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Wage Differentials in Taiwanese Manufacturing, 1982–1997*

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The present paper examines the impacts of technological change and trade flows on wage inequality across manufacturing industries. Using micro-level data from the Taiwan Manpower Utilization Survey (TMUS), 1982–1997, a slight decline in the log-wage differential between college and high-school workers is detected during this period. These results indicate that the accelerated growth in the relative supply of college graduates, combined with steady demand growth in favor of more highly educated workers, can largely explain the narrowing wage differentials within Taiwanese manufacturing over the period 1982–1997. In terms of demand-side factors, this study concludes that technology and trade are the two major forces driving the differences in wage inequality across industries.

Keywords: technological change, trade, wage inequality.

JEL classification codes: F1, J3, O3.

I. Introduction

A dramatic increase in wage inequality was evident in the USA during the 1980s, with wage levels among the relatively higher-educated workers advancing more rapidly than those of less-educated workers (Bound and Johnson, 1992; Katz and Murphy, 1992; Murphy and Welch, 1992). A similar pattern is also discernible in several of the Organization for Economic Cooperation and Development (OECD) countries (Freeman and Katz, 1995; Cardoso, 1998; Haskel, 1999). The key forces behind the rise in wage inequality appear to be changes in the supply and demand of skills. A reduction in the rate of growth of the relative supply of highly educated workers, combined with steady growth in the demand for such workers, has consistently provided a plausible explanation for increasing educational differentials in the 1980s in both Britain and the

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USA.[1] The two most widely cited explanations for the rise in demand for skilled labor are: (i) the change in the skill bias of technology; and (ii) the increased openness of economies.[2]

A number of recent surveys of the labor force have pointed to technological change as the major cause of the increasing disparity between skilled and unskilled workers. For example, Mincer (1991), Berndt *et al.* (1992), Krueger (1993), Berman *et al.* (1994) and Allen (2001) found that the introduction of computers and other related technologies is generally biased in favor of skilled workers and thus exacerbates wage inequality. Using plant-level data to further study the impact of technological change on wages, Dunne and Schmitz (1995) and Doms *et al.* (1997) suggested a positive correlation between wages and technology use.[3]

The link between trade and wage inequality has been identified in the Stopler–Samuelson theorem, which indicates that trade affects the relative factor reward by changing relative prices. Several researchers have investigated the role of international trade on wages, arguing that competition from low-wage countries has reduced the relative demand for unskilled workers and caused their wages to fall in relation to the wages of skilled workers.[4] However, empirical studies have presented conflicting evidence. Leamer (1994), Borjas and Ramey (1995), Wood (1995), Bernard and Jensen (1997), and Lovely and Richardson, (1998) suggested that trade plays an important role in explaining wage inequality, whereas Krugman and Lawrence (1993), Lawrence and Slaughter (1993), and Sachs and Shatz (1994) have argued that trade has only a minor, or indeed uncertain, effect on wage inequality.

More recent research has examined the relative importance of trade versus technology on wages. Feenstra and Hanson (1997) found that computers explained around 35% of the increase in the relative wages of non-production workers in the USA, while outsourcing could provide an explanation for only 15% of the increase. Minford *et al.* (1997) used a computable equilibrium model to examine the relative importance of technology and trade on the OECD labor market, concluding that of the joint effects in the OECD labor market, 38% were due to technology while the remaining 62% were attributable to trade.

1. Katz and Murphy (1992) and Gosling *et al.* (1994) found that the relative supply shifts could explain only a very small fraction of the rise in wage equality in the USA and the United Kingdom.
2. There are also economists who argue that institutional changes, such as the decline of trade unions or a reduction in minimum wages, have lowered the wages of low-skilled workers and thus contributed to the rise in wage inequality (Gosling and Machin, 1993; Machin and Manning, 1994; Freeman and Katz, 1995).
3. Using employer–employee matched data, DiNardo and Pischke (1997) and Entorf and Kramarz (1997) suggested that worker quality, rather than productivity enhancement, drives the positive relationship between technology and wages. Bartel and Sicherman (1999) also found that the wage premium associated with technological change is primarily due to the sorting of more able workers into those industries.
4. Feenstra and Hanson (1997) also suggest that outsourcing by multinationals may contribute to a worldwide increase in the relative demand for skilled labor.

Baldwin and Cain (2000) used a standard general equilibrium trade model to analyze the role of various economic factors in determining the behavior of relative wages in the USA from the late 1960s to the 1990s. They determined that a combination of the labor-demand shifts – arising from education-biased technological change and increasing import competition – along with an increase in the relative supply of more highly educated labor, was responsible for the widening wage inequality of the 1980s and 1990s. Although different analysts place different weights on the role of technology and trade forces – along with other factors – they generally agree that demand has been moving more towards higher education and skills levels.[5]

Research in this area has thus far received comparatively little attention in the developing countries. Unlike the evidence found in the USA and several advanced economies, the patterns of wage movements are different in developing countries. Feliciano (1993), Hanson and Harrison (1995), and Feenstra and Hanson (1997) found an increase in wage inequality in Mexico over the period 1986–1990. Robbins (1994) also reported a similar trend in Chile during the 1980s. However, Kim and Topel (1995) and Chan *et al.* (1999) identified a declining trend in wage inequality in both South Korea and Taiwan since the mid-1970s.[6] Part of the narrowing educational differentials in these two East Asian countries may be attributable to an increase in the relative supply of college graduates, but the source of this demand trend remains largely unexplained.[7]

Taiwan has experienced a small decrease in wage inequality over the last two decades, with the wages of highly educated workers falling slightly, relative to those of less-educated workers. Taiwan's rapid development during this period coincided with its active policies towards export promotion. Since the 1980s the Taiwan government has also adopted a number of policies encouraging the adoption of factory automation equipment. These policies include: (i) preferential taxation treatment; (ii) financial subsidies; (iii) technical assistance; and (iv) on-the-job training. According to the Ministry of Economic Affairs in Taiwan, the ratio of automation equipment value to total machinery equipment value increased substantially, from 25% in 1985 to 62% in 1997.

The purpose of this study is to provide direct evidence on the way in which changes in technology and trade affect inter-industry wage structures. Utilizing micro-level data from the Taiwan Manpower Utilization Survey (TMUS) covering the period between 1982 and 1997, this study investigates the impacts of technology and trade factors on wage differentials across industries. Since the measurement of technological change outside of manufacturing is inherently

5. It may also be difficult to disentangle technology and trade as possible sources because increased competition from international trade, for example, could stimulate more rapid technological change and consequent changes in production processes (Kosters, 1994; Hanson and Harrison, 1995).

6. Chan *et al.* (1999) used aggregate data to study the determinants of wage disparity in Taiwan.

7. Unlike South Korea and Taiwan, Japan did experience a modest increase in wage inequality in the 1980s (Katz *et al.*, 1995).

problematic (Griliches, 1994), the present analysis is restricted to workers within the manufacturing industries. The two measures of technological change used are: (i) the share of research and development (R&D) manpower in the industry; and (ii) growth in total factor productivity (TFP).

The results of this study suggest that a combination of the accelerated growth in the relative supply of college graduates and the steady growth in the demand for more highly educated workers during the period 1982–1997 can largely explain the narrowing wage differentials in Taiwanese manufacturing. On the demand side, technology and trade are identified as the two main potential forces driving the differences in wage inequality across industries.

The remainder of this paper is organized as follows. Section II describes the data and the measures of technological change and trade flows used in the analysis. The changes in overall wage inequality are examined in Section III. Section IV follows with a presentation of the impacts of technological change and trade flows on wage inequality. Conclusions are drawn in Section V.

II. Data and Measurement

The data used in this study are drawn from the TMUS, covering the period 1982–1997. These surveys include demographic and wage information that is consistent over time. All samples are drawn each year randomly, so individuals cannot be tracked longitudinally. Several restrictions are imposed on the data. First, all workers who are employed outside of manufacturing are excluded from the study, because measures of technological change are not available for the non-manufacturing sector. Second, analysis is restricted to workers 18–65 years of age, earning a minimum of NT$20 per hour (in 1991 NT dollars), while excluding employers, self-employed persons, or those working without pay.[8] Third, the data source is further restricted to full-time workers who usually work more than 40 hours per week. The major limitation of this labor force data is that it is not a panel one and does not allow an assessment of the impacts of technology and trade controlling for individual fixed effects.

Throughout, the paper focuses on log hourly wages for full-time workers, deflating monthly earnings by the gross domestic product (GDP) deflator for personal consumption expenditures, while defining the log average hourly wage as the natural logarithm of deflated monthly wage and salary earnings, divided by the product of 4 weeks and usual weekly hours. All wages are converted to 1991 NT dollars. Following the common practice in the literature, senior high-school graduates are identified as unskilled labor, while college graduates (or above) are identified as skilled labor. Unlike most developed countries, since 1968 the compulsory education system in Taiwan has remained at 9 years. Consequently, graduates of junior high schools are also used as an alternative proxy for unskilled labor. The 16 industries are defined with two criteria: (i) adequate

8. The exchange rate in 1991 was US$1 = NT$25.403.

sample size in all periods; and (ii) consistency with industry definitions for other measures of technological change used in the analysis.[9]

There is no direct measure of the rate of technological change faced by individual workers. Therefore, the microdata is linked with two alternative proxies for the rate of technological change within the industry. The two measures of technological change used here are: (i) the share of R&D manpower (RDL); and (ii) TFP growth (TFPG). The former is an input-based measure, while the latter is an output-based measure. These data are reported by two-digit industry in the manufacturing sector. The RDL variable is measured in levels, whereas TFPG measures technological change as the rate of change in output unaccounted for by growth in the quantity and quality of inputs.[10]

As for the measures of trade flows, the three variables used here are: (i) the ratio of exports to sales (EX); (ii) the ratio of imports to sales (IM); and (iii) the ratio of net exports to sales (NEX).[11]

III. Changes in Wage Inequality

The study begins by graphing the overall movements in wage inequality for Taiwan's manufacturing sector. Figure 1 summarizes the movements in wage inequality, by gender, for full-time workers. The figure plots the time series of overall wage inequality as measured by the log-wage differential between the ninetieth and the tenth percentiles of the wage distribution for men and women.[12] The ninetieth–tenth wage differential for males remained stable in the mid-1980s, followed by a substantial decline of 0.11 log points from 1988 to 1993, and then a slight increase from 1994 to 1997. Wage inequality for females expanded rapidly in the 1980s, and then remained fairly stable from 1991 to 1997. There was an overall decline in the log-wage gap between the ninetieth and tenth percentile – from 1.06 in 1982 to 0.97 in 1997 – a narrowing of 0.09 log points for all workers.

How do the changes in relative earnings documented in Fig. 1 translate into changes in real earnings? Fig. 2 attempts to answer this question by plotting the cumulative log real-wage growth of the tenth, fiftieth, and ninetieth percentiles of the wage distribution for all workers. The figure displays the log ratio of each

9. The 16 industrial categories are listed in the first column of Table2. Food and tobacco are combined, because there are insufficient observations of workers within the tobacco industry. Three industries are excluded (rubber, plastic, and miscellaneous), because there are no data for the technology variables.

10. RDL are taken from Taiwan's National Science Council. The series of TFPG are taken from the *Trends in Multifactor Productivity Annual Report* (Directorate General of Budget, Accounting and Statistics, 2000).

11. The data on exports and imports are taken from *Taiwan Monthly Statistics of Exports and Imports* (Ministry of Economic Affairs, 1992–1997, while the sales data are drawn from the *Taiwan Statistics Monthly of Industrial Production* (Ministry of Economic Affairs, 1992–1997).

12. This measure of wage inequality was suggested by Juhn *et al*. (1993).

Figure 1 Taiwan Relative Hourly Wages Changes, 1982–1997

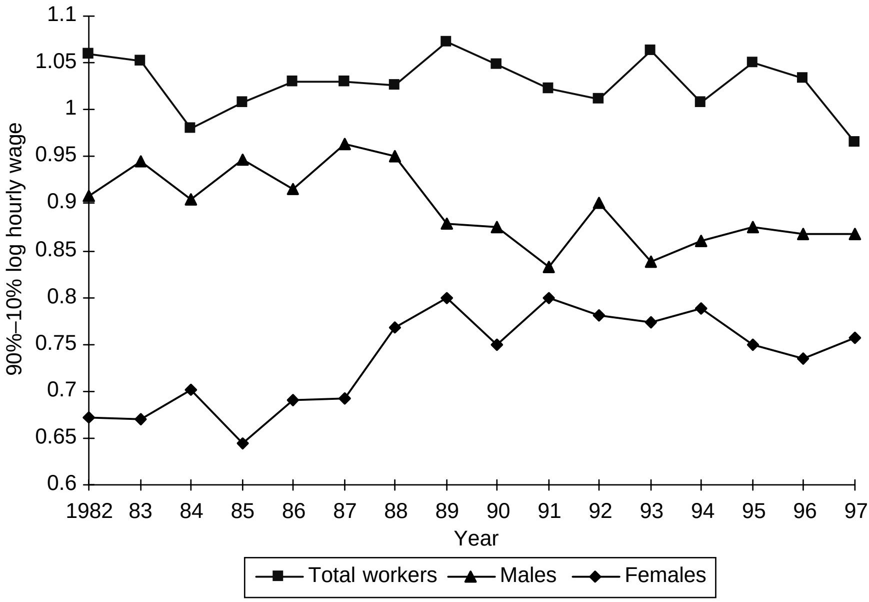


Figure 2 Cumulative Real Wage Growth by Decile

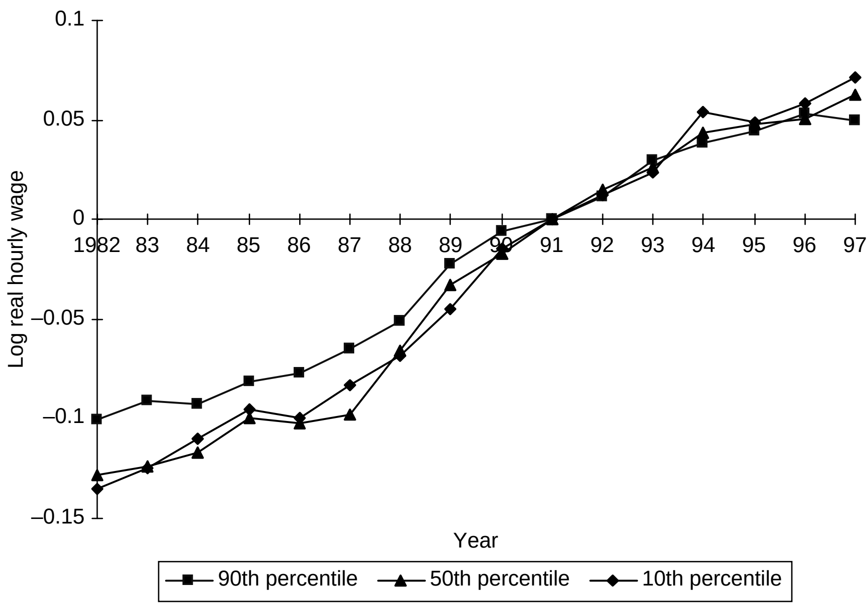
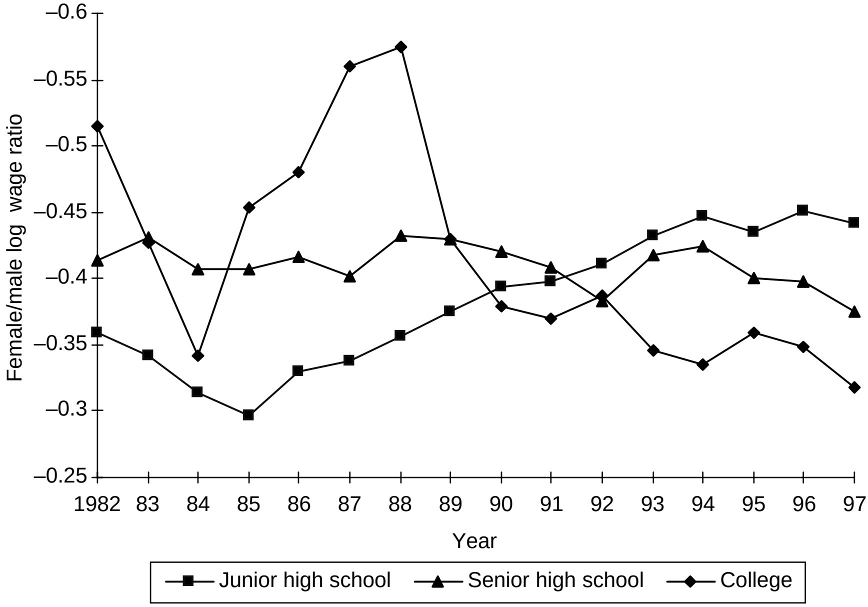


Figure 3 Female/Male Log Wage Ratios



group's real earnings in each year relative to that group's level of real earnings in the base year (1991), which appears to be a turning point for all series. As the figure shows, there was a 0.071 increase in real log earnings from 1991 to 1997 at the tenth percentile, but only a 0.049 increase at the ninetieth percentile in Taiwan's wage distribution.

Figure 3 displays changes in female and male log wage ratios for senior (junior) high school and college graduates. The male–female wage gap narrowed substantially for junior high-school workers from 1982 to 1985, before widening rapidly from 1985 to 1997. In contrast, the figure shows a slight narrowing of the gender earnings gap amongst senior high-school workers. The improvement in relative female earnings in the 1990s was greater among college workers than among high-school workers.

To explore the impacts of technological change and trade flows on wage differentials, a 'two-stage model' is estimated.[13] In the first stage, a standard human capital model is estimated by industry for each year. There are 16 industries and 15 sample years in this estimation. Therefore, a total of 240 wage differentials for college and senior (junior) high-school graduates are obtained.[14] This set of estimated wage differentials is used as a dependent variable to

13. A similar methodology was adopted by Lovely and Richardson (1998) and Bartel and Sicherman (1999).

14. Due to a lack of RDL data for 1982, this year is excluded in this estimation.

examine the relationship between wage differentials and industry measures of technological change and trade flows.

To obtain experience-adjusted wage differentials, the present analysis begins by estimating the simple human capital model for each year. Workers are classified into five groups according to their completed years of schooling: (i) workers with less than a junior high-school education (<9 years); (ii) junior high-school graduates (9 years); (iii) senior high-school graduates (12 years); (iv) workers with some college-level education (13–15 years); and (v) workers with at least a college degree (≥16 years).[15]

The wage regressions are estimated as the following form:

$$\begin{aligned}\ln W_i = \beta_0 + \beta_1 ED1_i + \beta_2 ED2_i + \beta_3 ED3_i + \beta_4 ED4_i + \beta_5 EXPER_i \\ + \beta_6 EXPER_i^2 + \beta_7 AGE_i + \beta_8 MALE_i + \beta_9 MAR_i + \beta_{10} SIZE_i + v_i\end{aligned} \tag{1}$$

where ln W_i is the natural logarithim of the hourly wage for salaried worker i; $ED1_i - ED4_i$ (9 years ($ED1_i$); 12 years ($ED2_i$); 13–15 years ($ED3_i$); and ≥16 years ($ED4_i$)) are four dummy indicators of education level; $EXPER_i$ represents the worker's experience on the current job;[16] $EXPER_i^2$ is the squared $EXPER_i$; AGE_i is the worker's age; $MALE_i$ is a dummy variable equal to 1 if the worker is male; and MAR_i is a dummy variable equal to 1 if the worker is married. The size of the employing firm is included to determine the employer-size wage premium. The term $SIZE_i$ is measured as a dummy variable that is equal to 1 if firms have >100 employees, otherwise 0.[17] Although the complete analysis utilizes information on five education groups, the study focuses primarily on two estimates of the wage gap: (i) the wage differential between college graduates and senior high-school graduates ($W_{sc} = \beta_4 - \beta_2$); and (ii) the wage differential between college graduates and junior high-school graduates ($W_{jc} = \beta_4 - \beta_1$). The complete regression results are shown in Appendix Table A1.[18]

The estimated values of the log-wage differentials between college graduates and senior (junior) high-school graduates over the period of 1982–1997 are reported in Table 1. The first three columns indicate that the earnings premium for senior (junior) high-school workers increased substantially in the 1990s, while the college earnings premium was relatively stable over the same period.[19] The log-wage differentials between college and senior high-school workers ranged from 42% in 1995 to 50.6% in 1987. Similarly, the log-wage differential between college and junior high-school workers ranged from 49.1% in 1994 to

15. The years of education variable were constructed from information on the highest degree achieved according to the standard educational classification of Taiwan.

16. The experience variable is measured as the months of experience on the current job.

17. With the exception of firm size, the Taiwan Manpower Utilization Survey contains little information about a worker's employer or firm.

18. To save space, only the regression results for five survey years are reported in Appendix Table A1.

19. Performing the *F*-tests, the hypothesis of equal coefficients is rejected for ED1, ED2, and ED3 for each year.

Table 1 Changes in Educational Premiums and Wage Differentials Between College Graduates and Senior (Junior) High-School Workers

Year	*(1) Senior high-school workers estimates*	*(2) Junior high-school workers estimates*	*(3) College graduates estimates*	*(4) = (3) − (1) Wage differentials between college and senior high-school workers*	*(5) = (3) − (2) Wage differentials between college and junior high-school workers*	*(6) Sample size*
1982	0.150	0.039	0.600	0.451	0.561	6861
1983	0.161	0.048	0.651	0.490	0.603	6965
1984	0.156	0.074	0.621	0.465	0.547	8141
1985	0.142	0.040	0.610	0.468	0.570	8126
1986	0.165	0.056	0.660	0.495	0.604	8314
1987	0.147	0.052	0.653	0.506	0.601	9125
1988	0.166	0.072	0.602	0.437	0.530	9159
1989	0.149	0.075	0.641	0.492	0.565	8737
1990	0.152	0.077	0.618	0.466	0.541	8021
1991	0.144	0.078	0.584	0.440	0.506	7680
1992	0.187	0.105	0.650	0.462	0.545	7347
1993	0.203	0.110	0.639	0.436	0.529	7251
1994	0.169	0.101	0.591	0.423	0.491	7067
1995	0.195	0.103	0.615	0.420	0.512	7142
1996	0.228	0.142	0.671	0.443	0.529	6407
1997	0.209	0.124	0.637	0.428	0.513	6862

Note: The educational premiums in (1), (2), and (3) are the coefficient estimates from ordinary least squares (OLS) log-wage regressions. Wage differentials are measured by the educational differences between college graduates and senior (junior) high-school workers. Controls include experience, experience squared, age, gender, marital status, and firm size.

60.4% in 1986. Figure 4 plots the time series of wage inequality, as measured by the two indicators of educational wage differentials. As the figure illustrates, there was a narrowing of the disparity between wages for college and senior (junior) high-school workers from 1982 to 1997.

To the extent that workers of varying educational levels are imperfect substitutes in production, relative supplies do exert a negative effect on relative wages. The relative number of employed college graduates (or above) is measured as the relative supply of college graduates in the labor market. Figure 5 shows that the proportion of college graduates in the manufacturing sector doubled in the 1980s, accelerating further between 1992 and 1997. The relative supply of college graduates increased from 2.94% in 1982 to 6.18% in 1997. Therefore, the rapid growth in the relative supply of highly educated workers in the 1990s appears to be an important explanatory factor in declining educational differentials. Because the impact of relative labor supply shifts cannot be investigated across industries, the present study focuses only upon the demand-side factors of wage inequality.

In order to illustrate the differences in inter-industry wage structures, the same approach is used in the estimation of wage differentials by industry for

Figure 4 College/Senior (Junior) High School Log Wage Ratios

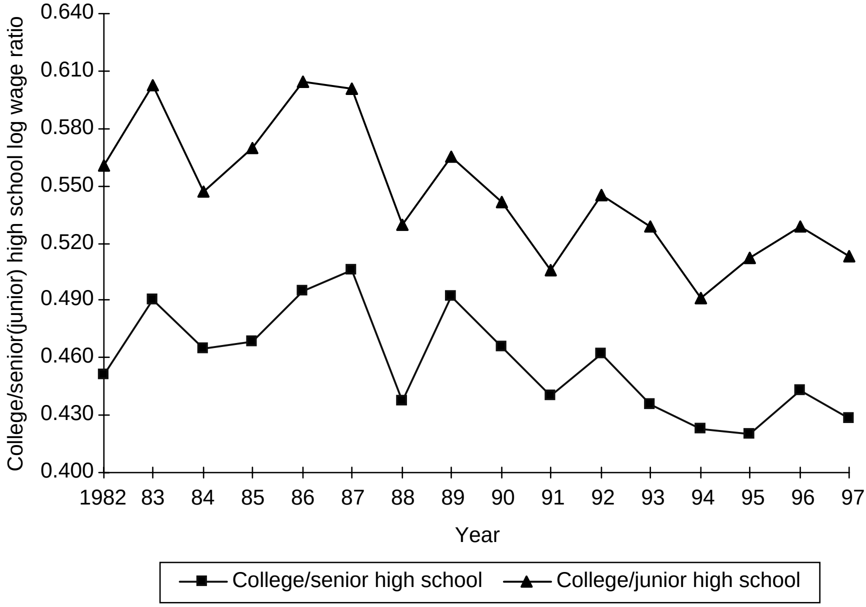


Figure 5 Relative Supply of College Graduates in Employment

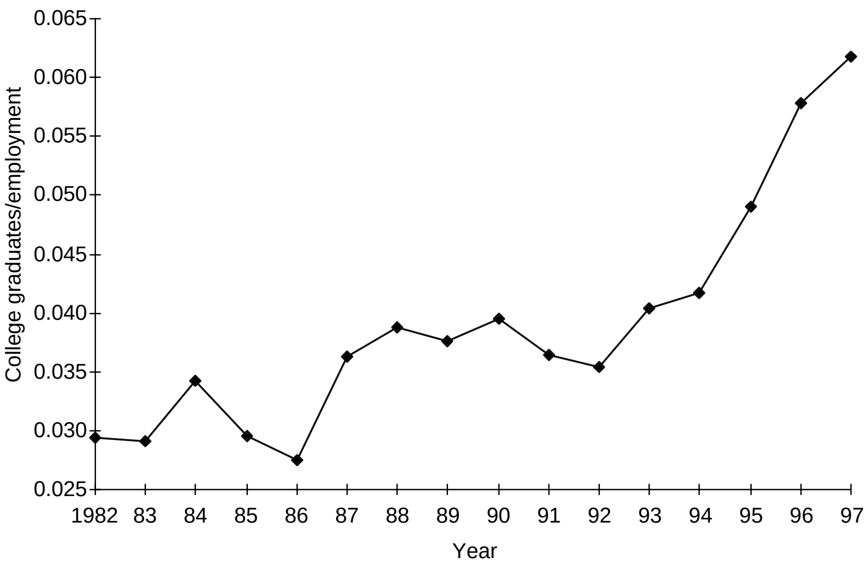


Table 2 Log-Wage Differentials Between College and Senior (Junior) High-School Workers, 1982–1997

Industry	*Log-wage differential between college and senior high school*			*Log-wage differential between college and junior high school*		
	1982	*1997*	*1982–1997*†	*1982*	*1997*	*1982–1997*†
Food and tobacco	0.524	0.514	0.402	0.626	0.656	0.544
Textile	0.427	0.413	0.419	0.511	0.471	0.487
Apparel	0.623	0.507	0.507	0.659	0.601	0.564
Leather	0.060	0.338	0.402	0.172	0.362	0.478
Furniture	0.198	−0.154	0.328	0.351	−0.147	0.425
Paper and printing	0.420	0.357	0.405	0.505	0.409	0.496
Chemical matter	0.591	0.479	0.447	0.635	0.644	0.575
Chemical products	0.271	0.377	0.408	0.367	0.439	0.515
Petroleum	0.631	0.351	0.387	0.797	0.601	0.550
Non-metallic	0.648	0.481	0.538	0.688	0.519	0.586
Basic metal	0.364	0.401	0.399	0.652	0.436	0.539
Fabricated metal	0.515	0.390	0.328	0.604	0.432	0.385
Machinery	0.242	0.291	0.387	0.307	0.351	0.455
Electronics	0.423	0.479	0.506	0.577	0.603	0.608
Transportation	0.239	0.287	0.407	0.402	0.350	0.492
Precision instruments	0.292	0.256	0.518	0.489	0.296	0.605
Mean	0.434	0.365	0.429	0.547	0.443	0.521
Standard deviation	0.178	0.156	0.062	0.166	0.191	0.060

Note: † The average estimate of log-wage differentials between college and senior (junior) high-school workers for the 16 years.

each year. Estimates of the log-wage differentials between workers with college and senior (junior) high-school degrees for each industry are reported in Table 2, which indicates that there are considerable variations in wage inequality across industries.[20] The log-wage differential between college and senior high-school workers in 1982 averaged 43.4%, with a standard deviation of 17.8%. The differential ranged between 6% in the leather industry and 64.8% in the non-metallic industry. In 1997, the log-wage differential within the furniture industry even turned negative. The wage gap fell to 36.5% across all industries in 1997, with a standard deviation of 15.6%. The wage differential between college and senior high-school workers over the period 1982–1997 averaged 42.9%, ranging from 32.8% in the furniture and fabricated metals industries to 53.8% in the non-metallic industry.[21]

The wage gap between college and junior high school is estimated as being even wider. The log-wage differential between college and junior high-school

20. The hypothesis of equal coefficients for ED1, ED2, and ED3 is rejected for most of the regressions.

21. The third (or sixth) column of Table2 reports the average estimates of log-wage differentials between college and senior (or junior) high-school workers for the 16 sample years.

workers averaged 54.7% in 1982 (with a standard deviation of 16.6%), ranging between 17.2% in the leather industry and 79.7% in the petroleum industry. The wage gap narrowed to 44.3% in 1997, with a standard deviation of 19.1%. For the period 1982–1997, the log-wage differential between college and junior high-school workers averaged 52.1%, ranging from 38.5% in the fabricated metals industry to 60.8% in the electronics industry.

To summarize, the analysis in this section shows a slight decline in both wage inequality and educational differentials in Taiwan over the period from 1982 to 1997. During this period, the log-wage differential between the ninetieth and tenth percentile workers narrowed by 0.04 for men, while widening by 0.09 for women. For all workers, the wage gap fell from 1.06 in 1982 to 0.97 in 1997. The narrowing wage disparity was due mainly to the rapid growth in wages among the tenth percentile workers. The reduction in the male–female wage gap in the 1990s was in fact greater among college workers than among senior (junior) high-school workers. There was also a modest fall in the estimated log-wage differential between college and senior (junior) high-school workers, from 0.45 (0.56) in 1982 to 0.43 (0.51) in 1997.

These findings are consistent with the evidence on Taiwan presented by the Chan *et al.* (1999) study using aggregate time series data. Although overall wage inequality fell slightly during this period, the variation in wage differentials between college and high-school workers was more widely dispersed across industries, suggesting that the increase in the relative supply of skilled labor can only partially explain the wage movements, and that factors on the demand side, such as technological change and international trade, should be further investigated.

IV. Technology, Trade, and Wage Inequality

In this section these sets of estimated inter-industry wage differentials are used as dependent variables to further examine the impacts of technological change and trade flows on wage differentials. Consider the following model:

$$Y_{jt} = \gamma_0 + \gamma_1 TC_{jt} + \gamma_2 TF_{jt} + \gamma_3 YEAR_t + \varepsilon_{jt}, \tag{2}$$

where Y_{jt} represents the log-wage differential between college and senior (junior) high-school workers in industry $_j$ at time period $_t$; TC_{jt} represents the industry rate of technological change; TF_{jt} represents the industry trade flows; and $YEAR_t$ are dummies for year. Several alternative measures of technological change and trade flows are utilized in this study. Table 3 reports the summary statistics for the variables used in the regression analysis.[22]

The ratio of R & D to sales in Taiwan's manufacturing sector expanded from 0.56% in 1982, to 1.14% in 1997. The TFPG rate climbed from an average of

22. The correlation matrix for measures of technological change and trade flows shows that no two of the measures are perfectly correlated.

Table 3 Definition of Variables and Summary Statistics

Variables	*Definition of variables*	*Mean (standard deviation)*
Wsc ($= \beta_4 - \beta_2$)	Log-wage differential between college and senior high-school workers	0.429 (0.143)
Wjc ($= \beta_4 - \beta_1$)	Log-wage differential between college and junior high-school workers	0.519 (0.155)
RDL	Share of RDL	0.009 (0.010)
TFPG	Total factor productivity growth	0.016 (0.071)
NEX	Net export ratio (export ratio-import ratio)	0.117 (0.505)
EX	Export ratio	0.428 (0.308)
IM	Import ratio	0.341 (0.309)

1.1% for the period 1978–1986 to an average of 1.7% for the period 1987–1995 (Chan *et al*., 1999). As Johnson (1997) pointed out, technological improvement may be biased towards either skilled or unskilled labor. In the former case, it results in an increase in the relative demand for skilled labor, enlarging the wage disparity between skilled and unskilled labor. In the latter, it causes a rise in the relative demand for unskilled labor, thereby reducing wage disparity. Empirical evidence supports the proposition that skill-biased technological change is a major causal factor in increasing wage inequality (Berndt *et al*., 1992; Berman *et al*., 1994; Allen, 2001).

The effect of net exports on wage disparity depends on the composition of net exports. If a decrease in net exports is due to an increase in unskilled, labor-intensive imports, then it is expected that this will result in a reduction in the relative demand for unskilled labor and therefore cause an increase in wage disparity. The composition of exports and imports changed drastically over the period under examination. The proportion of exported commodities with low-technology intensity fell from 49% in 1982 to 19% in 1997, while the proportion of exports with high-technology intensity increased from 18% in 1982 to 40% in 1997.

In terms of imports, during most of the period Taiwan imported a major fraction of its new machinery, although some was surely produced domestically. The benefit from importing equipment containing new technology is considered as an important source of industrial growth in Taiwan (Pack, 1992).[23] Nevertheless,

23. A lack of comprehensive information on the composition of imports at the industry level, prevents further examination of the contribution of embodied productivity growth coming from the importation of new equipment.

the proportion of low-technology intensity products fell from 21% in 1982 to 13% in 1997, while high-technology intensity imports fell from 62% to 52% during the same period. There was, however, an increase in the proportion of imports with medium-technology intensity, from 17% to 37% over the same period. This evidence suggests that net exports in Taiwan have increasingly become skilled-labor intensive and that the significant increase in exports with high-technological content was accompanied by an increase in the relative demand for skilled labor.

It is now possible to examine how technological change and trade flows have contributed to wage differentials between college and senior (junior) high-school workers. The ordinary least squares (OLS) results are presented in Table 4. As discussed by Dickens and Katz (1987) and Borjas (1987), the dependent variables in the 'second stage' regressions are themselves estimated-regression coefficients. Hence, the disturbances in these regressions are heteroscedastic. Because the exact form of the heteroscedasticity is unknown, the regressions are weighted by the inverse of the standard error of the dependent variable.[24] The first four columns provide the OLS estimates for the college–senior high school wage gap regressions, while the last four columns show the estimates for the college–junior high school wage gap regressions.

The OLS results show a significant positive correlation between the wage gap and the two measures of technological change. The coefficients of NEX and EX are significantly positive, while the coefficient of IM is significantly negative. In the context of an expanded Heckscher–Ohlin framework for Taiwan – where labor is divided into relatively skilled labor and relatively unskilled labor – the implication of the Stolper–Samuelson theorem is that the real incomes of highly skilled workers (who tend to be highly educated) will increase with expanded trade and the real incomes of less-skilled workers (who tend to be less-educated) will decrease. In accordance with the composition of exports and imports described above, the findings of this study are generally consistent with the prediction of the Stopler–Samuelson theorem.

The results of the present study indicate that the log-wage differentials between college and senior high-school workers widened in export-oriented industries and industries characterized by high rates of technological change. Similar results are obtained for the college–junior high school wage gap regressions, although the coefficients of net exports and exports are weakened. These results suggest overall that both technological change and trade flows are responsible for wage movements in Taiwan.

In conclusion, these empirical results advocate that skill-biased technological change plays an important role in explaining the wage differentials between college and high-school workers. Furthermore, international trade is confirmed as another major determinant of wage disparity. The results presented here are largely consistent with evidence on Taiwan presented by Chan *et al.* (1999).

24. Allen (1998).

Table 4 Regressions of Wage Differential on Technological Change and Trade Flows

	College/senior high school				*College/junior high school*			
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
Constant	0.4452	0.4447	0.4104	0.4022	0.5469	0.5640	0.5317	0.5379
	(15.05)***	(14.34)***	(13.54)***	(12.52)***	(17.32)***	(17.11)***	(16.70)***	(15.85)***
RDL	2.9227	2.9198			3.6914	3.7826		
	(6.46)***	(6.40)***			(7.42)***	(7.60)***		
TFPG			0.4281	0.4149			0.4702	0.4803
			(3.35)***	(3.22)***			(3.29)***	(3.33)***
NEX	0.0535		0.0516		0.0231		0.0179	
	(3.18)***		(2.79)***		(1.28)		(0.91)	
EX		0.0542		0.0622		0.0007		0.0101
		(2.59)***		(2.70)***		(0.03)		(0.41)
IM		−0.0525		−0.0370		−0.0541		−0.0290
		(−2.25)**		(−1.40)		(−2.12)**		(−1.01)
$\bar{R}^2$	0.19	0.19	0.08	0.08	0.22	0.22	0.07	0.06

Notes: EX, export ratio; IM, import ratio; NEX, net export ratio; RDL, share of R & D manpower; TFPG, total factor productivity growth.

All regressions include 14-year dummies. There are 240 observations for each regression. The regressions are estimated over a sample of 16 industries and are weighted by the inverse of the standard error of the dependent variable.

Figures in parentheses are t-statistics.

***, **, and * represent statistical significance at 1%, 5%, and 10% level, respectively.

Using aggregate data, they found that both technological change and trade flows are major forces shifting the relative demand in favor of skilled workers.

V. Conclusions

During the period 1982–1997, there was a slight decline in wage differentials between college and high-school workers in Taiwan's manufacturing sector, with the narrowing in overall wage inequality being associated with relatively large increases in real wages for the tenth percentile workers. At the same time, the fall in educational wage differentials was accompanied by a rise in wages for high-school workers. The accelerated growth in the relative supply of college graduates, combined with steady demand growth in favor of more highly educated workers, can largely explain the narrowing wage differentials between college graduates and high-school workers in Taiwanese manufacturing over the period 1982–1997.

This study examines the relationship between technological change, trade flows, and changes in the inter-industry wage structure. Overall, the results suggest a widening of wage differentials between college and high-school workers in industries characterized by higher rates of technological change. There is a positive correlation between the wage gap and two measures of technological change: (i) the share of R & D manpower; and (ii) TFPG. International trade in manufactured goods is also confirmed here as an important source of relative labor-demand shifts. These results conclude that technology and trade may well be the two main forces driving the differences in wage inequality across industries.

Appendix I

Table A1 Estimates of Returns on Schooling

	1982	*1985*	*1990*	*1995*	*1997*
Constant	3.523	3.653	3.983	4.153	4.086
	(255.5)***	(262.57)***	(228.23)***	(202.18)***	(197.66)***
ED1	0.039	0.040	0.077	0.103	0.124
	(4.15)***	(4.42)***	(7.44)***	(8.98)***	(10.76)***
ED2	0.150	0.142	0.152	0.195	0.209
	(16.76)***	(16.21)***	(15.39)***	(17.57)***	(18.83)***
ED3	0.351	0.333	0.355	0.355	0.359
	(21.38)***	(23.74)***	(23.83)***	(24.65)***	(26.32)***
ED4	0.600	0.610	0.618	0.615	0.637
	(29.24)***	(31.76)***	(33.56)***	(33.68)***	(37.95)***
EXPER	0.004	0.004	0.003	0.002	0.002
	(24.51)***	(26.82)***	(19.58)***	(16.43)***	(15.60)***
$EXPER^2$	-5.41×10^{-6}	-5.89×10^{-6}	-4.12×10^{-6}	-3.24×10^{-6}	-2.51×10^{-6}
	(−12.24)***	(−13.91)***	(−8.25)***	(−6.93)***	(−6.43)***

Table A1 Estimates of Returns on Schooling (Cont'd)

	1982	*1985*	*1990*	*1995*	*1997*
AGE	−0.001	−0.001	−0.002	0.001	0.004
	(−1.44)	(−2.71)***	(−3.41)***	(2.29)**	(7.04)***
MALE	0.354	0.340	0.390	0.388	0.352
	(48.08)***	(50.60)***	(54.42)***	(52.43)***	(48.24)***
MAR	0.100	0.110	0.107	0.087	0.071
	(12.16)***	(14.57)***	(13.38)***	(10.34)***	(8.33)***
SIZE	0.022	0.036	0.029	0.024	0.039
	(2.93)***	(5.28)***	(3.88)***	(2.95)***	(5.00)***
$\bar{R}^2$	0.51	0.49	0.49	0.50	0.50
Sample size	6861	8126	8021	7142	6862

Notes: Figures in parentheses are t-statistics.
***, and ** represent statistical significance at 1% and 5% level, respectively.

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