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Higher education planning and the wages of workers with higher education in Taiwan

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Abstract

A significant feature of Taiwan's educational development is the high degree to which the structure of educational expansion, especially in higher education, has been strictly planned by the government. The Ministry of Education controls the number of students who are allowed to attend all institutions of higher education (both private and public). We present evidence that this control over the relative supply of workers with higher education, rather than changes in relative demand for these workers, was the more important factor causing changes in the relative wages of Taiwanese workers with higher education between 1978 and 1995. For example, decisions by education planners in the 1980s to increase the number of students enrolled in universities and junior colleges led to a fall in the wages of workers with higher education relative to the wages of workers without higher education.

JEL classification: I28; J31; O15; O21; O53

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1. Introduction

Education has been of crucial importance in the economic development of Taiwan. Not only has educational expansion been one of the "principal engines of growth" (World Bank, 1993, p. 5), but there is also broad agreement that "the increasingly high level of education of Taiwan's population has helped to reduce income inequality" (Lau, 1986, p. 5). A significant feature of Taiwan's educational development is the high degree to which the structure of educational expansion, especially in higher education, has been strictly planned by the government. Most important decisions regarding higher education are made by the Ministry of Education. For example, the Ministry determines the number of private and public junior colleges and universities, which fields of study may be offered at each institution, the tuition charged by both private and public institutions, and the number of students allowed to attend each university in each major.

In the 1970s economic planners strictly limited growth in the number of students receiving higher education in Taiwan. Then, in the 1980s the number of students receiving higher education was allowed to increase at faster rates, modestly at first and then very rapidly after 1985. In this paper, we examine the impact of this increase in the supply of workers with higher education on relative wages—that is, the wages of workers with higher education relative to the wages of those with high school education only. What we call "relative wages" can also be thought of as a rough measure of the rate of return to higher education.

Various papers have studied the effect on wages of changes in the education composition of the labor force

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in both developed and developing countries. Representative U.S. studies include: Freeman (1975); Welch (1979), and Katz & Murphy (1992). Studies using data from developing countries include: Funkhouser (1994) for Central America, Robbins (1993) for Chile, Robbins and Gindling (1999) for Costa Rica, Choi (1996) for Korea, and Robbins and Zveglich (1996) for Taiwan. Our study is most similar to Choi (1996) and Robbins & Zveglich (1996).

Choi (1996) studies the effect of an exogenous increase in the relative supply of college-educated workers in Korea. As Choi (1996) notes, although the US studies have generally assumed that the relative labor supply of more-educated workers is exogenous—that is, it does not depend on the relative wage offered to more-educated workers—this assumption has been questioned in the context of the United States, where there is relatively free access to higher education. Because in Taiwan education planners determine the number of students allowed to attend college, and because the number of openings in higher education has been kept well below the demand for college education on the part of Taiwanese students, the assumption of exogenous labor supply of more educated workers is more tenable than in the United States.

Robbins and Zveglich (1996) use the same data (for 1978 to 1992) and similar techniques to those we use in this paper to examine the determinants of changes in the relative wages of university to primary educated workers. They focus on whether trade liberalization in Taiwan in the 1980s and 1990s led to an increase in the relative demand for more-skilled workers, which in turn caused changes in relative wages. Consistent with the results we present in this paper, Robbins and Zveglich (1996) conclude that changes in relative demand caused by trade liberalization were not the primary causes of changes in relative wages. Our present paper differs from Robbins and Zveglich (1996) in our focus on the impact of shifts in relative supply rather than relative demand. We conduct a detailed examination of the education planning process in Taiwan, which suggests a focus on testing the effect on relative wages of a significant increase in the relative supply of workers with a higher education which occurred in the mid-1980s. Our focus on examining the effects of this significant increase allows us to more directly test the effects of changes in the relative supply of more-educated workers on relative wages than is done by Robbins and Zveglich (1996).

2. Brief description of higher education planning in Taiwan[1]

The first nine years of school in Taiwan are compulsory and free: six years of primary education beginning at age 6, followed by three years of junior high school. Students who have completed nine years of compulsory education may take entrance examinations to either general or vocational senior high schools, which last three years, or to 5-year junior colleges. Graduates of general senior high schools may take entrance examinations for universities or 3-year junior colleges. Graduates of vocational senior high school may take entrance examinations for universities, 2-year or 3-year junior colleges (although most go to 2-year junior colleges).

Together, Taiwan's junior high schools, senior high schools and the first three years of 5-year junior colleges make up the national system of secondary education. The system of higher education consists of the final two years of 5-year junior colleges, 2-year and 3-year junior colleges, and universities. Two-year, 3-year and 5-year junior colleges offer similar courses in industry, commerce, business administration, marine products, medicines, nursing, and medical and other sciences. Five-year junior colleges also offer 6-year programs in pharmacy, marine engineering, navigation and veterinary medicine. All of these fields of study, plus others, are offered at universities.[2] The difference between universities and junior colleges is one of emphasis; junior college courses emphasize applied scientific and technical materials, with the goal of training "technicians," while universities courses emphasize more theoretical material. The structure of the education system in Taiwan is summarized in Fig. 1.

The line between universities and junior colleges is often blurred; at times junior colleges have simply been transformed into universities by the Ministry of Education. For example, beginning in 1989, almost all 3-year junior colleges were transformed into universities (Education Statistics of the Republic of China, 1997). In the planning process, education planners in Taiwan consider "higher education" to be composed of both universities and junior colleges. In this paper, we follow the lead of Taiwanese education planners and consider universities and junior colleges combined to be higher education in Taiwan. In the empirical analysis, we examine changes in the relative supplies and wages of workers with university degrees or junior college degrees compared to workers with senior high school degrees or less.

All public and private schools in Taiwan's higher education system must abide by Ministry of Education regulations. While the Ministry enforces its regulatory power through a variety of policy tools, the principal tool used by the Ministry to implement higher educational plan-

[1] Summarized from Education Statistics of the Republic of China (1997); Chang (1991); Gindling, Goldfarb and Chang (1995).

[2] Universities provide 4-year programs for general education, 5-year programs for teachers' preparation, 6-year programs for dentistry, and a 7-year program for medicine.

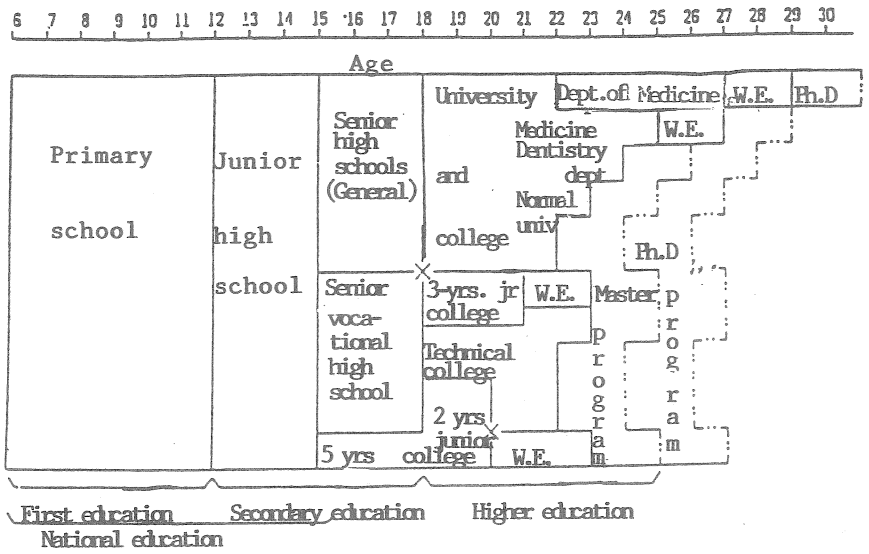

Fig. 1. School system in Taiwan. Notes: W.E. means working experience. X means that graduates can go to either school. Source: Education Statistics of the Republic of China, 1997, inside cover.

ning is to set the number of students who are allowed to pass the joint entrance examinations.[3] The Ministry of Education sets the number of students who pass the joint entrance examinations separately for each level of education and each type of major (technical or non-technical).[4] Students must list and rank their choices for both major and institution before taking the exam. Depending on the score on the exam, a student is assigned to a major at a specific university or junior college. The Joint Entrance Examinations are very competitive. Between 1978 and 1995, the proportion of test takers allowed into universities never rose above 40%, and the proportion of test takers allowed into junior colleges never rose above 30% (Sun, 1998). Almost all students who pass entrance examinations graduate in the type of major (technical or non-technical) initially assigned to them. Regressions of the number of university graduates on the enrollment quotas four years earlier yields an R-squared of 0.96, indicating that variations in enrollment quotas explain 96% of the variation in graduates from universities four years later. In regressions where we consider each type of major (technical or non-technical to be separate observations, the R-squared is 0.91.[5]

In setting enrollment quotas for each year the Ministry of Education takes into account the recommendations of the central government planning agency (Council of Economic Planning and Development) and requests by universities and junior colleges for new programs and students. The recommendations of the planning agency are based on the perceived need by industry for workers at different education levels and are derived from manpower planning models. From the 1950s to the 1980s the recommendation of the economic planning agency was the most important factor taken into account in Ministry of Education decisions. During this time, the planning agency had the confidence of the strong Taiwanese

[3] Other policy tools include regulating: the number of private and public junior colleges and universities; which fields of study may be offered at each institution; the tuition charge by both private and public institutions; the number of junior colleges and universities; tuition and fees; and subsidies to universities and junior colleges.

[4] Technical majors include: agriculture, natural sciences, engineering, medical sciences and mathematics and computer science. During 1956–61 and 1963–71, entrance exams for universities and junior colleges were held together; since 1972 they have been separate.

[5] These regressions are based on the data presented in Sun (1998). A similar regression analysis cannot be conducted for junior colleges because the number of years required to complete junior college is so variable.

The results of these regressions are consistent with statistics from the National Taiwan University, one of the largest and the most prestigious university in Taiwan, where over 92% of students graduate in the specific major (economics, electrical engineering, etc.) initially assigned to them (Education Statistics of the National University of Taiwan, 1997). Similar information is not available for other universities.

executive and acted as a miniature version of the cabinet (Sun, 1998). The government rigorously followed the policies formulated by the economic planning agency. The Ministry of Education was no exception, and during this period largely ignored the recommendations of university and junior college administrators in making decisions on enrollment quotas.

Table 1 presents the number of students receiving higher education for 1963 to 1995. While enrollments in higher education were allowed to grow at rates of 10 to 33 percent per year in the 1960s, in the 1970s economic planners greatly reduced growth in the number of students receiving higher education to approximately 3% per year.[6] The slow-down in enrollment growth rates in the 1970s occurred largely because economic planners were concerned that the explosive growth of universities and junior colleges in the 1960s had led to a decline in the quality of higher education.[7] In the words of Chang Pi-chi, a director of the planning agency's Manpower Development Department during this period (quoted in Chang, 1991, p. 741):

> In regard to volume growth, the higher education system had evolved overly fast, while the quality of education was not raised sufficiently.

Then, in the 1980s, the number of students receiving higher education was allowed to increase at faster rates. The number of students receiving higher education increased modestly at first—annual growth rates increased from below 3% in the 1977–78 school year to around 4.5% in the 1980–81 school year, where they remained until the mid-1980s. Then, in the 1986–87 school year the number of students began to increase more rapidly, with annual growth increasing to 4.7% in the 1986–87 school year and to 7.5% in 1988–89. Growth rates in enrollment remained high throughout the early 1990s, although rates have remained well below those of the 1960s. As shown below, this increase in enrollment led to a modest increase in the relative supply of workers with higher education in the mid-1980s, and a more rapid increase in the relative supply beginning in 1991.

We argue that the increase in enrollment quotas begun in the mid-1980s was the result of political factors external and internal to Taiwan, and was therefore largely exogenous to changes in relative wages. The 1970s and early 1980s were a time of political crisis in Taiwan. Externally, the United States discontinued official ties and Taiwan was ejected from the United Nations. Internally, Taiwan's success in promoting rapid industrialization had created general support for increased participation and democratization among the citizenry. These pressures led the Taiwanese government to adopt a series of political reforms, among the most important of which was the abolition of martial law in 1987. Within the Ministry of Education, the declining power of the central government in the late 1970s and 1980s manifested itself

Table 1
Number of students receiving higher education[a]

School year beginning	Number of students	Annual percent change
1962	50890	
1963	63126	24.04
1964	84353	33.63
1965	112744	33.66
1966	137292	21.77
1967	159711	16.33
1968	182221	14.09
1969	201178	10.40
1970	219601	9.16
1971	248137	12.99
1972	267925	7.97
1973	278847	4.08
1974	285523	2.39
1975	294913	3.29
1976	303427	2.89
1977	311745	2.74
1978	323993	3.93
1979	336222	3.77
1980	351082	4.42
1981	367204	4.59
1982	385506	4.98
1983	401400	4.12
1984	416158	3.68
1985	429211	3.14
1986	449543	4.74
1987	479189	6.59
1988	515515	7.58
1989	554197	7.50
1990	585589	5.66
1991	621891	6.20
1992	653658	5.11
1993	680953	4.18
1994	709250	4.16
1995	750674	5.84

[a] Notes: From Education statistics of the Republic of China, 1997, Table 5 (includes university, 3-year junior college and 2-year junior college).

[6] The Economic Development Plan approved by the Executive Yuan in 1972 called for limiting growth of the number of university students to 5% a year, the Economic Development Plan approved by the Executive Yuan in 1975 called for limiting growth in the number of university students to 3% per year.

[7] Education planners were also concerned that the mix of majors of graduates with higher education was inappropriate for manpower development needs. The 1972 and 1975 economic plans also called for an increase in the proportion of higher education graduates with technical degrees.

as a decline in the influence of the planning agency, and an increase in the influence of college administrator's demands for more programs and larger admittance quotas.[8] College administrator's demands may reflect the demands of potential students for higher education, which in turn may be influenced by the relative wages received by workers with higher education. If the demands of college administrator caused the change in Ministry of Education policy, then the increase in enrollment quotas in the mid- and late-1980s may not have been exogenous to relative wage changes. However, there is no indication that the increase in enrollment quotas occurred because of shifts in the demand for higher education by students. Demand for higher enrollment quotas was strong even during the period when enrollments were limited; the Ministry of Education limited enrollments despite these demands. The increase in enrollment quotas in the 1980s was more likely the result of the above-described political factors (largely exogenous to the labor market) which weakened the power of the central government and planning agency, and made it more difficult for the Ministry of Education to resist the continuing demands by students and college administrators for larger enrollment quotas.

3. Framework for analyzing relative wage changes

To examine the impact of exogenous changes in the relative supply of workers with higher education on the wages of workers with higher education relative to those with high school education, we follow Freeman (1975, 1980) and Katz and Murphy (1992), and consider the simplest CES production function with two factors: workers with and without higher education. The inverse demand function can be written as:

$$\log \mathrm{RWAGE} = \frac{\log \mathrm{RDEM} - \log \mathrm{RSUP}}{n} \quad (1)$$

where RWAGE is the wage of workers with higher education divided by the wage of workers without higher education, RDEM is an index of exogenous shifts in relative demand (changes in relative demand not caused by relative wage changes), n is the elasticity of substitution between workers with higher education and workers without higher education, and RSUP is an index of exogenous shifts in relative supply.

Our work focuses on whether the more important determinant of relative wage changes in Taiwan has been changes in relative demand or changes in relative supply. We have argued that observed changes in employment reflect exogenous shifts in relative supply. However, we do not directly observe relative demand shifts, only changes in equilibrium quantities and wages. Even without a direct measure of relative demand shifts, we can make some inferences about the relative importance of demand and supply changes by comparing changes in equilibrium wages and quantities. If relative demand changes have been more important, then we should find a positive correlation between changes in employment and changes in relative wages. If relative supply changes have been more important, then we should find a negative correlation between changes in employment and changes in relative wages.

4. Changes in relative employment (supply) and relative wages

We use data from the Manpower Utilization Survey, conducted in May from 1978 to 1995 in the Taiwan Area of the Republic of China. Using these data, we first estimate changes in the relative supply of workers with higher education compared to workers without higher education. Next, we estimate changes in relative wages (returns to education). We show that comparisons of changes in relative wages and relative supply are consistent with the hypothesis that changes in relative supply were a more important force than changes in relative demand in causing relative wage changes in Taiwan. Most important, we find negative correlation between changes in employment and changes in relative wages.

4.1. Relative employment (supply)

Fig. 2 presents two estimates of changes in relative supply. Panel A plots the change in the number of total hours worked by workers with higher education divided by the total hours worked by those with a senior high school education. The relative total hours worked of workers with higher education fell from 1978 to 1985, increased modestly from 1985 to 1991, and then increased more rapidly from 1991 to 1995.

Panel B address two possible problems with using panel A as a measure of relative supply: (1) panel A ignores those workers with less than a complete high school education (high school drop-outs, junior high school graduates and primary school graduates), and; (2) panel A implicitly assumes that university workers and junior college workers are perfect substitutes. To address these issues, we present estimates where those with less than a high school education are aggregated into the measure of high school graduates, and where junior college graduates are not counted the same as college graduates. We construct a ratio of the weighted sums of the

[8] The increase in enrollment quotas was accompanied by a relaxation of limits on the proportion of university graduates in the fields of humanities and social sciences. From 1991, the proportion of higher education graduates with technical degrees fell (see Sun, 1998).

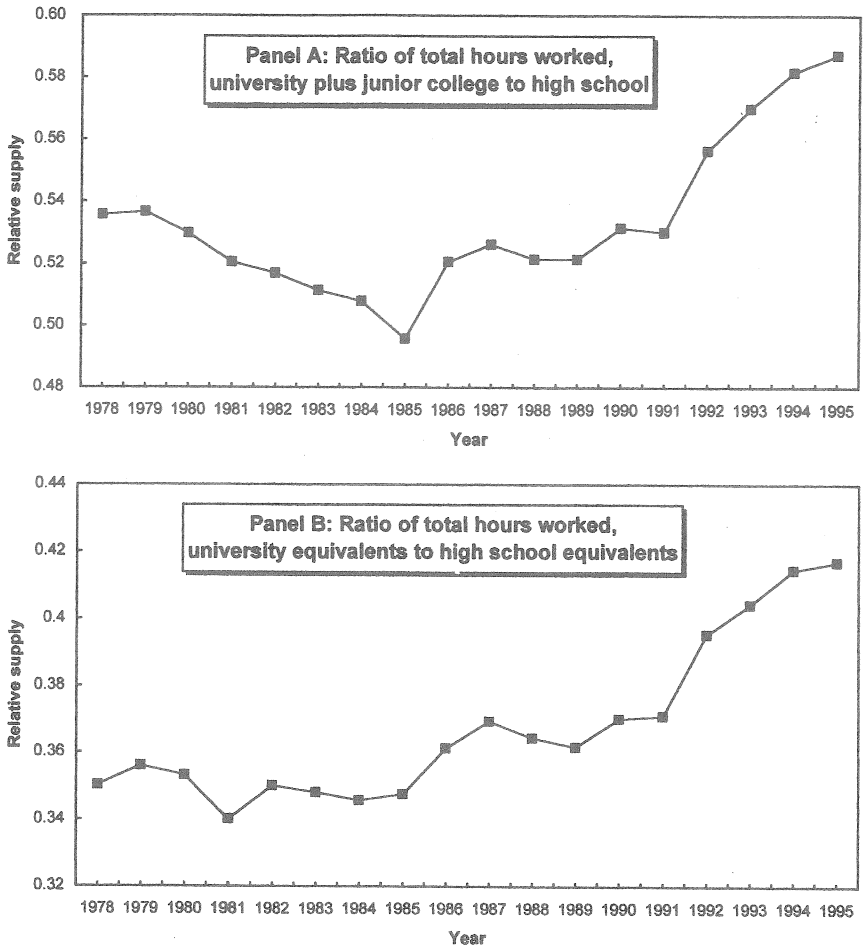

Fig. 2. Relative supply.

total hours worked of workers with different types of higher education divided by the weighted sum of workers with different types of less-than-higher education. The weights used are the relative wage rates of workers at different education levels.[9] The ratio of these weighted sums represents the ratio of university equivalent total hours worked to high school equivalent total hours worked, U_t^E/HS_t^E.

Specifically, high school equivalents, HS_t^E, are calculated as:

$$HS_t^E = HS_t + [(W_{JH}/W_{HS}) * JH_t] \quad (2)$$

where HS_t is the total hours worked of workers with a high school degree at time t, JH_t is the total hours worked of workers with a junior high degree or less at time t, W_{HS} is the hourly wage of workers with a high school degree, and W_{JH} is the hourly wage of workers with less than a high school degree (wages are measured as the mean for all years). University equivalents, U_t^E are calculated as:

$$U_t^E = U_t + [(W_{JC}/W_U) * JC_t] \quad (3)$$

where U_t are the total hours worked of workers with a university degree at time t, JC_t are the total hours worked of workers with a junior college degree or less at time t, W_U is the hourly wage of workers with a university degree and W_{JC} is the hourly wage of workers with a junior college degree.

[9] This aggregation scheme was suggested by an anonymous referee.

The pattern of change in panel B is similar to that in panel A. Relative supply falls from 1978 to 1985, and then increases from 1985 to 1995, modestly from 1985 to 1991, and then more rapidly from 1991 to 1995 (although the fall from 1978 to 1985 is much smaller in panel B than in panel A; 0.5% versus 5.6%).[10]

These changes in relative supply are consistent with the changes in enrollment in higher education presented in Table 1. While enrollment in higher education was being limited by the Ministry of Education, the relative employment of workers with higher education fell (from 1978 to 1985). Enrollment rates were allowed to increase modestly in the late 1970s and early 1980s. When these students began to graduate in the mid-1980s, the relative supply of workers with higher education began to increase. Enrollment rates were allowed to increase at even more rapid rates beginning in the 1986–87 school year. When these students began to graduate in 1991, relative supply also began to increase more rapidly.

4.2. Relative wages

Fig. 3 presents two measures of relative wages in Taiwan for 1978 to 1995: the difference between the log of mean hourly wages for workers with higher education (university plus junior college graduates) and the log of mean wages of workers with high school degrees; and the log of relative wages adjusted for changes in personal characteristics.[11] To control for changes in the personal characteristics not related to education which my be influencing measured relative wage changes we calculated the change in relative wages based on estimates from wage equations. As is customary, we use the log of wages as the dependent variable in the wage equations. For each year, we first regress the log of hourly wages on a variety of independent variables, including dummy variables for higher education and senior high school.[12] Then, to calculate the relative wages for each year we subtract the coefficient on the high school dummy variable from the coefficient on the higher education dummy variable.

Using both measures, relative wages rise on the whole between 1978 and 1987 (although they fluctuate during this period), and fall from 1987 to 1995. Using the log of relative wages adjusted for changes in personal characteristics, wages fall modestly from 1987 to 1991, and then faster from 1991 to 1995.[13]

[10] As noted in Section 2, we consider junior colleges and universities combined to be higher education in Taiwan. Given the structure of the Taiwanese education system, and changes in that structure over the period in which we are interested, we are reluctant to separate junior college graduates from university graduates. Nevertheless, it is useful to examine separately changes in the supply of university compared to junior college graduates. These numbers are presented in the appendix, Table 6. The ratio of the total hours worked of university to high school graduates falls from 1978 to 1985, then increases from 1985 to 1995. The ratio of the total hours worked of junior college to high school graduates increases throughout the period, with an acceleration from 1991 to 1995—from 1978 to 1985 the ratio increased by 7.7%, from 1985 to 1991 the increase was 7.1%, while from 1991 to 1995 the increase was over 13%.

Throughout the period studied here, the ratio of high school graduates to those with less than a high school degree increased at fairly steady, and rapid, rates. An alternative aggregation to calculate relative supply would divide the total hours worked of those with higher education by the simple sum of workers with a high school education or less. Using this aggregation scheme, the relative supply of those with higher education increases in each year. Consistent with the enrollment numbers presented in Table 1, the rate of growth is higher after 1985 than before (see Table 6 in the Appendix A).

We have information only on graduates, and cannot distinguish between terminal high school graduates and high school graduates with some higher education but no college degree (college drop-outs). We suspect that the latter group is small. As noted earlier, over 90% of entrants to universities complete university in four years in the major initially assigned to them. Similarly, we cannot distinguish between those workers with a terminal junior high school graduates and high school drop-outs (those with some high school but no degree).

[11] To calculate relative supply levels, we include all workers in the sample. Specifically, we multiply average hours worked at each education level by the total number of employees at each education level. To calculate average hours worked, we exclude any observations from the sample where reported hours worked were below 1 or above 98.

To calculate relative wages we use data from only paid employees (excluding self-employed, owners and un-paid family workers). We do this because of possible data problems with using the wages of all workers to estimate returns to education; for example, the wages of the self-employed may include returns to capital as well as returns to labor, and therefore are not appropriate for measuring returns to human capital such as education.

[12] Other independent variables were: a dummy variable for junior high school graduates, experience (age-education-6), experience squared, gender, years of tenure in the current job, and a dummy variable that was equal to one if the worker is married.

[13] Fig. 6 in the appendix presents several alternative specifications of the adjusted and unadjusted log relative wage ratios.

Consistent with Fig. 2, the ratio of the wages of workers with a university degree only to those with a high school degree only increases from 1987 to 1987, and then falls from 1987 to 1995. Unlike in Fig. 2, the university/high school wage ratio falls fastest from 1987 to 1988, is relatively stable from 1988 to 1993, and then falls rapidly again from 1993 to 1995. The change in the relative wage of workers with only a junior college degree to those with only a high school degree increases from 1978 to 1987. Unlike in Fig. 2, the junior college/high school relative

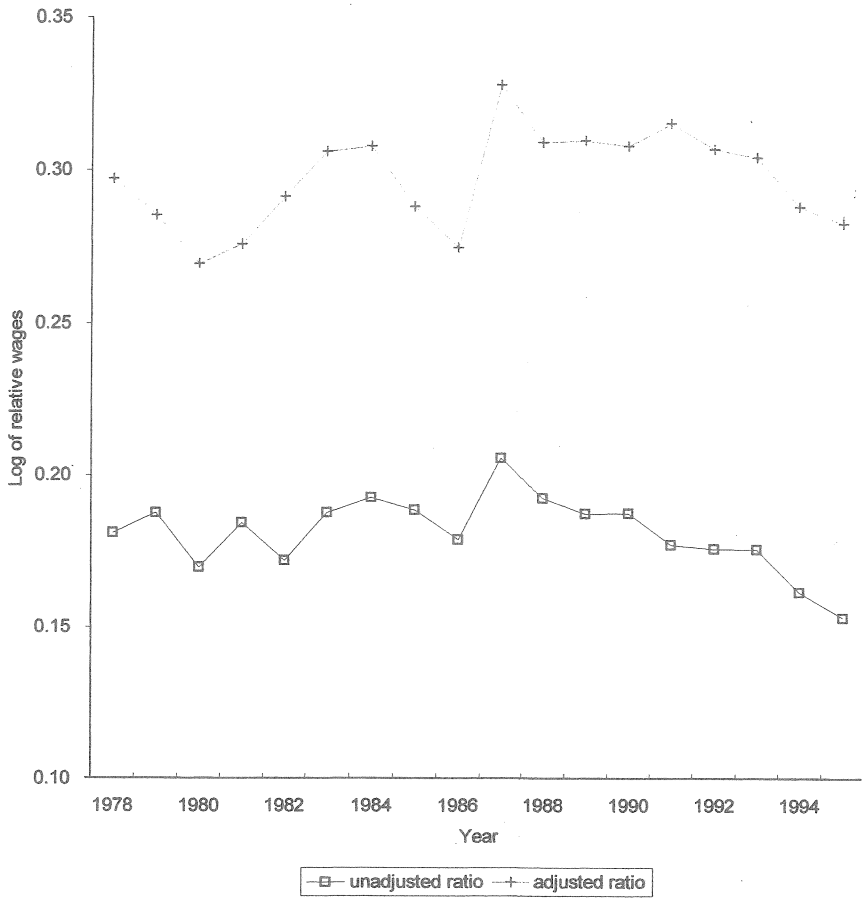

Fig. 3. Relative wages. Log ratio of wages of workers with higher education (university and junior college) to the wages of workers with a high school education.

wage continues to increase until 1991, but then falls from 1991 to 1995.

The patterns of change in the relative wage of university and junior college graduates to the wages of workers with a junior high degree or less are consistent with the patterns of relative wage change presented when we compare those with higher education to those with a high school education only. Specifically, the relative wage of university graduates to junior high and below increases from 1978 to 1987, and then falls from 1987 to 1995. The relative wage of junior college graduates to junior high and below falls moderately from 1978 to 1991, and then more rapidly from 1991 to 1995.

Fig. 6 presents the relative wage of high school graduates to junior high workers, which falls throughout the 1978–1995 period. Fig. 6 also shows that the relative wage of university to junior college graduates falls throughout the period for which we have data.

Table 2 presents the change in the log of relative wages for the 1978–1987, 1987–1995, and 1991–1995 periods, along with the *f*-statistics for the hypothesis that the change in the log of relative wages was significantly different from zero. The rise in relative wages from 1978 to 1987, the fall in relative wages from 1987 to 1995, and the fall in relative wages from 1991 to 1995 are all significantly different from zero at 1%.[14]

[14] Table 7 in Appendix A presents the ratio of the wages of university graduates only to high school graduates, as well as *f*-test statistics. As in the body of the paper, the university/high school wage ratio changes significantly from 1978 to 1985, and then again from 1989 to 1995. Unlike in Table 2, the fall in wages between 1991 and 1995 is not significantly different from zero.

Table 2
Change in the log of relative wages by work experience, 1978–1987, 1987–1995, and 1991–1995[a]

	All workers	Experience	
		10 years or less (recent graduates)	more than 10 years (older workers)
1978–87	0.0337*** (5.96)	−0.0084 (0.23)	0.0710*** (11.85)
1987–1995	−0.0402*** (16.63)	−0.0535*** (18.18)	−0.0312*** (4.71)
1991–1995	−0.0314*** (11.09)	−0.0604*** (24.58)	−0.0076 (0.31)

[a] Notes: *F*-statistics in parentheses for the hypothesis that the change in the relative wage is significantly different from zero. Experience is measured as age minus years of schooling minus 6. * significant at 10%; ** significant at 5%; *** significant at 1%.

5. Did changes in relative wages cause the changes in relative supply?

If relative supply changes were the more important determinants of changes in relative wages, then we should find a negative correlation between changes in relative supply and changes in relative wages. If relative demand changes were the more important, then we should find a positive correlation between changes in relative supply and changes in relative wages.

5.1. Comparing relative wage and relative supply changes

A comparison of Figs. 2 and 3 suggests that relative supply changes were the primary force causing relative wage changes throughout the period for which we have data. Increasing relative wages from 1978 to 1987 are correlated with a fall in relative supply, while falling relative wages from 1987 to 1995 are correlated with a rise in relative supply. The figures suggest that the initial increase in relative supply (begun in 1985) influenced relative wages with a two-year lag. The evidence that the exogenous supply shift of the mid-1980s caused relative wages to fall is especially strong; after 1987 relative wages fall in all but two years, and fall fastest during the period when the relative supply increased most rapidly (after 1991).

5.2. Inner-product tests

Katz and Murphy (1992) develop a further test of whether the data are consistent with the hypothesis that relative supply changes cause relative wage changes within an environment of stable relative demand. To control for changes in the demographic composition of the labor force, the Katz and Murphy (1992) inner-product test divides the data into narrowly defined demographic groups. Applying this method, we divide the data into (three) education, (two) sex, and (ten) age groups.[15] We then calculate the product of the change in the relative total hours worked and relative wage for each demographic group between selected years. A negative product is consistent with the hypothesis that changes in supply drive changes in relative wages, whereas a positive product is not consistent with that hypothesis. Finally, we calculate a weighted average of these changes, referred to as the inner-product. If the inner-product is negative, the evidence is, on balance, consistent with the hypothesis that changes in relative supply drive changes in relative wages, while a positive inner-product is not.

Specifically, we evaluate the inner-product between the years t and T by calculating

$$(\underline{W}_t - \underline{W}_T) * (\underline{X}_t - \underline{X}_T) \quad (4)$$

where $\underline{X}_t$ is a vector of the relative total hours worked for each demographic group (each education/sex/age group) in year t. The elements of this vector are the total hours worked in each demographic group i divided by total hours worked in year t. Following Katz and Murphy (1992), we use the sample of all workers to calculate the relative total hours worked vector. $\underline{W}_t$ is a vector of relative wages for each demographic group in year t. The elements of this vector, W_{ti}, are the average hourly wage for each demographic group (w_{ti}) deflated by a wage index calculated based on a fixed demographic distribution among workers. Specifically, we calculate $W_{ti}=w_{ti}/[\Sigma_i((N_i/N)*w_{ti})]$, where w_{ti} is the mean hourly wage at time t of demographic group i, N_i is the mean total hours worked in demographic group i over the

[15] The education groups are: junior high school and below (compulsory education), senior high school and higher education. We also conducted the inner-product test with the following education groups: junior high school and below, senior high school, junior college and university. These inner-products are also consistently negative for all periods.

entire 1978–1995 period, and N is the mean total hours worked in all demographic groups over the entire 1978–1995 period. Mean hourly wages for each demographic group (w_{ti}) are calculated using the sample of salaried employees only.

The results of the inner-product tests for various sub-periods between 1978 and 1995 are presented in Table 3. In all periods, the inner-product is negative.[16] These results indicate that, in terms of their influence on relative wages, changes in relative supply dominated any relative demand changes.[17]

5.3. Comparing relative wage changes for recent graduates and older workers

The increase in the relative number of workers graduating from college should affect the supply of younger but not older workers. If older and younger workers are imperfect substitutes in production, then we would expect changes in the relative number of graduates from institutions of higher education to affect the wages of recent graduates more than the wages of older workers (Welch, 1979). Table 2 presents changes in the relative wages for older workers (those with more than 10 years since graduating) and recent graduates (those with 10 years or less since graduating). The results indicate that, for the earlier 1978–1987 period, the relative wages of older workers rise faster than the relative wages of recent graduates. In fact, as we can see from Table 2, the change in the relative wages of recent graduates between 1978 and 1987 is not significantly different from zero. This evidence is not consistent with the hypothesis that relative wage changes between 1978 and 1987 were driven primarily by changes in relative supply.

On the other hand, for the more recent period, 1987–1995, the evidence is consistent with the hypothesis that changes in relative wages were driven primarily by changes in relative supply. From 1987 to 1995 the relative wages of recent graduates fall by more than the relative wages of older workers. The timing of the relative wage changes for recent graduates is additional evidence that the increase in the relative supply of workers with higher education in the mid-1980s caused relative wages to fall. During the period when the relative supply increased most rapidly, 1991 to 1995, the relative wages of recent graduates fell while the relative wages of older graduates did not change significantly.[18]

Table 3
Inner products of changes in relative wages with changes in relative employment between selected years

	1978	1983	1987	1991
1983	−0.0030			
1987	−0.0070	−0.0010		
1991	−0.0157	−0.0076	−0.0021	
1995	−0.0249	−0.0056	−0.0059	−0.0007

5.4. Controlling for changes in relative demand—time-series regression estimates of the inverse demand function

5.4.1. Framework

To examine whether the negative correlation between relative employment and relative wages holds after controlling for changes in relative demand, we estimate Eq. (1). Specifically, we estimate the following equation:

$$\log(\mathrm{RWAGE}_t)=a+b\log(\mathrm{RDEM}_t)+c\log(\mathrm{RSUP}_t)+e_t \quad (5)$$

where $\log(\mathrm{RWAGE}_t)$=log of the wage of workers with higher education divided by the wage of workers with a senior high school education in time t, derived from the coefficients estimated in the wage equations (see Fig. 3).

e_t=error term.

$\log(\mathrm{RSUP}_t)$=log of exogenous relative supply shifts. One way to interpret the coefficient on log(RSUP), b, is as the correlation between relative employment and relative wages after controlling for changes in relative demand; that is, as an extension of the tests already carried out.

$\log(\mathrm{RDEM}_t)$=log of the ratio of an index of exogenous relative demand shifts for workers with higher education divided by an index of exogenous relative demand shifts for workers without higher education in time t.

[16] To test the robustness of the inner-product results, we also calculated several other of the inner-products for 1978–1987 and 1987–1995; one set of estimates compares changes in the log supply and log wage ratios; another set of estimates is based on a comparison of three-year averages around the end-years for each period, yet another set uses the number of employees (rather than hours worked) to measure relative supply. No matter the measure or sub-period we use, the calculated inner-products are always negative.

[17] Robbins and Zveglich (1996) also calculate inner-product tests for Taiwan using a variety of measures of relative supply. The results they present are consistent with those presented here. That is, they find negative inner-products no matter the period studied.

[18] The results are identical if we use the university/high school ratio as the measure of relative wages (see appendix Table 7).

5.4.2. Describing relative demand shifts

We have argued that increases in the relative supply of workers with higher education after 1985 caused relative wages to fall. However, if the relative demand for workers with higher education had fallen from 1985 to 1995, then relative demand changes rather than changes in relative supply might have been the cause of falling relative wages for workers with higher education.

Exogenous shifts in relative demand are not directly observable from the data. In the literature describing changes in the Taiwanese labor market, shifts in the relative demand for more-skilled workers in Taiwan over the past 40 years are most often associated with changes in the composition of production caused by international trade, which in turn cause changes in the distribution of employment across industries. After Taiwan shifted from an import substitution trade strategy to an outward-oriented one in the early 1960s, there was an increase in the production of low-skilled labor intensive exports, causing a fall in the relative demand for more-skilled workers.[19] However, by 1978 (the first year for which we have data) the composition of manufacturing exports was becoming more skilled-intensive. According to Chu (1996), "the phase of labor surplus ended in Taiwan around 1968, which is regarded as the 'turning point' from labor surplus to scarcity" (p. 25), resulting in an increase in the percentage of skill-intensive products in exports and an increase in the demand for more-skilled workers (Chu, 1996). This increase in the proportion of workers in skilled-intensive manufacturing continued until the late 1980s. "In the late 1980s, however, the industrialization process came itself to an end and the 'tertiarisation' of the economy began...the manufacturing sector lost ground in the evolution of the sector structure of GDP in favor of services to the business sector" (Bourguignon, Fournier, & Gurgand, 1998, p. 5). These changes are illustrated in Table 4. From 1978 to 1987 the proportion of labor in the very low-skilled agricultural sector fell, while the proportion of workers in more-skill intensive manufacturing and commerce sectors rose. At the same time, within both the manufacturing and commerce sectors, the proportion of labor with higher education increased. Then, from 1987 to 1995 the proportion of labor in manufacturing declined from 39% to 27%, while the proportion of labor in (financial and other) services increased from 19% to 24% (with smaller increases in commerce and construction). This "tertiarisation" of the economy did not result in a fall in the demand for more-skilled workers, as the growing service sectors were also those sectors most intensive in labor with higher education. Therefore, the shift towards services and away from manufacturing that occurred between 1987 and 1995 cannot explain the fall in relative wages after 1987.

[19] Robbins and Zveglich (1996) note that the 1980 to 1992 (and beyond) was a period of accelerated trade liberalization. However, they do not present evidence that there was any dramatic change in trade strategy in the mid and late 1980s.

Table 4
Changes in the distribution of employment by industry and level of education

Panel A: Percent of total hours worked by industry

Industry	1978	1985	1987	1995
Agriculture	17.56	12.26	9.56	9.05
Mining	0.61	0.55	0.41	0.17
Manufacturing	33.73	37.18	38.79	27.38
Utilities	0.61	0.56	0.46	0.39
Construction	8.65	7.28	7.01	10.83
Commerce	14.70	17.01	17.86	22.53
Transportation	6.54	6.27	6.59	5.44
Financial services	2.04	2.62	3.06	3.35
Services	15.57	16.28	16.28	20.85

Panel B: Skill-intensity by industry university equivalent/high school equivalent ratio

Industry	1978	1985	1987	1995
Agriculture	0.007	0.007	0.011	0.025
Mining	0.075	0.055	0.050	0.061
Manufacturing	0.059	0.081	0.094	0.163
Utilities	0.239	0.470	0.535	0.462
Construction	0.037	0.053	0.068	0.101
Commerce	0.100	0.112	0.143	0.176
Transportation	0.097	0.116	0.146	0.215
Financial services	0.476	0.575	0.553	0.751
Services	0.401	0.409	0.472	0.569

The above discussion suggests measuring changes in relative demand using changes in the structure of employment between industries. One widely used measure of shifts in relative demand is the fixed-input-ratio manpower requirements index of Freeman. Freeman (1975, 1980) argues that, given a fixed-input technology within each industry, shifts in relative demand for more-educated workers can be measured using shifts in the composition of output (or total employment) by industry. Following Freeman (1975, 1980), we calculate a manpower requirements index of the relative demand for workers with higher education (1) compared to workers with senior high school education (2) in year t, holding relative wages constant:

$$RDEM_{12t}=DEM_{1t}/DEM_{2t}, \text{ where}$$

$$DEM_{zt}=\sum_j a_{zj}*E_{jt}, \quad (6)$$

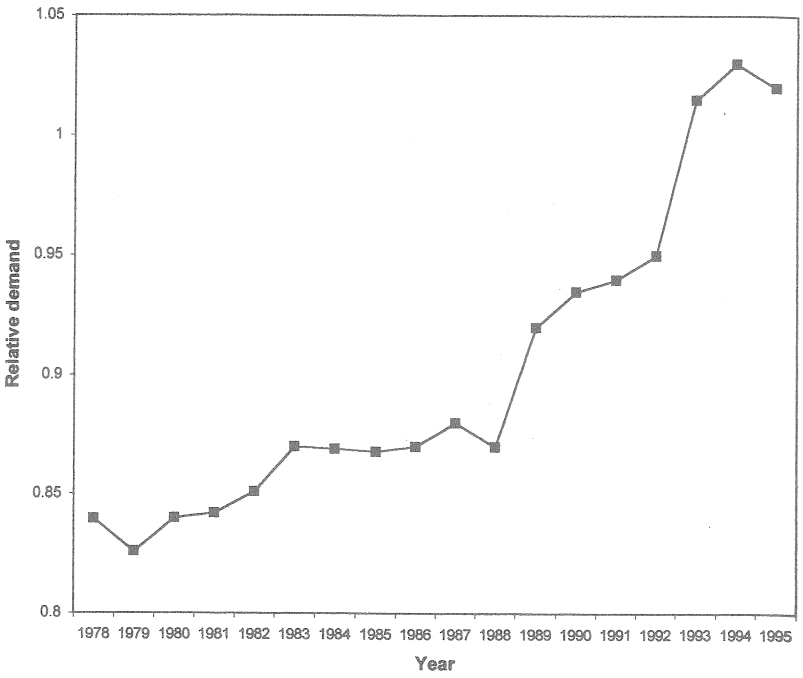

Fig. 4. Relative demand. Freeman's fixed-input-ratio index.

where a_{zj} is the proportion of education group z (z=1 for university equivalents and 2 for high school equivalents) in industry j in the base year (we use the average of 1978–1980 as the base year), E_{jt}=total employment in industry j in year t.

Fig. 4 presents our estimate of the Freeman manpower requirements estimate of shifts in relative demand for 1978 to 1995. Using this measure, relative demand increases modestly from 1978 to 1988, and then much more rapidly from 1988 to 1995. Clearly, if Fig. 4 is a reasonable description of changes in relative demand, then changes in relative demand cannot explain the fall in relative wages after 1987.

This manpower requirements estimate of relative demand is appropriate only if the ratio of different types of labor used in production within each industry remains constant over time. This assumption may be violated, especially in an environment of rapid technological change, industrial development, and social transformation (such as that in Taiwan in the 1970s, 1980s and 1990s).[20] The results presented in Table 4 show that the proportion of workers with higher education within each industry from 1978 to 1995 does change.

Using data from the United States, Katz and Murphy (1992) construct measures of relative demand shifts that take into account shifts in the employment structure both between and within industries. Robbins and Zveglich (1996) construct between- and within-industry indexes of shifts in relative demand using the technique described in Katz and Murphy (1992) and the same Taiwanese data we use. Consistent with the results of the Freeman manpower requirements estimate of shifts in relative demand, Robbins and Zveglich (1996) present evidence that between-industry shifts in employment were towards workers with higher education throughout the 1978–1992 period, and that the shifts were larger after 1986

[20] Even if input-coefficients remained fixed within narrowly defined industries, this measure of relative demand will only be appropriate if the industries are defined narrowly enough. If the industries are not defined narrowly enough, the estimate of relative demand may actually reflect relative supply changes. Unfortunately, we are only able to divide the data into 10 industry groups (a two-digit classification). The Manpower Surveys report a three-digit industry classification. However, we could not use the three-digit classification because a change in definition made the three-digit codes before 1993 inconsistent with the post-1993 codes. There is some evidence that our fixed-input coefficient estimate of relative demand does reflects changes in relative supply; changes in our calculation of relative demand are closely correlated with changes in relative employment and supply–stable from 1978 to 1988, rising from 1988 to 1995.

Table 5
Time-series estimates of inverse demand functions[a]

Specification		Coefficient (*t*-statistics)			
Dependent variable: log of relative wage		log RSUP	log RDEM	time-trend	*R*-squared
Relative supply not lagged (16 observations)					
1. H^E_U/H^E_{HS}	A.	−0.135 (0.78)	0.142 (0.89)		0.047
	B.	−0.197 (20.8)*		0.003 (2.43)*	0.201
2. H_U/H_{HS}	A.	−0.221 (1.46)	0.189 (1.23)		0.106
	B.	−0.169 (1.73)*		0.007 (1.98)*	0.199
Relative supply is lagged 2 periods (18 observations)					
1. H^E_U/H^E_{HS}	A.	−0.586 (1.98)*	0.522 (2.25)**		0.353
	B.	−0.724 (2.09)*		0.009 (2.40)**	0.339
2. H_U/H_{HS}	A.	−0.346 (4.61)***	−0.095 (1.58)		0.725
	B.	−0.342 (3.31)***		−0.000 (0.21)	0.711

[a] Specifications: Relative supply: 1. Relative supply is measured as the ratio of university equivalents to high school equivalents; 2. Relative supply is measured as the ratio of total hours worked by university graduates to the total hours worked by high school graduates. Relative demand: A. Freeman's fixed-input-ratio index; B. Time-trend. Notes: * significant at 10%; ** significant at 5%; *** significant at 1%.

than before. They also find that within-sector shifts in demand were towards less-educated workers. Adding between- and within-industry shifts in demand to characterize overall shifts in the relative demand for more-skilled workers, they present evidence that relative demand increased at a steady rate over the entire 1978–1992 period. Furthermore, using an extension of the technique presented in Katz and Murphy (1992) and Robbins and Zveglich (1996) infers what changes in overall relative demand for university equivalents to primary school equivalents were assuming a variety of possible numbers for the elasticity of substitution for the 1978–1992 period. The results of this analysis are also consistent with a steady rate of increase in the relative demand throughout the 1978–1992 period.

The results presented in Robbins and Zveglich (1996) provide no evidence of a fall in the relative demand for more-educated workers after the mid-1980s. The results presented in Robbins and Zveglich (1996) suggest that the relative demand for more-educated workers increased at fairly steady rates between 1978 and 1992. These results suggest that we proxy shifts in relative demand by using a time-trend in the estimation of Eq. (5).

5.4.3. Estimates of the inverse demand functions

Table 5 presents estimates of Eq. (5) using two different estimates of relative demand; the Freeman manpower requirements estimate and a linear time-trend. We report results using unlagged relative supply and relative supply lagged two years. The length of the lag is suggested by an examination of Fig. 2 and Fig. 3, which show that relative wages began to fall two years after relative employment initially began to increase.

The estimates presented in Table 5 should not be considered conclusive. Both the imprecise estimates of relative demand used, and the short time-series we have available, reduce the confidence that we have in the specific estimates of the elasticity of substitution and of the significance levels of the coefficients. Given these caveats, the results presented in Table 5 are consistent with the results presented in the rest of this paper. Most importantly, in all estimates the coefficient on the relative supply variable is negative, indicating that increases in relative supply are correlated with decreases in relative wages. However, the coefficient on relative supply is significantly different from zero only in the regressions where relative demand is proxied using a time trend (and then is significant at 1% once, at 5% once and at 10% twice).

The results imply estimates of the elasticity of substitution that range from 2.3 to 7.4.[21] These estimates are

[21] Estimates of the inverse-demand functions comparing university (excluding junior college) workers to senior high school workers are presented in appendix Table 8. In these estimates, the coefficients on relative supply are always negative, and are significantly different from zero at 1% in one-half of the estimates. Using the results reported in Table 8 yield estimates of the elasticity of substitution from 1.4 to 6.0.

larger than those for the United States—Bound and Johnson (1992) present an estimate of 1.75, Katz and Murphy (1992) present an estimate of 1.4—but smaller than the estimate for Korea presented by Choi (1996) of 8.7.[22]

The coefficients on the variables measuring shifts in relative demand are always positive, although they are significantly different from zero only for the time-trend specification. If we interpret these coefficients as estimates of Eq. (4), then the coefficient on relative supply in specification A should be equal to the negative of the coefficient on relative demand. *F*-tests of the equality of the coefficients (for the manpower requirements specification of relative demand) on relative demand and relative supply leads us to conclude that these coefficients are not significantly different (except for the signs). However, since individually each coefficient is not significant, these *f*-tests are not very informative.[23]

6. Conclusions

In this paper we present evidence that the policy of Taiwanese education planners in the 1980s to increase the number of students receiving higher education led to a decrease in the relative wages of workers with higher education. Using data from the 1978–1995 Manpower Utilization Surveys, we show that, when the relative supply of workers with higher education increased in response to the policy expanding access to higher education, relative wages for workers with higher education fell. Furthermore, relative wages fell fastest in response to the most rapid increases in relative supply. This is consistent with the hypothesis that relative supply changes were more important than relative demand changes in determining relative wage changes. If relative demand had been the more important determinant, then changes in relative employment would have been positively correlated with changes in relative wages. Using the inner-product test developed in Katz and Murphy (1992), we show that the negative correlation between relative wages and relative supply occurs even after controlling for demographic changes in the labor force.

If older and younger workers are imperfect substitutes in production, then we would expect changes in the relative number of graduates from institutions of higher education to affect the wages of recent graduates more than the wages of older workers. We show that, in response to the increase in relative supply, the relative wages of recent graduates fell more quickly than did the relative wages of older workers.

Using time-series data, we examine the impact on relative wages of changes in relative supply after controlling for relative demand shifts. In these equations, the coefficient on relative supply is always negative (although it is not always significantly different from zero), indicating that even after controlling for relative demand shifts, relative supply and relative wages are inversely correlated in Taiwan over the period for which we have data. Further, we find no evidence that the relative demand for workers with higher education fell after 1985. Therefore, we find no evidence that the fall in the relative wages of workers with higher education was caused by changes in relative demand.

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[22] One potential explanation for the larger elasticity of substitution estimates in Taiwan and South Korea can be found in trade theory. The framework we have used so far to analyze changes in relative wages is valid for a closed economy; in a closed economy the elasticity of substitution will be determined by production technologies and consumer preferences, and relative factor demand curves will slope down. However, the effect of changes in relative supply on relative wages may be quite different in a small, open economy. Standard trade theory predicts that in the long run, because product prices (and therefore the value of the marginal product of labor) are determined internationally, relative factor demand curves in a small, open economy will be perfectly elastic (for example, see the discussion in Johnson & Stafford, 1999). Therefore, changes in the relative supply of more-educated workers should have no effect on relative wages in a small, open economy. While Taiwan is a small, open economy, the changes we observe occur over the relatively short-run. Therefore, even if the standard trade theory model held in the long-run, we still might expect to see some impact on relative wages from changes in relative supply. However, because Taiwan is closer to the trade economist's small open economy than is the US, it is reasonable to expect the effects of changes in relative supply on relative wages to be smaller in Taiwan than in the US (We are grateful to an anonymous referee for making us aware of this point.)

[23] In Table 8 the estimated coefficients on the relative demand variable are positive in 6 of 8 cases. In the cases where the coefficients are positive, they are also significant at 5% in 5 of 6 cases. *F*-tests indicate that the coefficients on the relative supply and relative demand variables are significantly different in 3 of four cases.

Appendix A

Table 6
Ratio of total hours worked between education levels

Year	University/ high school	Junior college/high school	University and junior college/high school	University/high school and below	University and junior college/high school and below	High school/junior high and below
1978	0.28	0.26	0.54	0.05	0.10	0.24
1979	0.27	0.27	0.54	0.05	0.10	0.26
1980	0.26	0.27	0.53	0.06	0.12	0.28
1981	0.27	0.25	0.52	0.06	0.12	0.30
1982	0.25	0.27	0.52	0.01	0.13	0.32
1983	0.24	0.27	0.51	0.06	0.13	0.35
1984	0.24	0.27	0.51	0.07	0.14	0.38
1985	0.21	0.28	0.50	0.06	0.14	0.38
1986	0.23	0.29	0.52	0.07	0.16	0.43
1987	0.23	0.30	0.53	0.07	0.16	0.44
1988	0.23	0.29	0.52	0.08	0.17	0.49
1989	0.23	0.29	0.52	0.08	0.18	0.54
1990	0.23	0.30	0.53	0.08	0.19	0.56
1991	0.23	0.30	0.53	0.08	0.20	0.58
1992	0.23	0.33	0.56	0.09	0.22	0.63
1993	0.24	0.33	0.57	0.10	0.23	0.68
1994	0.24	0.34	0.58	0.10	0.24	0.71
1995	0.24	0.34	0.59	0.10	0.25	0.73

Table 7
Change in the log of relative wages by work experience, 1978–1987, 1987–1995, and 1991–1995 (wages of university graduates relative to the wages of high school graduates)[a]

	All workers	Experience	
		10 years or less (recent graduates)	more than 10 years (older workers)
1978–1987	0.072*** (16.11)	0.0263 (1.18)	0.0100*** (15.46)
1987–1995	−0.053*** (15.84)	−0.0544*** (13.69)	−0.0415** (4.83)
1991–1995	−0.017 (1.78)	−0.0676*** (7.25)	−0.0017 (0.012)

[a] Notes: F-statistics in parentheses for the hypothesis that the change in the relative wage is significantly different from zero. * significant at 10%; ** significant at 5%; *** significant at 1%.

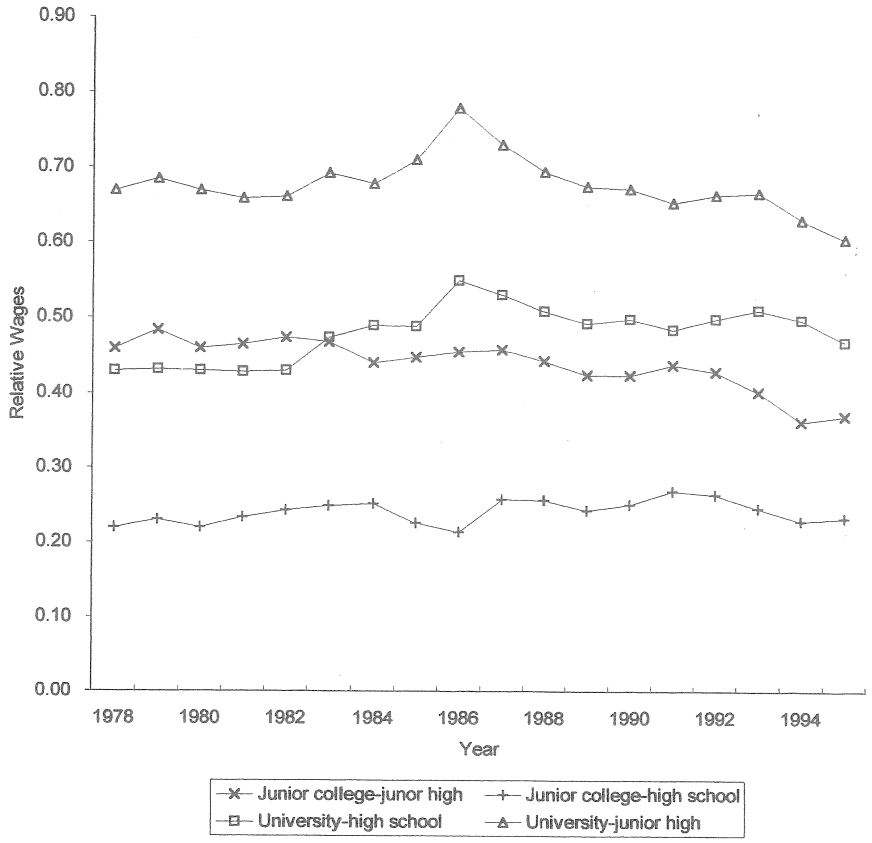

Fig. 5. Alternative specification of the relative wage, adjusted for changes in personal characteristics.

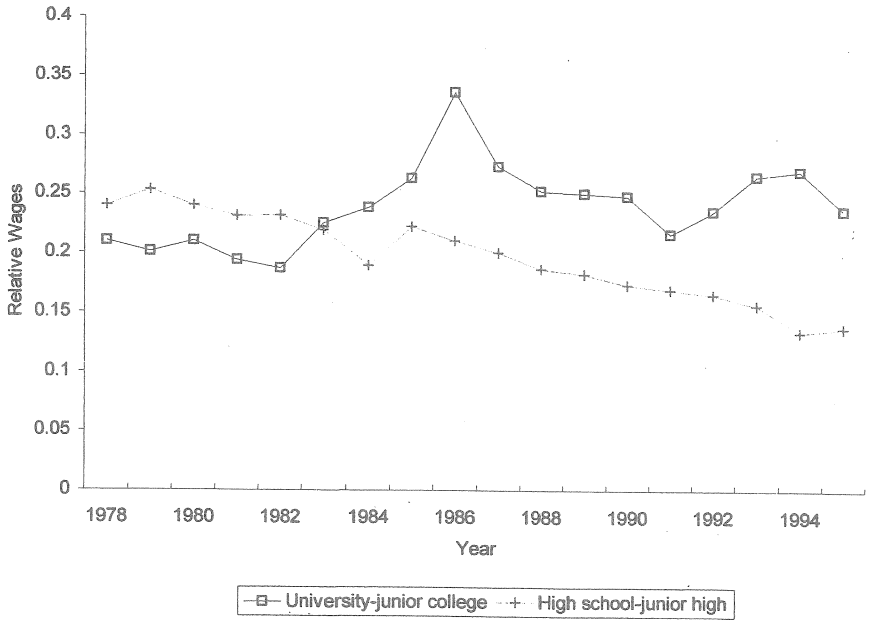

Fig. 6. Other wage ratios, adjusted for changes in personal characteristics.

Table 8
Time-series estimates of inverse demand function[a]

Specification		Coefficient (*t*-statistics)			
Dependent variable: log wage of university graduates minus log wage of high school graduates		log RSUP	log RDEM	time-trend	R-squared
Relative supply not lagged (16 observations)					
1. H^E_U/H^E_{HS}	A.	−0.066 (0.23)	0.276 (0.99)		0.230
	B.	−0.306 (2.54)**		0.007 (5.20)***	0.545
2. H_U/H_{HS}	A.	−0.333 (5.03)***	0.127 (2.14)**		0.693
	B.	−0.267 (3.62)***		0.002 (2.60)**	0.732
Relative supply is lagged 2 periods (18 observations)					
1. H^E_U/H^E_{HS}	A.	−0.586 (1.98)*	0.522 (2.25)**		0.353
	B.	−0.724 (2.09)*		0.009 (2.40)**	0.339
2. H_U/H_{HS}	A.	−0.346 (4.61)***	−0.095 (1.58)		0.725
	B.	−0.342 (3.31)***		−0.000 (0.21)	0.711

[a] Specifications: Relative supply: 1. Relative supply is measured as the ratio of university equivalents to high school equivalents. 2. Relative supply is measured as the ratio of total hours worked by university graduates to the total hours worked by high school graduates. Relative demand: A. Freeman's fixed-input-ratio measure; B. Time-trend. Notes: * significant at 10%; ** significant at 5%; *** significant at 1%.

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