable, such as genetic factor, that causes low health endowments and children's lower academic performance. In such a case, the associations among LBW, parental education, and subsequent academic outcome are not causal; all variables are merely indicators of the underlying genetic endowment. In this article, 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 toward sons and daughters. 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 intergenerational contracts and expectations of mutual obligations in raising sons and daughters.[3]

Parish and Willis (1993) found that investment in children in Taiwanese families was often frustrated by credit constraints, with earlier-born female children faring particularly poorly because of the need for them to start work at an early age to support their younger siblings. 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 intrafamilial contract that shaped the human capital development system and encouraged the maintenance of different roles for men and women, with such gender stratification resulting systematically from a sequence of choices made across the life cycle.

In the present study, we combine two national population data sets 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 data sets enable us to overcome the problems of measurement error and lack of statistical power, especially for LBW children. Second, we

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

2. 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 increase as parental education increases. 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 to their NBW children, the gap could also decrease with higher parental education.

3. In Taiwan, parents rely on their sons to look after them in their old age, while daughters generally contribute resources to the extended family of the husband.

Table 1. University Attendance, by Birth Weight and Mother's Education

	Full Sample		Normal Birth Weight (> 2,500 g)		Low Birth Weight (≤ 2,500 g)	
Mother's Education	Mean	*SD*	Mean	*SD*	Mean	*SD*
Mother Has High Educational Level	0.3210	0.4669	0.3238	0.4679	0.2660	0.4419
Number of observations	289,976		276,081		13,895	
Mother Has Low Educational Level	0.1068	0.3088	0.1084	0.3108	0.0768	0.2663
Number of observations	997,973		947,247		50,726	

explore the relationship between parental education and academic outcome by gender for LBW babies. Finally, we account for the heterogeneity within the group of LBW children by using detailed information on gestational age and birth weight.

DATA SETS

The first data set we 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 A1.

After we dropped observations for those who died before age 18 and for those with missing values on the explanatory variables, the linkage between the two national data sets yielded a sample of 1,287,949. Table 1 presents data on university attendance, by birth weight and by the mother's educational attainment, with senior high school and above being referred to as *high education* and the remainder being designated as *low education*.[4] Consistent with the prior literature, educational achievements are strongly correlated with parental education. Students with highly educated mothers had a much higher probability of attending university (32.1% vs. 10.7%) than those with low-educated mothers.

On the other hand, LBW students had lower test outcomes than NBW students; for example, 32.4% of NBW children with a highly educated mother attended a university, and 10.8% of NBW children with a mother with a low educational level did so; the corresponding figures for their LBW counterparts were 26.6% for those with a highly educated mother and 7.7% for a mother with a low level of education. In summary, mother's education is positively associated, and LBW is negatively associated, with academic achievement.

MAIN RESULTS

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

$$Y_{ijt} = \alpha + \beta_1 LBW + \beta_2 HEF + \beta_3 HEM + \gamma_1 LBW \times HEF + \gamma_2 LBW \times HEM + \delta X_{ijt} + \mu_j + \nu_t + \varepsilon_{ijt}, \quad (1)$$

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

where Y_{ijt} is the university attendance of individual i born in county or city j in year t, *HEF* is high-education father, and *HEM* is high-education mother.

The regressors included a dummy variable for LBW, mother's education (coded as 1 if mother's education is senior high school or above), father's education (coded as 1 if father's education is senior high school or above), and their interaction terms. Other explanatory variables (X) included gender (male = 1); dummy variables for twin, birth order, mothers' age, and birth year (ν_t); birth county (μ_j); family income (in log); and government-employed household.[5] ε_{ijt} represents the disturbance term.

Eq. (1) indicates that the marginal effect of LBW on university attendance depends on 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 $\beta_1 + \gamma_1 \times HEF + \gamma_2 \times HEM$. 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 for both the whole sample and by gender are reported in Table 2.

Our results suggest that students born with LBW and with low-education parents have a 4.5% lower probability of attending a university; however, because a college or senior high school education for fathers or mothers can buffer the LBW shock by raising the probability of attending college by 0.7% and 1.0%, respectively the marginal effect of LBW for those who have highly educated parents is only –2.8% but is statistically significant. This implies that a highly educated father and mother can together offset around 40% (1.7 / 4.5) of the negative effect of LBW. Furthermore, Table 2 also suggests that parental education, family income, and government-employed households are all positively correlated, and birth order is negatively correlated, with the probability of attending college.

As shown in Table 2, the coefficient for gender is small and insignificant. Furthermore, differences in the estimations from the regressions for males and females are small and not always in favor of boys; nevertheless, the coefficients of the interaction between LBW and a highly educated mother were larger in the regression for males (1.5%; significant) than in the female regression (0.6%; nonsignificant). It therefore seems clear that highly educated mothers still discriminate against daughters with lower health endowments.

SENSITIVITY TESTS

McCormick et al. (1992), Boardman et al. (2002), and Hack et al. (2002) found that adverse birth outcomes were more profound among those with very low birth weight (VLBW; < 1,500 gm) than among those with moderately low birth weight (MLBW; 1,500 gm–2,500 gm). In Table 3, we explore 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 college by 11%, while MLBW reduces this probability by only 4.7%. Furthermore, the negative effect of VLBW is not buffered by a high educational level of parents. Therefore, VLBW clearly represents an index of high risk.

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 preterm babies. We can therefore categorize LBW babies into two groups: full-term (gestational age greater than 38 weeks) or preterm (gestational age less than 38 weeks). Full-term LBW babies are defined here as those who are likely to experience intrauterine growth retardation.[6] As Table 4 shows, compared with a NBW baby, the likelihood of a preterm LBW baby attending college in adulthood is 4.6%

5. Data on gender, twin status, birth order, mother's age, birth year, and birth county were available from birth certificate records. 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.

6. We are grateful to the editors for providing this perspective.

Table 2. Logit Results for University Entrance

	Full Sample		Male		Female	
Variable	Coefficient	Marginal Effects	Coefficient	Marginal Effects	Coefficient	Marginal Effects
Low Birth Weight	–0.4067** (0.0197)	–0.0450	–0.4388** (0.0293)	–0.0487	–0.3785** (0.0266)	–0.0417
Father Has High Educational Level	0.6296** (0.0066)	0.0696	0.6463** (0.0091)	0.0717	0.6119** (0.0095)	0.0673
Low Birth Weight × Father Has High Educational Level	0.0596† (0.0316)	0.0066	0.0526 (0.0467)	0.0058	0.0684 (0.0429)	0.0075
Mother Has High Educational Level	0.4895** (0.0069)	0.0541	0.4625** (0.0096)	0.0513	0.5194** (0.0100)	0.0572
Low Birth Weight × Mother Has High Educational Level	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	—	—	—	—
Number of Observations	1,287,949		666,754		621,195	
Likelihood Ratio Chi-Square	119,527.53		60,565.91		59,167.80	
Pseudo-R^2	0.1141		0.1112		0.1179	

Note: Other regressors include eight dummy variables for mother's age (ages 20–22, 23–25, 26–28, 29–31, 32–34, 35–37, 38–40, and above 40) and dummy variables for twin, county, and birth year. Numbers in parentheses are standard errors.

†Significant at the 10% level; **Significant at the 1% level.

lower, while the likelihood of a full-term LBW baby attending college in adulthood is 4.5% lower. A highly educated parent can buffer the negative effect of a full-term LBW by 0.8% to 1.2%; however, neither the father nor the mother can buffer the negative effect of LBW for preterm LBW babies.

The final sensitivity test checks whether the strong correlation between parental education levels affects our results by 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 5 shows that the marginal effect of LBW and its interaction with different parental education variables remains at –4.4% to –4.6% and 1.2% to 1.4%, respectively. These results are similar to those shown in Table 2. Hence the potential problem of multicollinearity does not jeopardize our previous estimations.

Table 3. Sensitivity Test of the Interaction Between University Attendance, Very Low Birth Weight (VLBW) or Moderately Low Birth Weight (MLBW), and Parental Education: Full Sample

Variable	Coefficient	*SE*	Marginal Effects
VLBW	–0.9986**	0.1686	–0.1105
MLBW	–0.4266**	0.0239	–0.0472
Father Has High Educational Level	0.6310**	0.0065	0.0698
Mother Has High Educational Level	0.4911**	0.0069	0.0543
VLBW × Father Has High Educational Level	–0.1516	0.2557	–0.0168
VLBW × Mother Has High Educational Level	0.1357	0.2521	0.0150
MLBW × Father Has High Educational Level	0.0528	0.0383	0.0058
MLBW × Mother Has High Educational Level	0.0944*	0.0387	0.0104
Family Income	0.0101**	0.0001	0.0011
Government Employee	0.5167**	0.0084	0.0571
Number of Observations		1,287,949	
Likelihood Ratio Chi-Square		119,521.47	
Pseudo-R^2		0.1141	

Note: Other explanatory variables include male and dummy variables for birth order, mother's age, twins, county, and birth year.

*Significant at the 5% level; **Significant at the 1% level.

Table 4. Sensitivity Test of the Interaction Between University Attendance, Preterm Low Birth Weight (PLBW) or Full-term Low Birth Weight (FLBW), and Parental Education: Full Sample

Variable	Coefficient	*SE*	Marginal Effects
PLBW	–0.4180**	0.0347	–0.0463
FLBW	–0.4030**	0.0237	–0.0446
Father Has High Educational Level	0.6285**	0.0066	0.0696
Mother Has High Educational Level	0.4898**	0.0069	0.0542
PLBW × Father Has a High Educational Level	0.0389	0.0534	0.0043
PLBW × Mother Has a High Educational Level	0.0740	0.0529	0.0082
FLBW × Father Has a High Educational Level	0.0743*	0.0387	0.0082
FLBW × Mother Has a High Educational Level	0.1107**	0.0400	0.0123
Number of Observations		1,287,949	
Pseudo-R^2		0.1142	

Note: Other explanatory variables include male, log family income, governmental employee, and dummy variables for birth order, mother's age, twins, county, and birth year.

*Significant at the 5% level; **Significant at the 1% level.

Table 5. Sensitivity Test of the Interaction Between University Attendance, Low Birth Weight (LBW), and High Parental Education for Father, Mother, or Either Parent

	(1)		(2)		(3)	
Variable	Coefficient	Marginal Effects	Coefficient	Marginal Effects	Coefficient	Marginal Effects
LBW	–0.3982** (0.0193)	–0.0441	–0.3973** (0.0172)	–0.0448	–0.4206** (0.0213)	–0.0463
Father Has High Educational Level	0.8058** (0.0060)	0.0893	—	—	—	—
LBW × Father Has High Educational Level	0.1071** (0.0263)	0.0119	—	—	—	—
Mother Has High Educational Level	—	—	0.7579** (0.0063)	0.0854	—	—
LBW × Mother Has High Educational Level	—	—	0.1190** (0.0267)	0.0134	—	—
Either Parent Has High Educational Level	—	—	—	—	0.8567** (0.0060)	0.0944
LBW × Either Parent Has High Educational Level	—	—	—	—	0.1301** (0.0271)	0.0143
Number of Observations	1,287,949		1,287,949		1,287,949	
Likelihood Ratio Chi-Square	112,212.56		110,499.29		111,197.08	
Pseudo-R^2	0.1092		0.1053		0.1112	

Note: Other explanatory variables include male; log family income; governmental employee; and dummy variables for birth order, mother's age, twins, county, and birth year. Numbers in parentheses are standard errors.

**Significant at the 1% level.

CONCLUSION

This study has combined two unique national Taiwanese data sets 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 highly educated parents can offset the negative effects of LBW by as much as 40%. Furthermore, the buffering effects are significant only for sons, which suggest that highly educated parents discriminate against LBW daughters. Finally, parents with high levels of education can buffer the LBW shock only among MLBW children (as compared with VLBW children) and full-term LBW children (as compared with preterm LBW children). These results suggest the importance of considering 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 use more structured and detailed data in the analysis of the problem to better understand the mechanisms involved in this biosocial link. For example, an implicit assumption in our research is that LBW, and 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 a high return on their investment. Our finding that gender is a risk factor might suggest that parental investment is especially low for LBW daughters. To investigate

these complex mechanisms, we need to know more about the production function that can transform parental investments into outcomes, the preferences of parents that govern the intrahousehold distribution of resources, and the ways in which these factors interact with parental education. Unfortunately, our data set contains no detailed information that would allow us to identify either parents' differential investments in LBW and NBW children or their preferences with regard to intrahousehold resource distribution. The strong buffering effect of parental education found in this study, however, points to a potentially intriguing research direction if appropriate data can be obtained to identify these mechanisms.

Appendix Table A1. Summary Statistics of Variables

Variables	Mean	*SD*
University Attendance, Full Sample	0.155	0.362
Gestational Age (weeks)	39.74	1.197
Birth Weight (grams)	3,287.3	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: Number of observations = 1,287,949.

REFERENCES

Almond, D., K. Chay, and D. Lee. 2005. "The Costs of Low Birth Weight." *Quarterly Journal of Economics* 121:1031–83.

Becker, G. 1981. *A Treatise on the Family*. Cambridge, MA: Harvard University Press.

Behrman, J. and M. Rosenzweig. 2004. "Returns to Birth Weight." *Review of Economics and Statistics* 86:586–601.

Boardman, J.D., D.A. Powers, Y.C. Padilla, and R.A. Hummer. 2002. "Low Birth Weight, Social Factors and Development Outcomes Among Children in the United States." *Demography* 39:353–68.

Bonjour D., L.F. Cherkas, J.E. Haskel, D.D. Hawkes, and T.D. Spector. 2003. "Returns to Education: Evidence From U.K. Twins." *American Economic Review* 93:1799–812.

Breslau, N., J.E. DelDotto, G.G. Brown, S. Kumar, S. Ezhuthachan, K.G. Hufnagle, and E.L. Peterson. 1994. "A Gradient Relationship Between Low Birth Weight and IQ at Age 6 Years." *Archives of Pediatric and Adolescent Medicine* 148:377–83.

Brinton, M. 1988. "The Social-Institutional Bases of Gender Stratification: Japan as an Illustrative Case." *American Journal of Sociology* 94:300–34.

———. 1993. *Women and the Economic Miracle: Gender and Work in Postwar Japan*. Berkley, CA: University of California Press.

Conley, D. and N. Bennett. 2000. "Is Biology Destiny? Birth Weight and Life Chances." *American Sociological Review* 65:458–67.

Currie, J. and R. Hyson. 1999. "Is the Impact of Health Shocks Cushioned by Socioeconomic Status? The Case of Low Birth Weight." *American Economic Review* 89:245–50.

Greenhalgh, S. 1985. "Sexual Stratification: The Other Side of 'Growth With Equity' in East Asia." *Population and Development Review* 11:265–314.

Hack, M., D. Flannery, M. Schluchter, L. Carter, E. Borawski, and N. Klein. 2002. "Outcomes in Young Adulthood for Very Low Birth Weight Infants." *New England Journal of Medicine* 346(3):149–57.

Kandel, E. and S.A. Mednick. 1991. "Perinatal Complications Predict Violent Offending." *Criminology* 29:519–29.

McCormick, M.C., J. Brooks-Gunn, K. Workman-Daniels, J. Turner, and G.J. Peckham. 1992. "The Health and Developmental Status of Very Low Birth Weight Children at School Age." *Journal of the American Medical Association* 267(16):2204–208.

Parish, W.L. and R.J. Willis. 1993. "Daughters, Education and Family Budgets—Taiwan Experiences." *Journal of Human Resources* 28:863–98.

Perlman, J. 2001. "Neurobehavioral Deficits in Premature Graduates of Intensive Care—Potential Medical and Neonatal Environmental Risk Factors." *Pediatrics* 108:1339–48.

Raine, A., P. Brennan, and S.A. Mednick. 1994. "Birth Complications Combined With Early Maternal Rejection at Age 1 Year Predispose to Violent Crime at Age 18 Years." *Archives of General Psychiatry* 51:984–88.

Tibbetts, S. and A. Piquero. 1999. "The Influence of Gender, Low Birth Weight and Disadvantaged Environment in Predicting Early Onset of Offending: A Test of Moffitt's Interactional Hypothesis." *Criminology* 37:843–77.

Yu, W.H. and K.S. Su. 2006. "Gender, Sibship Structure, and Educational Inequality in Taiwan: Son Preference Revisited." *Journal of Marriage and Family* 68:1057–68.

赴國外研究心得報告

計畫編號	NSC 95-2415-H-002-005 2006/8/1 – 2007/10/31
計畫名稱	新生兒出生體重的長期影響
出國人員姓名 服務機關與職稱	劉錦添　國立台灣大學經濟學系教授
出國時間地點	Cambridge, MA, USA; July 14- August 6, 2007
國外研究機構	NBER Summer Institute and Harvard University

工作記要：

本人於 2007 年 7 月 14 日至 8 月 6 日至美國麻州 Cambridge 市參加 NBER 每年暑期研討會(Summer Institute)，並至波士頓市拜訪 Harvard Center for Risk Analysis 研究人員 James K. Hammitt 教授以及紐約 NBER Health Economics Program Director Michael Grossman 教授討論雙方共同合作研究計畫。NBER 暑期研討會係美國經濟學界年度盛會，每年暑期自 7 月初至 8 月上旬，連續一個月舉辦不同領域的研討會。本人參加的研討會主要是個體經濟領域。個體經濟領域包括 Health Economics，Health Care，Labor Studies，Children Program，Aging，Social Insurance，Environmental Economics，Education Economics，以及 Empirical Personnel Economics。本人目前係 NBER Research Associate，今年係應 Health Economics Program Director Michael Grossman 與 Children Program Director Gruber 邀請參加暑期研討會。本人今年度國科會計畫和研討會中 Labor Studies，Children Program 與 Health Economics 性質接近。

今年 7 月 31 日至 8 月 1 日，NBER 特別邀請 Guido Imbens 與 Jeffrey Wooldridge 兩位教授講授三天“What’s New in Econometrics?” Minicourse，參加學者高達 150 人。這三天課程兩位教授輪流講授個體計量方法最新的發展。另外，哈佛大學在健康經濟學的研究是全世界最重要的研究重鎮，Harvard Center for Risk Analysis 在健康風險方面的研究亦是享譽國際學術界。本人和該中心已有十年合作關係，

和 James K. Hammitt 已共同發表將近二十篇學術論文。另外，本人和 Michael Grossman 亦有合作研究正在進行，最近完成一篇 “Parental Education and Child Health : Evidence from a Natural Experiment in Taiwan,”已列入 NBER Working paper No. 13466，並已投至國際期刊。