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HOW MANY AND WHAT INSTRUMENTS ARE NEEDED TO ESTIMATE RETURNS TO EDUCATION? THE CASE OF TAIWAN

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Abstract: This paper applies the 2SLS instrumental variable method to estimate the rate of return to education using data from the 1990, 2000, and 2010 Taiwan's Manpower Utilization Survey. Tests are conducted to determine the most effective valid instrument from all combinations of the four IVs. The estimated rate of return to education is relatively higher by the IV method than by the OLS method. However, adding more IVs do not imply a better estimation and institutional, geographic, and cultural variables are more plausible candidate for valid instruments. Moreover, downward bias by OLS estimation is found to be greater for females than for males.

Keywords: Human capital investment; return to education; endogenous bias; ability bias; instrumental variable; local average treatment effect

JEL Classification: J24; I21

I. INTRODUCTION

Human capital investment has been identified as one of the important sources for a country's long-run economic growth.[1] For the past four decades, Taiwan, a small island of 36,000 kilometers with only a quarter of arable land and limited natural resources, had achieved the so-called "economic miracle" with average annual economic growth rate of 8.45% between 1960 to 2000. Taiwan's remarkable economic performance is consistent with the human capital theory to a large extent due to the development of a well-educated and better-trained labor force, which speeds up industrialization processes and upgrading of technology to sustain the long-run growth of the economy. Chuang (1999) finds that during the 1964-1994 period, 30% of Taiwan's average annual economic growth can be attributed to human capital. Lin (2004) also discovers that higher education had a positive effect on economic growth in Taiwan for the period 1965-2000; one additional percent of higher education stock is estimated to increase real output by approximately 0.19%. Moreover, examining the relation between education and growth, Chuang (2000) finds that higher education unidirectional caused economic growth in Taiwan over the period 1952-1995. Wu (2003) notices an increasing trend of rates of return to education in Taiwan from 1978 to 2001.

These findings on the education-growth nexus of Taiwan's economic miracle can be described as follows. Since the adoption of an open trade policy in the early 1960s, Taiwan has experienced drastic and rapid structural changes from an agriculture-oriented to an industry-oriented economy. In fact, the output share of industry increased from 23.03% in 1961 to 39.36% in 1978, subsequently remaining relatively stable until the mid 1980s. The structure of exports changed from labor-intensive products in the 1960s, to capital-intensive in the 1970s and technology-intensive in the 1980s. This open trade and rapid industrialization process increased the demand for skilled labor, which increased the return on education, and the increase in the quality of workers facilitated the process of accessing, absorbing, and applying technology upgrades and thus the subsequent economic growth.[2]

The Human capital theory emphasizes education and on-the-job training to enhance labor productivity and hence wage rates of workers.[3] The economic return to education not only influences an individual's educational choice but also affects the labor quality of the whole society. Therefore, from both individual and social points of view, the estimation of return to education is an important measure for human capital investment decisions and thus has a profound effect on human development.[4]

Due to the heterogeneity of an individual's ability, the conventional OLS estimation of the wage equation will be subject to the ability bias because the intercept of the wage equation by the OLS method reflects personal ability, which is correlated with the marginal cost of receiving education. Moreover, if the heterogeneity of an individual's ability is revealed by the different slopes of the wage equation, i.e., the greater the return to education, the higher the incentive for educational investment, then under this situation, the estimation results by the OLS method will be further inflated. As there exist heterogeneous returns to education, reflected by the intercept and slope of the wage equation, the adoption of the OLS method to estimate the return to education requires that explanatory variables and the error term be mutually independent. Failure to satisfy this condition will render a bias in estimation by the OLS method. More importantly, educational investment is an endogenous decision process that is heavily influenced by personal characteristics and family background factors. As the education variable is not exogenous, conventional OLS estimation will be subject to bias.[5]

Griliches (1977) proposes to use the instrumental variable method to tackle the problems of ability bias and endogeneity.[6] However, the major difficulty is to find a valid instrumental variable, especially for cross-section data analysis such as the estimation of return to education. Heckman and Vytlacil (1999) point out that the instrumental variable has to be correlated with an individual educational choice and uncorrelated with an individual's ability. Most of the existing literature has shown that it will be relatively difficult to find a valid instrumental variable from the demand side of education, as we are not quite certain that the demand factor for education has no correlation with an individual's wage rate. Therefore, economists are inclined to use supply factors for education such as family background factors as the instrumental variable. For example, Trostel, Walker and Woolley (2002) use parents and spouse's education as instrumental variables to estimate male and female return to education for 28 countries, finding that the estimated rate of return to education is typically higher when calculated by the IV method than by the OLS method. Other studies, such as Arcand, D'hombers and Gyselnck (2004), Patrinos and Sakellariou (2005), and Sakellariou (2006), adopt the father's years of education as the instrumental variable; all of these find results similar to those of Trostel, Walker and Woolley (2002).[7]

As people are not convinced that family background factors are uncorrelated with an individual's ability, recent studies have switched to supply side factors of the labor market as the instrumental variable.[8] For example, Angrist and Krueger (1991) use birth season as the instrumental variable, as differences in birth season cause different dates of school enrollment and hence different times for completing compulsory education. Apparently, birth season has a correlation with years of schooling, but none with an individual's ability. Johnson and Nye (2011) find that people born in Dragon years tend to have higher educational achievement than those are not in Chinese society. The major reason is not because people born in Dragon years are more intelligent but due to culture preference Chinese parents desire to give more educational resources to child born in the "Year of the Dragon". Harmon and Walker (1997) use the compulsory educational policy in the U.K. as the instrumental variable because the change in educational policy is exogenous but in fact influences people's minimum years of schooling. Chuang and Lai (2008) also find that nine-year compulsory education close the education gap between different ethnic groups in Taiwan. As the instrumental variable is subject to the educational choice of particular demographic groups, the results estimated by the IV method can be interpreted as the marginal rate of return to education for those particular demographic groups. Likewise, the estimated rate of return to education for the IV method is usually higher than that for the OLS method.[9]

There are other instrumental variables in the literature. For instance, Duflo (1999) chooses birth date

before and after institutional change, and personal residential area, as the educational resources may be different under different policies, as instrumental variables. Moretti (2004) uses estimated demographic structure in the city and land-grant university as instrumental Variable to estimate estimated spillover effect of education and social rate of return to education.

Conventionally, under the assumption of mutual independence of the explanatory variables and the error term, estimates from the OLS method are interpreted as the average marginal rate of return to education. However, if it is not the case, as it usually is, the OLS estimates will subject to the endogeneity bias.

For the past forty or more years, investment in education has expanded greatly in Taiwan due to the government's expansionary education policy, the process of rapid industrialization, and the conventional wisdom that "To be a scholar is to be at the top of society." The average years of education for employed workers in Taiwan has increased tremendously from 7.18 years in 1978 to 14.62 years in 2010, while for the same period, the per capita income raised from US$1,461 to US$19,175 a roughly thirteen-fold increase. According to the human capital theory, education enhances labor productivity and hence increases wage rates. But what is the economic return for an additional year of schooling? With its past dynamic and remarkable achievement, Taiwan should be a very interesting case study for estimation rates of return on education. Previous empirical studies on returns to education in Taiwan, e.g., Psacharopouls (1985); Gindling, Goldfarb, and Chang (1995); Chuang and Chao (2001); and Wu (2003), among others, have neglected either the endogeneity problem of education or the heterogeneity of unobserved ability, thus tending to encounter the endogeneity bias and ability bias for the estimates of returns to education.[10] The two exceptions are Gurgand (2003) and Spohr (2003), who adopted the IV method to estimate returns to education for Taiwan but with a simple instrumental variable or special attention to specific groups only. Gurgand (2003) estimates the influence of education on a farmer's income, adopting a simple instrumental variable of the share of primary and high school farmers to replace the formal years of education, while Spohr (2003) uses the nine-year compulsory education policy as the instrumental variable and adopts the yearly wage instead of the hourly wage as the dependent variable.[11]

How many and what kinds of instruments are valid for estimation remains an empirical question. Instead of using a single instrumental variable, this paper intends to deal with the problems by using four different types of instrumental variables, namely the nine-year compulsory education policy, born in Dragon years, area of residence, and sibling status. To identify a better estimate of the rate of return to education for Taiwan, we test the validity of various combinations of all instruments. We find that the combination of the compulsory education policy, born in Dragon years, and area of residence, is the most efficient valid instrument and may give a better estimation for the rate of return to education. This result suggests that adding more instruments may not improve the estimation validity and variables such as compulsory education policy, born in Dragon years, and area of residence are better instrument than family background like sibling status. These results may provide useful implications and shed lights on how to use valid IVs to estimate rates of return on education for other countries.

This paper is organized as follows. Section II specifies the empirical model. Section III contains data description, estimation results, and sensitivity analysis. The conclusion follows in Section IV.

II. THE EMPIRICAL MODEL

As in the literature, we use Mincer's (1974) specification of wage equation as the basic model for the estimation of rate of return to education, and an additional educational choice equation is also stated as

$$Y_i = X'\delta + \beta S_i + u_i,$$

$$S_i = Z_i'\alpha + v_i,$$

where Y is the real hourly wage in logarithmic form; X is other variables affecting an individual's wage rate, such as work experience, marital status, industry, and firm size; S denotes years of schooling; Z is explanatory variables including instrumental variables that determine one's educational choice; u and v are error terms for wage and educational choice equations, respectively; and the

coefficient β represents the average rate of return to education for additional years of schooling. To cope with the endogeneity and ability bias problems of investment in education, a 2SLS instrumental variable estimation method is used.

A) The selection of instrumental variables

The use of instrumental variables to estimate return to education requires that instrumental variables satisfy the orthogonality condition; i.e., instrumental variables have no correlation with the individual's ability or error term. Furthermore, under the heterogeneous return to education, instrumental variables have to be uncorrelated with one's earning capability in addition to the orthogonality condition; i.e., Z is uncorrelated with β. In other words, allowing for a heterogeneous return to education, the instrumental variable should be correlated with one's educational choice, but uncorrelated with one's wage rate.[12]

We first adopt the nine-year compulsory education policy as our instrumental variable. Numerous studies have shown that the compulsory educational policy has a significant effect on return to education; see, e.g., Angrist and Krueger (1991); Cruz and Moreira (2005); and Sakellariou (2006), among others. From a policy perspective, the implementation of a compulsory educational policy significantly enhances the structure of labor quality of the developing countries, especially for those groups subject to family liquidity constraints.[13] Thus, the use of the compulsory educational policy as the instrumental variable not only solves for problem of endogeneity and ability bias caused by the OLS method but also gives us estimates for the rate of return to education for those who are subject to liquidity constraints, an important factor that hinders educational investment for economically disadvantaged people. Most research on return to education in developing countries has proved that using institutional factors as the instrumental variable tends to result in a higher estimated rate of return to education than that found by the OLS method.[14]

Compulsory educational policy is an institutional change that includes the building of new junior high schools and recruitment of new educational staff and teachers, and thus it is closely related to an individual's educational investment but has no direct relationship with an individual's ability. As educational resources are different among different residential areas, it thus has different impacts on individual's educational achievement, while having nothing to do with an individual's ability. In Chinese cultural tradition, Dragon is a symbol for Power, Nobel, and Dignity, thus Chinese parents would like to have their kids born in the year of the Dragon. For those born in Dragon year they tend to receive more attentions and concerns investment from their patents, thus, other thing being equals, children born in the Dragon year tend to receive more educational investment, even compared with their siblings, by their parents.[15] From the viewpoint of the life cycle of household income, elder children tend to have less family education resources than their young siblings do, as family income is usually low in the early stage.[16] Moreover, the greater the number of siblings for a given family budget constraint, the fewer the educational resources that are given to each child. Thus, born in Dragon year, the existence of young siblings and the number of such siblings will be correlated with an individual's educational achievement, but these factors have no correlation with an individual's ability or wage. Therefore, this paper adopts the nine-year compulsory education policy, born in Dragon year, residential area, and the existence of young siblings as instrumental variables for educational choice.[17] In the literature, some researches, see, e.g., Trostel, Walker and Woolley (2002); Arcand, D'hombers and Gyselnck (2004); Patrinos and Sakellariou (2005); and Sakellariou (2006), among others, use family background variables such as the father's education as the instrumental variable. As this variable had been criticized for not being a good instrumental variable, as a father's education may influence an individual's ability or wage through genes or social connections, we thus exclude father's education as an additional instrumental variable.

B) Tests of validity for instrumental variables

Econometrically, in the 2SLS estimation, a valid instrumental variable should satisfy two conditions: Instrument relevance and Instrument exogeneity. The relevant tests include using the partial coefficient of

determination or F-test to test the explanatory power and sign of the instrumental variable on the endogenous education variable at the first step of regression.[18] As for the exogeneity test, the over-identifying restrictions test is used on the orthogonality condition for all the instruments.[19] In the second stage of regression, we adopt the Durbin-Wu-Hausman test for exogeneity.[20]

III. DATA ANALYSIS AND ESTIMATION RESULTS

This paper uses the nine-year compulsory educational policy, which was implemented in Taiwan in 1968, as one of the instrumental variables. For a broader inclusion of samples, we adopt data from the 1990, 2000, and 2010 Taiwan Manpower Utilization Survey conducted by the Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Taiwan, Republic of China. The MPUS data are repeated cross sections and stratified random samples of around 20,300 households (about 60,000 persons aged 15 and above in these sampled households) from about 532 villages and neighborhoods in Taiwan, and they are not panel data. For the use of instrumental variables, we choose samples only with complete intergenerational information. Tables 1 and 2 present all the variable names, definitions, and basic statistics.

Residential area is classified into urban and rural areas. Based on the official classification of Taiwan's Ministry of the Interior, cities, towns, or villages with over fifty thousand residences are classified as urban areas. Due to data limitations, it is not possible to acquire residence information for samples during their study period. We use current residence as a proxy for the residence during schooling age.[21]

Table 1
Variable name and definition

Name	*Definition*
Wage	Real hourly wage in logarithmic form.
Years of education	Education levels include illiterate and self educated, primary school, junior high school, senior high school, vocational school, junior college, university, graduate school and above. The corresponding years of education are 0, 6, 9, 12, 12, 14, 16, and 18 years, respectively.
Tenure	Years working at current job.
Work experience	Work experience is proxied by age-years of education-6-tenure. As males in Taiwan need to serve two years in the army, an additional 2 years is thus further subtracted for males.
Male	Dummy variable: 0 for female, 1 for male.
Marital status	Dummy variable: 0 for single, 1 otherwise.
Industry	Industry in which the individual works are dummy variables, which include agriculture, forestry, fishery, and husbandry; manufacturing; water, electricity, fuel, and coal; construction; wholesalers, retailers, and restaurants; transportation, storage, and communications; finance, insurance, and real estate; and public and personal services. Wholesalers, retailers, and restaurants is the reference group.
Firm size	Dummy variables include 1-9 persons, 10-49 persons, 50-99 persons, 100-499 persons, 500 persons and above, and the public sector. 1-9 persons is the reference group.
Residential area	Residential area is classified into urban and rural areas and represented by a dummy variable: 0 for rural area, 1 for urban area. Based on the official classification of Taiwan's Ministry of Interior, cities, towns, or villages with a population of residences of over fifty thousand are classified as urban areas.
Status of young siblings	Having younger siblings in the family is represented by a dummy variable: 1 for yes and 0 for no.
Born in Dragon years	A dummy variable: 1 for people born in Dragon years and 0 for others.
Compulsory educational policy	People affected by the nine-year compulsory educational policy implemented in1968. A dummy variable: 0 for those who were born before 1956 (not affected by the policy) and 1 for those who were born after 1956 (affected by the policy).

Table 2
Summary of basic statistics for variables

Variable name	*1990*		*2000*		*2010*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Age	27.79	6.81	28.44	7.13	28.94	7.55
Years of education	10.83	2.76	12.56	3.71	14.62	4.15
Tenure	3.55	4.17	3.12	4.55	3.13	3.93
Work experience	6.09	5.70	5.54	5.11	5.29	4.93
Male	0.66	0.47	0.69	0.45	0.68	0.46
Marital status	0.32	0.47	0.30	0.42	0.29	0.41
Industry						
Agriculture	0.05	0.21	0.03	0.19	0.02	0.16
Manufacturing	0.38	0.49	0.27	0.46	0.24	0.42
Water, electricity, fuel, and coal	0.01	0.07	0.01	0.06	0.01	0.05
Construction	0.11	0.31	0.10	0.29	0.09	0.25
Wholesalers, retailers, and restaurants	0.18	0.39	0.19	0.41	0.20	0.44
Transportation, storage, and communications	0.06	0.23	0.09	0.29	0.06	0.32
Finance, insurance, and real estate	0.05	0.23	0.15	0.35	0.21	0.43
Personal and public services	0.17	0.37	0.14	0.35	0.13	0.31
Firm size						
1-9 persons	0.44	0.50	0.47	0.57	0.46	0.54
10-49 persons	0.26	0.44	0.24	0.45	0.25	0.49
50-99 persons	0.07	0.26	0.08	0.28	0.08	0.27
100-499 persons	0.11	0.31	0.10	0.29	0.10	0.33
500 persons and above	0.04	0.19	0.03	0.18	0.03	0.21
Public sector	0.09	0.28	0.08	0.26	0.10	0.31
Instrumental variable						
Educational policy (IV1)	0.69	0.35	0.82	0.35	0.92	0.35
Born in Dragon years (IV2)	0.13	0.17	0.14	0.18	0.14	0.19
Residential area (IV3)	0.68	0.47	0.71	0.51	0.74	0.56
Young Siblings (IV4)	0.74	0.44	0.72	0.41	0.69	0.35
Observations	21453		22681		24966	

Source: 1990, 2000, 2010 Manpower Utilization Survey, DGBAS, Taiwan

The respective figures for the three time period 1990, 2000, and 2010 are as follows. The total samples are 21453, 22681, and 24966 persons, average ages are 27.79, 28.44, and 28.94 years old, average years of education are 10.83, 12.56, and 14.62 years, with an average tenure of 3.55, 3.12, and 3.13 years and work experience of 6.09, 5.54, and 5.29 years. Among them, females comprise 34%, 31%, and 32% and males 66%, 69%, and 68%; 32%, 30%, and 29% are married; 38%, 27%, and 24% work in manufacturing, 18%, 19% and 20% in wholesalers, retailers, and restaurants; 5%, 15% and 21% in finance, insurance, and real estate; 77%, 79%, and 79% work at small- and medium-size firms (below 100 persons); only 4%, 3%, and 3% work at large enterprises (500 persons and above); and 9%, 8% and 10% work in the public sector; 69%, 82%, and 92% receive nine-year compulsory education; 13%, 14%, and 14% were born in the year of the Dragon; 68%, 71%, 74% live in urban area and 32%,

29%, and 26% in rural area; 74%, 72%, and 69% have young siblings.

Data from different time period reveal that overtime education year, work in service sector and SMEs, and live in urban area show an increasing trend, while marriage rate, work in agriculture and manufacturing, and have young siblings show a declining trend.

A) Tests and search for the valid IVs

We use the IV method or so-called 2SLS method to estimate rate of return to education for Taiwan. The results of first stage regression for educational choice using 2010 data are presented in Table 3. The four instrumental variables, educational policy (IV1), born in Dragon years (IV2), residence area (IV3), and status of young siblings (IV4), as expected, all have a positive and significant effect on individual's educational achievement. These results imply that those who receive compulsory education, live in urban areas, born in Dragon years, and have no young siblings tend to have more education. Moreover, even including all four instrumental variables into the educational choice regression, as in column 5 of Table 3, the estimated coefficients all remain significant and have expected signs.

To ensure that our instrumental variables are valid instruments, we further test for instrument relevance and exogeneity. From both the partial coefficient of determination and the F-test of first stage regression in Table 3, all four instrumental variables have significant correlations with years of education. Among them, born in Dragon years has the most explanatory power for an individual's education. As for the exogeneity test, from Table 4, the DWH test shows no potential commitment of endogeneity problem for the four instruments and over-identifying restrictions test cannot reject the null

Table 3
Results of first stage regression on educational choice (2010)

	IV1	*IV2*	*IV3*	*IV4*	*IV1+IV2+IV3+IV4*
Age	0.5017***	0.4998***	0.4919***	0.4611***	0.4215***
	(23.66)	(21.44)	(18.44)	(20.44)	(19.47)
Age^2	-0.0104***	-0.0097***	-0.0092***	-0.0088***	-0.0074***
	(-25.32)	(-26.71)	(-22.45)	(-21.44)	(-16.37)
Educational policy	1.2417***				0.9635***
	(9.96)				(9.17)
Born in Dragon years		1.0457***			1.1744***
		(17.83)			(16.48)
Residence area			1.2944***		0.2333***
			(3.47)		(3.22)
Young siblings				-0.1966***	-0.1877***
				(37.33)	(39.76)
Constant	3.4455***	3.2102***	3.2455***	3.1177***	2.0974***
	(12.11)	(10.66)	(12.45)	(11.79)	(9.48)
Partial R^2	0.0104	0.0571	0.0198	0.0114	0.1032
F-test	79.63	108.41	41.62	34.77	297.44
Adj-R^2	0.1766	0.2054	0.1949	0.1755	0.2744
Observations	24966	24966	24966	24966	24966

Notes: 1. Figures in the parentheses are t statistics.
2. *, **, and *** stand for statistical significance levels at 90%, 95%, and 99%, respectively.
3. The F-test is for the instrument relevance condition (the significance of coefficients of all the instrumental variables). A rule of thumb is that F statistics should be greater than 10, and that any values below 10 imply that the selected instrumental variables have insignificant explanatory power and thus generate estimation bias.

hypothesis of exogeneity for them. showing that the four instruments are not all exogenous and no potential endogeneity within the four instruments may bias the estimation.[22]

Table 4 lists the estimation results for the rates of return to education for the OLS and IV methods using 2010 data. First, by considering a parsimonious formulation of the Mincerian wage equation, which includes only variables like tenure and work experience in addition to education, the estimated rates of return to education, tenure, and work experience are 5.78%, 5.14%, and 2.63%, respectively. Including additional explanatory variables, which include marital status, industry, and firm size, the estimated rates of return to education, tenure, and work experience drop to 5.01%, 4.22%, and 2.22%, respectively. It should be noted that by construction, a valid instrumental variable should not be correlated with wage or any variable that explains wage; therefore, in the spirit of the IV method for estimating wage equation, the omitted variable bias problem should be negligible. We find that those additional explanatory variables are all significant with the expected signs; in general, those who are married, work in construction and finance, insurance, and real estate sectors, and work at large enterprises tend to receive higher wages. Note that from Table 4, the result of the conventional OLS estimation rejects the null hypothesis of the DWH test that the education variable is exogenous; hence, this result justifies the use of the IV method for the estimation of return to education

From Table 4, using the nine-year compulsory education policy (IV1) as the instrument, the estimated rate of return to education is 9.01%, higher than 5.78% by the OLS method. This result remains true (8.02% for IV and 5.01% for OLS) even after controlling for additional explanatory variables. Thus, the estimated average rate of return to education by the conventional OLS method will be biased downward because of the endogeneity of education variable. The instrument variable by the compulsory education policy suggests that compulsory education will increase the rate of return to education, as the implementation of compulsory education reduces the marginal cost of education, especially for those children whose families are subject to credit constraints.

The instrument of born in Dragon years (IV2) also shows an estimated rate of return to education of 6.81%, higher than the estimate found by the OLS. This result implies that return to education is higher for those born in Dragon years than those born not in Dragon years, as Chinese parents tend to provide more and better educational resources for their kids born in Dragon years because of culture preference for Dragon, a symbol of noble and dignity.

As for the instruments of family background, the estimated rates of return to education for residence area (IV3) and the status of young siblings (IV4) are 8.75% and 8.66%, respectively, again higher than that found by the OLS method. This result implies that one lives in residence area or has no younger siblings will tend to receive more family educational resources, thus resulting in more education and a higher rate of return to schooling.

However, taking four instrumental variables jointly, the estimated rate of return to education is still higher for the IV method (6.57%) than for the OLS method but lower than estimates by any single instrument. The reason is that an estimate using a single instrumental variable usually represents the rate of return for one particular demographic subgroup, and as we increase the number of instruments in the first stage regression, the estimated educational achievement will in general become closer to the real value and thus approach the average marginal rate of return to education for the whole group.

Comparing the estimates through four instruments, we find that the estimated rate of return to education is the highest for compulsory education, followed in order by residence area, status of young siblings, and born in Dragon years. This result suggests that institutional factors such as compulsory education have a stronger effect on return to education than do family background factors such as residence area or having young siblings. In other words, as the compulsory education is a comprehensive institutional change which generally reduces the marginal cost of education for people, especially those subject to credit constraints, it is thus the most significant effect on return to education. Those born in Dragon years may receive more educational resources from their parents; however, their abilities do not necessarily better than those were not born in Dragon

Table 4
Estimated rates of return to education: OLS vs. IV (2010)

	OLS		*IV1*		*IV2*		*IV3*		*IV4*		*IV1+IV2+ IV3+IV4*	
Years of education	0.0578***	0.0501***	0.0901***	0.0802***	0.0681***	0.0605***	0.0875***	0.715***	0.0866***	0.0722***	0.0657***	0.0599***
	(29.64)	(22.32)	(15.77)	(14.22)	(10.44)	(10.97)	(8.66)	(8.11)	(9.66)	(8.42)	(15.66)	(13.42)
Tenure	0.0514***	0.0422***	0.0501***	0.0466***	0.0495***	0.0411***	0.0466***	0.0401***	0.0458***	0.0397***	0.0477***	0.0409***
	(23.56)	(20.17)	(19.11)	(17.66)	(17.14)	(14.25)	(16.89)	(14.22)	(17.01)	(14.88)	(20.17)	(17.02)
Tenure^2	-0.00151***	-0.0011***	-0.0016***	-0.0011***	-0.0015***	-0.0011***	-0.0015***	-0.0011***	-0.0015***	-0.0010***	-0.0015***	-0.0012***
	(-17.22)	(-14.34)	(-13.28)	(-9.44)	(-15.11)	(-11.85)	(-11.12)	(-9.55)	(-10.66)	(-8.42)	(-15.11)	(-12.02)
Work experience	0.0263***	0.0222***	0.0102***	0.0084*	0.0098***	0.0079**	0.0101	0.0082	0.0118***	0.0083***	0.0089***	0.0072***
	(13.11)	(12.04)	(1.98)	(1.71)	(1.82)	(1.95)	(0.40)	(0.61)	(2.97)	(2.67)	(3.39)	(2.95)
Work experience^2	-0.0003***	-0.0002***	0.0001**	0.0001	0.0002**	0.0001	0.0002***	0.0002***	0.0002**	0.0001*	0.0001*	0.0001
	(-4.64)	(-3.99)	(1.79)	(1.01)	(2.11)	(1.16)	(2.36)	(2.38)	(2.09)	(1.54)	(1.72)	(1.11)
Male	0.3017***	0.2866***	0.2744***	0.2511***	0.3023***	0.2766***	0.2915***	0.2514***	0.3018***	0.2811***	0.3069***	0.2870***
	(30.11)	(26.75)	(30.11)	(27.44)	(29.47)	(25.69)	(30.10)	(26.77)	(29.67)	(25.44)	(31.19)	(28.01)
Marital Status		0.1074***		0.1115***		0.1045***		0.1154***		0.1205***		0.1209***
		(9.11)		(10.01)		(10.22)		(9.55)		(10.21)		(10.33)
Industry												
Agriculture		-0.3012***		-0.3511***		-0.3566***		-0.3619***		-0.3579***		-0.3228***
		(-15.11)		(-16.21)		(-16.02)		(-15.78)		(-15.02)		(-14.97)
Manufacturing		-0.0415***		-0.0544***		-0.0512***		-0.0611***		-0.0597***		-0.0498***
		(-4.77)		(-5.12)		(-5.22)		(-5.04)		(-6.00)		(-5.89)
Water, electricity, fuel and coal		0.1574		0.0803		0.0738		0.0922*		0.1005		0.1001
		(1.45)		(0.99)		(0.95)		(1.59)		(1.12)		(1.02)
Construction		0.1421***		0.1021***		0.0945***		0.0886***		0.0911***		0.0845***
		(10.71)		(4.16)		(4.68)		(4.15)		(5.79)		(5.97)
Transportation, storage, and communications		0.0407*** (2.12)		0.0322* (1.75)		0.0311* (1.68)		0.0326** (1.94)		0.0367** (2.10)		0.0309** (1.99)
Finance, insurance, and real estate		0.1115*** (6.22)		0.1556*** (7.29)		0.1503*** (7.05)		0.1594*** (7.15)		0.1390*** (6.59)		0.1337*** (6.35)

contd. table 4

	OLS		*IV1*		*IV2*		*IV3*		*IV4*		*IV1+IV2+ IV3+IV4*	
Personal and public services		-0.0454** (-2.66)		-0.0461*** (-2.90)		-0.0444*** (-2.80)		-0.0375** (-2.24)		-0.0433*** (-2.76)		-0.0413*** (-2.63)
Firm size												
10-49 persons		0.0447***		0.0501***		0.488***		0.0502***		0.0508***		0.0474***
		(4.74)		(5.01)		(5.08)		(5.11)		(5.01)		(4.87)
50-99 persons		0.0622***		0.0789***		0.0815***		0.0901***		0.0911***		0.0844***
		(3.21)		(6.27)		(6.33)		(6.45)		(5.68)		(5.75)
100-499 persons		0.0677***		0.0945***		0.1021***		0.1078***		0.1101***		0.1024***
		(4.66)		(8.72)		(8.57)		(8.64)		(7.89)		(7.77)
500 persons +		0.1091***		0.1412***		0.1409***		0.1416***		0.1298***		0.1175***
		(5.11)		(6.79)		(6.37)		(6.75)		(5.66)		(5.49)
Public sector		0.1544***		0.2066***		0.2122***		0.2321***		0.2097***		0.2078***
		(6.99)		(13.75)		(13.74)		(12.69)		(12.50)		(12.48)
Constant	3.2277***	3.2122***	3.7616***	3.6616***	3.6042***	3.6916***	3.4428***	3.4292***	3.4614***	3.6104***	3.4557***	3.6056***
	(101.76)	(98.74)	(33.31)	(34.20)	(43.93)	(47.13)	(26.48)	(27.86)	(71.00)	(74.96)	(74.50)	(78.41)
Observations	24966	24966	24966	24966	24966	24966	24966	24966	24966	24966	24966	24966
Adj-R^2	0.2994	0.3211	0.2322	0.2947	0.2102	0.3011	0.2034	0.2917	0.2455	0.3324	0.2671	0.3422
DWH test for exogeneity	1.77	1.22	1.42	1.33	1.51	1.22	1.01	0.84	1.07	0.99		
Over-identifying restrictions test											3.04	2.12

Notes:
1. Figures in the parenthesis are t statistics; *, **, *** represent statistical significance levels at 90%, 95%, and 99%, respectively.
2. Reference group: wholesalers, retailers, and restaurants for industry; 1-9 persons for firm size.
3. Instrumental variables: IV1 for compulsory educational policy, IV2 for born in Dragon years, IV3 for residence area; and IV4 for having young siblings.
4. Null hypothesis of DWH test for exogeneity is that education variable is exogenous.
5. Null hypothesis of over-identifying restriction is that all the including instrumental variables are jointly exogenous.

years, thus the effect on return to education should be minimum.

Actually, the estimated rate of return to education found by the OLS method is not the average marginal rate of return to education, or so-called average treatment effect (ATE) as return to education may differ among different subgroup; it also encounters the problems of the endogeneity bias and the ability bias. In contrast, estimates by the IV method not only avoid the problems of the endogeneity and ability biases but also provide an estimate of the marginal rate of return to education for a particular demographic subgroup (Card (1999, P.1855)), an estimate close to the local average treatment effect (LATE) (Heckman, Lalonde, and Smith (1999)).

B) Sensitivity Analysis

Previous analysis shows that the estimated rate of return to education found by the conventional OLS method will be biased downward, as the education variable is endogenous. The IV method not only solves the endogeneity and ability bias problems but also provides an estimated rate of return to education for a particular demographic subgroup. Theoretically, a valid instrument needs to satisfy both the instrument relevance and instrument exogeneity conditions. However, Donald and Newey (2001) point out that the most difficult task is to choose the most suitable instrumental variable from a set of IVs.[23] Likewise, we further conduct a sensitivity analysis to test for relevance and exogeneity conditions for all the possible combinations of our five instrumental variables to verify the most appropriate instruments. The results are shown in Table 5.

From Table 5, we find that the inclusion of more IVs will reduce the estimated rate of return to education because the result from one single IV represents only one particular demographic subgroup. The inclusion of further IVs will increase the explanatory power for education achievement at the first stage; therefore, the estimated rate of return to education will conceptually approach the real average marginal rate of return to education at the second stage wage regression.

Table 5
Estimated rates of return to education for various combinations of IVs

Combination of IVs	*ROR to education*	*Adj-R²*	*F-test for relevance*	*Over-identifying restrictions test*
IV1	0.0901	0.2322	79.63	
IV2	0.0681	0.2102	108.41	
IV3	0.0875	0.2034	41.62	
IV4	0.0866	0.2455	34.77	
IV1+IV2	0.0795	0.2355	123.47	
IV1 +IV3	0.0814	0.2345	92.87	
IV1+IV4	0.0808	0.2177	101.42	
IV2+IV3	0.0756	0.2357	87.62	
IV2+ IV4	0.0749	0.2279	115.09	
IV3+IV4	0.0801	0.2249	73.41	
IV1+IV2+IV3	0.0729	0.2738	206.47	1.53
IV1+IV2 +IV4	0.0732	0.2511	158.15	1.42
IV1+IV3+IV4	0.0788	0.2509	122.69	2.07
IV2+IV3+IV4	0.701	0.2611	171.25	1.76
ALL	0.0657	0.2671	266.41	3.04

Notes: 1. IV1 for compulsory educational policy; IV2 for born in Dragon years; IV3 for residence area; and IV4 for having young siblings.

2. *, **, and *** represent the statistical significance levels at 90%, 95%, and 99%, respectively.

However, the two conditions of instrument relevance and exogeneity still need to be satisfied as valid instruments. Moreover, the criterion for the most effective valid instrument among the IVs is the one that provides the minimum mean square error (MSE) for the estimation of rate of return to education at the second stage wage regression. From Table 5, we find that any single instrumental variable satisfies the instrument relevance condition. Among all the IV combinations, the combination of compulsory education policy (IV1), born in Dragon years (IV2), and residence area (IV3) not only satisfies both the relevance and exogeneity conditions but also has the lowest MSE value. Thus, the combination of IV1, IV2, and IV3 is the most effective valid instrument for education variable. These results imply that to add more instruments does not mean more appropriate and institutional, cultural, and geographic variables are more plausible candidate for valid instruments.

C) Returns to education in Taiwan

Based on the previous analysis, we choose V1+IV2+IV3 as the valid IVs for our estimation of rate of return to education in Taiwan for the year 1990, 2000, 2010. Results in Table 6 show that rate of return to education in Taiwan for the past twenty years experiencing a declining trend. This has to do with the expansionary higher education policy during the period and slowdown of Taiwan's economic growth since 2000.[24] The return to tenure remained higher than that of work experience, implying job-specific training is more important than general training for worker's productivity. Other variables such as individual's characteristics, marital status, firm size and types of industry all significantly affect individual's wage. Workers who are male, married, hired by larger firms, employed in construction, transportation, storage and communication, and finance and real estate industries, tend to receive higher wages. However, the wage premium on male shows a significant declining trend implying that labor market condition is improving by less sexual discrimination.

Table 7 shows estimation results of IV1+IV2+IV3 as the instrument for males and females using 2010 Taiwan Manpower Utilization Survey data.[25] We find that the estimated return to education is higher for the IV method than for the OLS method for both males and females; however, the estimated rate of return is higher for females than for males in both the OLS and IV methods. For the parsimonious formation of wage equation with only education, tenure, and work experience as the explanatory variables, the estimated rate of return to education is 5.43% for males and 7.99% for females by the OLS, and that of the IV method is 5.97% for males and 14.69% for females.[26] Including additional explanatory variables of marital status, affiliated industry, and firm size, the estimated rate of return to education is 4.74% for males and 6.48% for females by the OLS, and that of the IV method is 4.86% for males and 10.58% for females. These results imply that the downward bias by OLS estimation is greater for females than for males, as females are likely to be underinvested in or discriminated against education due to family background factors. Thus, for those whose educational choice is critically influenced by family factors, such as females, the IV method will mitigate the endogenous downward bias and provide a better estimate for their marginal rates of return to education.

IV. CONCLUSION

Conventional OLS estimation of rate of return to education by the Mincerian wage equation has its statistical simplicity in empirical studies, provided that the education variable is uncorrelated with the error term. If this basic statistical assumption is not true, as is indeed the case in educational choice, the endogeneity and ability bias of the education variable will cause the estimated rate of return to education to be biased downward by the OLS method. To solve for the endogeneity and ability bias problems, this paper uses the IV method to estimate rate of return to education using data from the 1990, 2000, and 2010 Taiwan Manpower Utilization Survey. Instrumental variables include the nine-year compulsory education policy, born in Dragon years, residence area, and status of young siblings. The four IVs individually satisfy both the instrument relevance and exogeneity conditions.

The results show that the estimated rate of return to education is higher for the IV method than for the OLS

Table 6
Returns to education in Taiwan for 1990, 2000, and 2010:
IV1+IV2+IV3 as the IVs for education

Variable	*1990*		*2000*		*2010*	
Year of Education	0.0692***	0.0644***	0.0685***	0.0631***	0.0626***	0.0512***
	(12.49)	(10.21)	(14.33)	(11.62)	(13.77)	(10.55)
Tenure	0.0478***	0.0402***	0.0578***	0.0503***	0.0591***	0.0509***
	(14.97)	(13.22)	(13.97)	(15.66)	(19.45)	(17.33)
Tenure^2	-0.0012***	-0.0011***	-0.0019***	-0.0015***	-0.0020***	-0.0016***
	(-9.49)	(-8.01)	(-8.11)	(-10.44)	(-17.22)	(-15.33)
Work experience	0.0215***	0.0172***	0.0233***	0.0172***	0.0239***	0.0201**
	(9.11)	(7.22)	(10.44)	(9.08)	(8.49)	(5.45)
Work experience^2	-0.0004***	0.0002**	-0.0005***	-0.0003***	-0.0005***	-0.0003**
	(-3.19)	(2.07)	(-3.17)	(-3.69)	(-4.97)	(-2.19)
Male	0.4078***	0.3699***	0.3022***	0.2278***	0.1877***	0.1566***
	(41.97)	(39.54)	(22.87)	(20.79.33)	(17.44)	(15.97)
Marital status		0.1497		0.1178***		0.0924***
		(9.71)		(6.84)		(7.43)
Industry						
Agriculture		-0.3233**		-0.3017*		-0.2022**
		(2.08)		(-1.81)		(-2.79)
Manufacturing		-0.1074		-0.0897*		-0.0598
		(-1.55)		(2.22)		(-1.12)
Water, electricity,		0.20117**		0.2840**		0.2122**
fuel and coal		(2.12)		(2.45)		(2.87)
Construction		0.1566***		0.1991***		0.2004***
		(8.42)		(10.51)		(8.22)
Transportation, storage,		0.0811***		0.1266***		0.1022***
and communications		(5.97)		(8.69)		(5.61)
Finance, insurance,		0.1011***		0.2367***		0.1784***
and real estate		(5.19)		(11.79)		(12.67)
Personal and		-0.0797		0.1899***		0.1547***
public services		(-1.012)		(4.67)		(7.11)
Firm size						
10-49 person		0.0461***		0.0312***		0.0303***
		(4.33)		(7.51)		(8.44)
50-99 person		0.0709***		0.0612***		0.0519***
		(10.24)		(9.11)		(7.01)
100-499 person		0.0911***		0.0791***		0.0714***
		(12.79)		(6.75)		(5.66)
500 person+		0.1101***		0.1236***		0.1359***
		(9.66)		(6.66)		(10.17)
Public sector		0.1597***		0.1671***		0.1814***
		(9.01)		(12.78)		(15.39)
Constant	3.1219***	2.8713***	3.6697***	3.1012***	3.4367***	2.9099**
	(43.97)	(36.77)	(88.49)	(78.14)	(99.91)	(66.71)
Observations	21453	21454	22681	22681	24966	24966
Adj-R^2	0.2712	0.3111	0.2677	0.3067	0.2738	0.3132

Notes: 1. Figures in the parenthesis are t statistics; *, **, *** represent statistical significance levels at 90%, 95%, and 99%, respectively.
2. Reference group: wholesalers, retailers, and restaurants for industry; 1-9 persons for firm size.

Table 7
Estimated rates of return to education for males and females

	OLS				*IV1+IV2+IV3*			
Explanatory variable	*Male*		*Female*		*Male*		*Female*	
Years of education	**0.0561*****	**0.0501*****	**0.0784*****	**0.0693*****	**0.0612*****	**0.0501*****	**0.1517*****	**0.1107*****
	(21.57)	(20.66	(28.44)	(19.47)	(6.72)	(7.11)	(10.69)	(11.42)
Tenure	0.0501***	0.0435***	0.0588***	0.0567***	0.0468***	0.0401***	0.0288***	0.0297***
	(19.78)	(10.66)	(17.55)	(12.33)	(15.44)	(13.79)	(4.65)	(6.11)
Tenure^2	-0.0015***	-0.0010***	-0.0016***	-0.0013***	-0.0015***	-0.0012***	0.0010	-0.0007
	(-20.44)	(-19.45)	(-10.67)	(-11.66)	(-18.74)	(-11.07)	(0.84)	(-1.01)
Work experience	0.0229***	0.0181***	0.0297***	0.0266***	0.0102*	-0.0028	-0.0175*	0.0075
	(9.44)	(10.67)	(11.45)	(9.48)	(1.54)	(-0.44)	(-1.98)	(0.99)
Work experience^2	-0.0005***	-0.0003***	-0.0006***	-0.0004***	0.0003**	0.0002**	0.0005***	0.0002
	(-4.97)	(-2.66)	(-3.66)	(-4.54)	(2.12)	(1.97)	(2.98)	(0.51)
Marital status		0.0901***		0.0078		0.1122***		0.0080
		(11.23)		(0.45)		(12.84)		(0.61)
Industry								
Agriculture		-0.3544***		-0.0014		-0.3311***		-0.0414
		(-14.69)		(-0.68)		(-21.66)		(-1.05)
Manufacturing		-0.0109		-0.0797***		-0.1274***		-0.2012***
		(-0.17)		(-5.67)		(-4.05)		(-7.67)
Water, electricity, fuel, and coal		0.1988*** (3.66)		0.0011 (0.12)		0.1566** (2.33)		0.0078 (0.54)
Construction		0.1544***		0.0017		0.0967***		0.0009
		(10.21)		(0.12)		(5.88)		(0.07)
Transportation, storage, and communications		0.0707*** (3.11)		0.0614 (1.01)		0.0079 (1.01)		0.0301 (0.84)
Finance, insurance, and real estate		0.1399*** (5.22)		0.1022** (3.74)		0.2012*** (7.77)		0.0984*** (3.33)
Personal and public services		0.0007		-0.0453***		-0.0079		-0.0098
		(0.10)		(-4.12)		(-0.09)		(-1.02)
Firm size								
10-49 persons		0.0299***		0.0874***		0.0610***		0.1097***
		(2.660)		(5.31)		(5.22)		(6.17)
50-99 persons		-0.0466		0.1235***		0.0811*		0.1616***
		(-1.11)		(7.66)		(1.99)		(4.84)
100-499 persons		0.0091		0.1311***		0.0907***		0.2019***
		(0.81)		(8.45)		(4.67)		(11.49)
500 persons and above		0.0354**		0.1719***		0.1219***		0.2261***
		(2.11)		(6.63)		(4.56)		(7.36)
Public sector		0.0514***		0.2677***		0.1517***		0.3834***
		(2.96)		(11.49)		(8.44)		(17.66)
Constant	4.0214***	3.9471***	3.1066***	3.0029***	4.1174***	3.6745***	2.9934***	3.0017***
	(122.67)	(111.49)	(55.48)	(67.49)	(34.41)	(33.29)	(25.61)	(28.43)
Observations	24966	24966	24966	24966	24966	24966	24966	24966
Adj-R^2	0.2067	0.2457	0.1894	0.3233	0.2567	0.2789	0.2866	0.3127

Notes: See Notes in Table 3.

method. Among them, the highest estimated rate of return to education (9.01%) is for the instrument of compulsory education policy, implying that a comprehensive institutional change such as a nationwide compulsory educational policy significantly reduces the marginal cost of education for the people, especially those who are subject to family credit constraints. Thus, the impact on education is greater for the compulsory educational policy than for residence area or family factor.

As there is more than one instrument, any combination of IVs can be a valid instrument. We further perform tests of relevance and exogeneity for all the possible combinations of four IVs and choose the one with the minimum MSE in the second stage wage regression as the most effective valid instrument. The result shows that the combination of compulsory education policy (IV1), born in Dragon years (IV2), and residence area (IV3) is the most efficient valid instrument, which may give a better estimation for the rate of return to education. Using this instrument, we further estimate rates of return to education for both males and females, finding that the estimated rate of return to education is 5.97% for males and 14.69% for females, which is higher than that found by OLS, especially in the female group. As females are likely to be underinvested in or discriminated against education due to family credit constraints, this paper shows that the downward bias will become more serious for females than for males through OLS estimation. Our results suggest that adding more instruments does not mean more appropriate, and institutional, cultural, and geographic variables are more plausible candidate for valid instruments.

NOTES

1. See, for example, Barro and Sala-i-Martin (1995).
2. The number of students above college education increased from about 5000 person in the 1950s to 1,343,603 person in 2010.
3. Card (1999) provides a comprehensive literature survey on empirical studies of the relationship between education and productivity.
4. Return to education is one of important measures in constructing the Human Development Index (HDI), which is considered to be a more inclusive index for measuring human welfare and has been announced every year by the United Nations since 1990.
5. For discussion of factors that determines an individual's educational choice, see, for example, Haveman and Wolfe (1995).
6. Griliches (1977) uses the viewpoint of the efficiency unit in the labor market and considers human capital to be homogenous; thus, people choose to have different stocks of human capital. In this regard, to solve for the problems of ability bias and measurement error, an effective estimation method is the instrumental variable method. Sometimes this type of model is also called the common coefficient model.
7. See Card (2001) for a detailed comparison and discussion of the estimation results by OLS and IV methods.
8. If there is an inter-generational transfer effect, family background factors such as parents' education may be correlated with an individual's ability. From a genetics point of view, an individual's innate ability is inherited through the genes.
9. Card (2001) has an alternative interpretation. He thinks that people with low education tend to have higher rates of return to education because they are the group influenced by the education policy, which reduces their original high marginal cost of education. Thus, low education is not the result of low ability.
10. The former is caused by educational decisions and is endogenous rather than exogenous, and the latter arises as more able people, other things being equal, receive more education according to the human capital theory. See, for example, Heckman, Lochner, and Todd (2003) for a detailed discussion.
11. See Card (1999) for the discussion of different interpretations of estimated coefficients of education variable for using the hourly wage and the yearly wage as the dependent variable.
12. See, for example, Blundell *et al.* (2003) for detailed discussion on this point.
13. In 1968, Taiwanese government implemented the nine-year compulsory educational policy, which directly affected the school enrollment rate of children aged 12 to 14. Groups particularly influenced by compulsory education are poor or minority groups, which are usually subject to credit constraints.
14. See, for example, Card (2001) for a detailed literature review on this line of research.

15. In their research on Chinese family, Johnson and Nye (2011) find that children born in Dragon year receive more education than their siblings.
16. Using data from the 1989 Survey of Women's Living Status in the Taiwan Area, Parish and Wills (1993) find that younger siblings tend to have an advantage in receiving better education than their elder siblings.
17. We also regard the number of siblings as the instrumental variable; the estimated results are similar to what we have reported here.
18. See Bound, Jaeger, and Baker (1995) and Staiger and Stock (1997) for detailed descriptions of the relevant tests. The F-test can be used to joint test the significance of coefficients of all the instrumental variables. A rule of thumb is that F statistics should be greater than 10, and that any values below 10 imply that the selected instrumental variables have insignificant explanatory power or a weak instrument and thus generate estimation bias.
19. Assume that the number of selected instruments is m and the number of relevant endogenous variables is k. If m=k, the regression coefficients are exactly identified. If m>k, the regression coefficients are over-identified. If m<k, the regression coefficients are under-identified.
20. The estimation process is similar to test for the omitted variable, as it was first proposed by Durbin (1954), Wu (1973), and Hausman (1978), respectively; hence it is also called the Durbin-Wu-Hausman (DWH) test. For a discussion of DWH test of exogeneity, see, for example, Davidson and MacKinnon (2003).
21. A possible bias from this assumption is that current residence may not be the same as the residence of schooling age, i.e., the residence of schooling age was in a rural (urban) area, but current residence is in an urban (rural) area. However, according to data from Panel Study of Family Dynamics, conducted by Academia Sinica since 1999, for those who were born between 1953 and 1963, the percentage of those living in rural areas during their schooling years but currently living in urban areas is 1.23%, while that for those living in urban areas during their schooling years but currently living in rural areas is only 0.91%. Thus, the bias of using the current residential area for the residence of schooling age is likely to be limited.
22. To verify the exogeneity of the four instruments, see the next section on the sensitivity analysis for a detailed exogeneity test on various combinations of the four instrumental variables.
23. See Donald and Newey (2001) for a detailed discussion on the selection and combinations of instrumental variables.
24. The number of higher education institutions was 105 in 1986, it had risen to 163 in 2010. Taiwan's average annual economic growth rate was 8.45% during 1960 -2000 period; however, it dropped to 3.43% in 2000-2010.
25. We also perform the estimation of males and females for 1990 and 2000. The rates of return for education were higher for 1990 and 2000 and the trend remained the same as shown in previous analysis. We, therefore, do not report them here and the results are upon request by the readers.
26. These results are similar to those in Spohr (2003).

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