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貿易、技術與工資差距之研究

中文摘要

本研究係利用 1982-1997 年台灣人力運用調查資料，配合製造業產業別的技術指標，來檢視技術對工資差異的影響。實證結果發現，在 1980 年代至 1990 年代期間，台灣製造業受雇員工教育程度在大學以上和高中的工資差距呈現微幅縮小的趨勢。我們觀察供給面因素發現，台灣近年來教育程度在大學以上的員工比例有顯著升高的現象。而在需求面因素方面，則顯示技術進步是解釋產業間工資差距的主因。總要素生產力成長率比較高的產業，其教育程度在大學以上和高中程度的工資差距明顯較大。在研發密集較高、工程師和專門技術人員比例較高，以及專利申請件數較高的產業，受雇員工受教育的報酬也有較高的現象。

關鍵詞：技術、工資結構、工資差距

Technological Change and Wage Structure in Taiwan, 1982-1997

Abstract :

This paper examines the correlation between technological change and changes in the interindustry wage structure. Using micro-level data from the Labor Force Survey in 1992-1997, we find the log wage differential between college and high school graduates remained very stable or even declined slightly during this period. One possible explanation is the rapid increase in the relative supply of college graduates. On the demand-side factors, we find technological change is the main force driving the differences in wage inequality across industries. The log wage differentials between college and high school graduates are higher in industries with high rates of total factor productivity growth. Further, our results show a strong positive correlation between returns to schooling and three out of four of the technological change measures - the ratio of R&D to sales, the employment share of engineers and technicians, and the number of patents applied normalized on employment.

Keyword : technological change, wage structure, wage inequality

Technological Change and Wage Structure in Taiwan, 1982-1997

I. Introduction

During the 1980s, the United States experienced a dramatic increase in wage inequality. The wages of more educated workers increased to those of less educated workers (Katz and Murphy, 1992; Murphy and Welch, 1992; Bound and Johnson, 1992). Similar pattern also prevails in several OECD countries (Freeman and Katz, 1995; Cardoso, 1998; Haskel, 1999). While the increase in educational differentials has been well documented, there is no consensus as to its explanations. The literature has focused on supply-side and demand-side factors, with the latter garnering the majority of the attention.[1] Two main explanations for the rise in demand for skilled labor are the skill-based technological change and the increased openness of the economies.[2]

A number of recent papers using surveys of the labor force indicate that technological change was the major cause of increased dispersion between skilled and unskilled workers. For example, Mincer (1991), Berndt, Morrison, and Rosenblum (1992), Krueger (1993), Berman, Bound and Griliches (1994), and Allen (1998) have found that the introduction of computers and related technologies was biased in favor of skilled workers and thus increased the wage inequality. Further, Dunne and Schmitz (1995) and Doms, Dunne and Troske (1997) use plant-level data to study the wage impacts of technological change and found a positive relationship between wages and technology use.

Several other researchers link the rise in wage inequality to the increasing

[1] Katz and Murphy (1992) and Gosling, Machin and Meghir (1994) found that the relative supply shifts could explain only small fraction of the rise in wage equality in the U.S. and the U.K.

[2] There are also economists arguing that institutional changes such as the decline of unions or the reduction of minimum wages has decreased the wages for low skilled workers and thus contributed to a rise in wage inequality (Gosling and Machin, 1993; Machin and Manning, 1994).

openness of the economies, arguing that competition from low-wage countries has reduced the relative demand for unskilled workers and caused their wages to fall relative to those of skilled workers[3]. However, empirical studies provide mixed evidence. Leamer (1994), Borjas and Ramey (1995), Wood (1995), Bernard and Jensen (1997), and Lovely and Richerson (1998) found that trade plays an important role in explaining wage inequality, whereas Krugman and Lawrence (1993), Lawrence and Slaughter (1993), and Sachs and Shatz (1994) found that trade has only a minor or uncertain effect on wage inequality.

To date, research in this issue in developing countries has received comparatively little attention. Unlike the evidence found in the United States 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 for Mexico over the period 1986-1990. Robins (1994) found a similar pattern in Chile during the 1980s. In contrast, Kim and Topel (1995) and Chan, Chen and Hu (1999) documented a declining wage inequality in Korea and Taiwan respectively since the mid-1970s.[4] Part of the narrowing educational differentials in East Asian countries can be attributed to an increase in the relative supply of college graduates, but the source of this trend in demand remains unexploited.

The purpose of this study is to provide direct evidence on how changes in technology affect the interindustry wage structure. Utilizing micro-level data from the Labor Force Survey in 1982-1997, we study the correlation between returns to schooling/wage differentials and technological change in Taiwan. Currently, employer-employee matched datasets are not available. We therefore use industry-

[3] Feenstra and Hanson (1997) also suggest that outsourcing by Northern multinationals may contribute to a worldwide increase in the relative demand for skilled labor.

level measures of technological change instead. Since the measurement of technological change outside the manufacturing is very problematic (Griliches, 1994), our analysis is restricted to workers in manufacturing. The four measures of technological change we use are the ratio of R&D to sales in the industry, the share of engineers and technicians in industry employment, the number of patents applied normalized on industry employment, and total factor productivity (TFP) growth.

The remainder of the paper is organized as follows: In Section 2, we describe the data and technology measures used in our analysis. The changes of wage structure are examined in Section 3. Section 4 presents the correlation between technological change and wage structure. Conclusions follow in Section 5.

II. Data and Measurement

A. Microdata

The data used in this study are drawn from the Labor Force Surveys for the period 1982-1997. We impose several restrictions on the data. First, we exclude individuals who work outside of manufacturing because good measures of technological change are not available for the nonmanufacturing sector. Second, we restrict to workers between the age of 18 and 65, not employer, self-employed or working without pay, and earn minimum of 20 NT$ per hour in 1991 N.T. dollars. Third, we only keep full-time workers who usually work more than 30 hours per week.

Throughout the paper, we focus on log hourly wages for full-time workers. We deflate monthly earnings by the GDP deflator for personal consumption expenditures and define the log average hourly wage as the natural logarithm of deflated monthly wage and salary earnings divided by the product of four weeks and usual weekly

[4]Chan, Chen and Hu (1999) use aggregate data to study the determinants of wage dispersion in Taiwan.

hours[5]. Industries are defined with two criteria: (1) adequate sample size in all periods and (2) consistency with industry definitions used for other measures of technological change.

B. Measures of Technological Change

Since we do not have a direct measure of the rate of technological change faced by the individual in his or her place of work, we link the microdata with several alternative proxies for the rate of technological change in the industry in which the individual works. As no single proxy is perfect, it is important to use several alternative measures in the analysis.

The four measures of technological change that we use are (1) the ratio of R&D expenditures to sales (RD); (2) the employment share of engineers and technicians (SKR); (3) the number of patents applied normalized by employment (PATL); and (4) TFP growth (TFPG). Briefly, our proxies can be divided into two categories: the first two proxies are input-based measures and the latter two are output-based measures. The TFP growth measures technological change as the rate of change in output that is not accounted for by the growth in the quantity and quality of inputs.

The correlation matrix for these measures of technological change is presented in Appendix A (Table A1). It shows that no two of our proxies are significantly correlated. Therefore, there is no redundancy in using all of them in our analysis.

Ⅲ. Changes in Wage Structure

To obtain experience-adjusted returns of schooling, we estimate the following regression model:

$$\ln W_{it} = \alpha_0 + \alpha_1 ED_{it} + \alpha_2 EXPER_{it} + \alpha_3 EXPER_{it}^2 + \alpha_4 AGE_{it} + \alpha_5 MALE_{it} + \alpha_6 MAR_{it} + \alpha_7 SIZE_{it} + u_{it} \quad (1)$$

[5] All wages are converted to 1991 N.T. dollars.

where $\ln W_{it}$ is the natural logarithim of the hourly wage for salaried worker i in year t, ED_{it} is the years of schooling completed, $EXPER_{it}$ represents the worker's experience on the current job[6], $EXPER_{it}^2$ is the squared $EXPER_{it}$, AGE_{it} is the worker's age, $MALE_{it}$ is a dummy variable indicating the worker's gender, MAR_{it} is a dummy variable indicating the worker's marital status. The size of the employing firm is included to capture the employer-size wage premium. $SIZE_{it}$ is measured as a dummy variable which equals 1 if firms with more than 100 employees and 0 otherwise.[7] Under this specification, the coefficient of ED_{it} (α_1) is the estimated returns of schooling.

In another specification, ED_{it} is replaced by four binary indicators of education level (less than 12 years (ED0), 12 years (ED1), 13 to 15 years (ED2), and 16 or more years (ED3)) to obtain direct estimate of wage gaps among workers with varying education levels[8]. The regression takes the following form:

$$\begin{aligned}\ln W_{it} = \beta_0 + \beta_1 ED1_{it} + \beta_2 ED2_{it} + \beta_3 ED3_{it} + \beta_4 EXPER_{it} + \beta_5 EXPER_{it}^2 \\ + \beta_6 AGE_{it} + \beta_7 MALE_{it} + \beta_8 MAR_{it} + \beta_9 SIZE_{it} + v_{it}\end{aligned} \tag{2}$$

We focus primarily on the wage differential between college graduates and high school graduates ($W_{hc} = \beta_3 - \beta_1$).

The estimated values of the returns to schooling and log wage differentials between college graduates and high school graduates are reported in Table 1. The return of schooling ranges from 3.3 percent in 1985 to 4.6 percent in 1996. The log wage differential between college and high school graduates ranges from 42.7 percent in 1994 and 1995 to 50.9 percent in 1987. Figure 1 plots the time series of wage

[6] The experience variable is measured as the months of experience on the current job.
[7] With the exception of firm size, the Labor Force Survey contains little information about a worker's employer or firm level data.
[8] Using the worker's completed years of schooling, we categorize workers into four groups: (1) workers with less than a high school education (less than 12 years); (2) high school graduates (12 years); (3) workers with some college (13 to 15 years); and (4) workers with at least a colllege degree (16 or more years).

inequality as measured by the educational wage differentials. As the figure illustrates, wage inequality remained very stable or even declined slightly from 1982 to 1997.

To the extent that workers in different educational level are imperfect substitutes in production, relative supplies exert a negative effect on relative wages. Relative number of all college graduates in the employment is measured as the relative supply of college graduates in the labor market. Figure 2 shows that the relative supply of college graduates just about doubled between the early 1980s and mid 1990s, and accelerated between 1994-1997. These changes are consistent with the changes in the wage differentials between college and high school graduates.

In order to illustrate the differences in interindustry wage structure, we follow the same approach to estimate the returns of schooling and wage differentials by industry. Estimates of the returns to schooling and the log wage differentials between workers with college and high school degrees for each industry are reported in Table 2. The 16 two-digit manufacturing industries are classified in our analysis.[9] There is considerable variations in the wage structure across industries. The rate of return to schooling in 1982 averaged 3.5 percent, with a standard deviation of 1.5 percent. It ranges between 1.7 percent in Furniture industry and 8.1 percent in Petroleum industry. Returns to schooling increased to 3.9 percent across all industries in 1997, with a standard deviation of 1.6 percent and a range between 0 percent in Furniture industry and 6.4 percent in Electronics industry. For the period of 1982-1997, returns to schooling averaged 3.8 percent and ranges from 1.9 in Furniture industry to 5.7 percent in Petroleum industry.

Estimates of the wage gap are even more dispersed. The log wage differential between college and high school graduates averaged 43.7 percent in 1982, with a

[9] Food and tobacco are combined because there are insufficient observations of workers in the tabacco industry. Three industries are excluded (rubber, plastic, and miscellaneous) because there are no data

standard deviation of 17.9 percent and a range between 6 percent in Leather industry and 64.9 percent in Petroleum industry. The wage gap decreased to 36.6 percent in 1997, with a standard deviation of 15.8 percent. In Furniture industry, the log wage differential even turned to be negative. For the period of 1982-1997, the log wage differential between college and high school graduates averaged 43.4 percent. It ranges from 33.1 percent in Furniture industry to 54.3 percent in Non-Metallic industry.

Taken together, the analysis in this section shows that the wage dispersion between college graduates and high school graduates have remained stable or even slightly declined during the past 15 years. This result is consistent with the evidence found in Taiwan by Chan, Chen and Hu (1999). Nevertheless, there is considerable dispersion in the interindustry wage structure. The variation in wage differentials between college and high school graduates is more widely dispersed relative to returns of schooling across industries. This suggests that the increase in the relative supply of skilled labor may only explain some of the wage movements and factors on the demand side, such as technological change and international trade should be further investigated.

IV. Technological Change and Wage Structure

In this section, we use these sets of estimated premium as dependent variables and examine the relationship between returns to schooling/wage differentials and technological change. Consider the following model:

$$Y_{jt} = \gamma_0 + \gamma_1 TC_{jt} + \varepsilon_{jt} \qquad (3)$$

where Y_{jt} is the returns to schooling or the log wage differentials between college and high school graduates in industry j at time period t, and TC_{jt} represents the industry

for two of the technology variables.

rate of technological change. Several alternative measures of technological change are utilized in our study. In order to examine the relative importance of technological change and trade flows on wage inequality, we also include measures of trade flows in wage gap regressions. The three measures of trade flows we use are export ratio (EX_{jt}), import ratio (IM_{jt}), and net export ratio (NEX_{jt}). Table 3 reports summary statistics for the variables used in the regression analysis.

To account for unobserved heterogeneity among industries, both random effects and fixed effects are estimated in our analysis. The former assumes that industry-specific factors are uncorrelated with the regressors. In contrast, the latter allows for such a correlation. For selecting an appropriate specification, the procedure suggested by Hausman (1978) can be used to test the hypothesis of no correlation.

Table 4 and Table 5 reports regressions of returns to schooling, and the college-high school wage gap on technological change and trade flows variables. The regressions are weighted by the inverse of the standard error of the dependent variable. Both tables report the results estimated using fixed effects or random effects model. In most cases, the Hausman statistics show that the fixed effects model is a more appropriate specification for the regressions of returns to schooling and the log wage differential between college and high school graduates.

The main findings in Table 4 is the existence of a significant correlation between returns to schooling and three out of four of the technological change measures. With the exception of TFP growth, R&D intensity, employment share of engineers and technicians, and the number of patents applied (normalized on employment) are all significantly and positively associated with returns of schooling. Consider two industries, one with virtually no employment of engineers and technicians and another with 10 percent of the workers are engineers and technicians. The rate of returns to schooling is 1.2 percent greater in the latter industry than the former. Our findings

suggest the strong correlation between industrys' premiums and the industrys' rates of technological change.[10]

In Table 5, we find that the log wage differentials between college and high school graduates are higher in industries with high TFP growth. However, there is only a weak relationship between the other three indicators of technological change. The coefficients of R&D intensity, employment share of engineers and technicians, and the number of patents applied (normalized on employment) are all insignificantly positive and negative. In the last two columns of Table 5, the inclusion of trade flows measures does not change the main result. We find trade flows is uncorrelated with the college-high school wage gap.

To summarize, our results are consistent with skill-biased technological change playing a dominant role in explaining the wage differentials between college and high school graduates. When we distinguish those measures of technological change that are input-based (ratios of R&D to sales and employment share of engineers and technicians) from those that are output-based (the number of patents applied normalized by employment and TFP growth), we find that the former have a stronger relationship with returns to schooling, whereas the latter tend to have a stronger relationship with the college-high school wage gap.

The results presented here are somewhat at odds with evidence found by Chan, Chen and Hu (1999) for Taiwan. They use an aggregate data and found that both technological change and trade flows are responsible for the narrowing wage dispersion. In contrast, we find trade has only a small effect on wage inequality.

[10] One possible explanation for the positive correlation between returns to schooling and rates of technological change is that workers in industries with higher rates of technological change are more able. Bartel and Sicherman (1999) found there is no correlation between industrys' premiums and the industrys' rates of technological change, when all observed and unobserved individual characteristics are held constant. Due to lack of individuals' panel data, we can not investigate the role of unobserved individual characteristics directly.

V. Conclusions

During the period of 1982-1997, the wage differential between college and high school graduates remained very stable or even slightly declined in Taiwan. Part of the narrowing wage inequality can be attributed to an increase in the relative supply of college graduates, but the source of this trend in demand remains largely unexploited. This paper examines the correlation between technological change and changes in the interindustry wage structure.

The results show a strong positive correlation between returns to schooling and three out of four of the technological change measures – the ratio of R&D to sales, the employment share of engineers and technicians, and the number of patents applied normalized on employment. Furthermore, we find the log wage differentials between college and high school graduates are higher in industries with high rates of TFP growth. Overall, our results suggest that returns of schooling and the college-high school graduates wage differentials increase in industries characterized by higher rates of technological change. This finding suggests that skill-biased technological change is the main force driving the differences in wage inequality across industries.

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Figure 1 Wage Differentials between College and High School Graduates

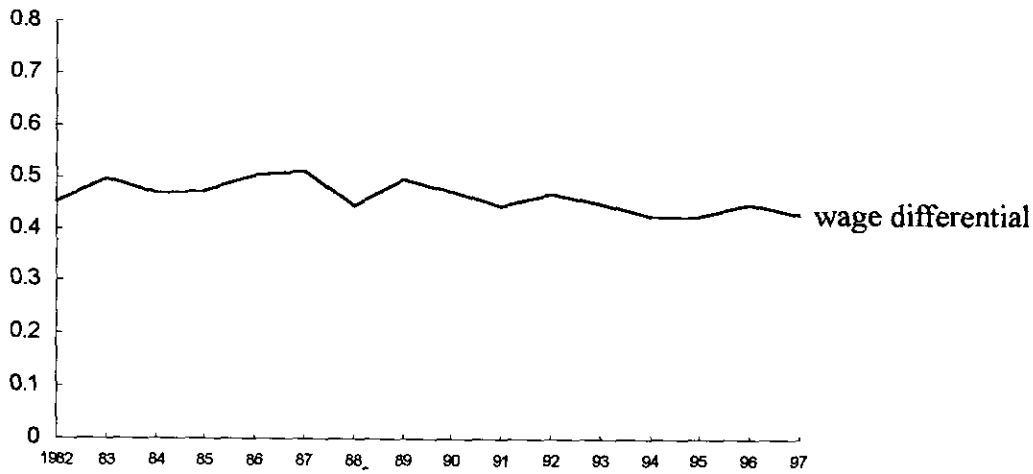

Figure 2 Relative Supply of College Graduates in Employment

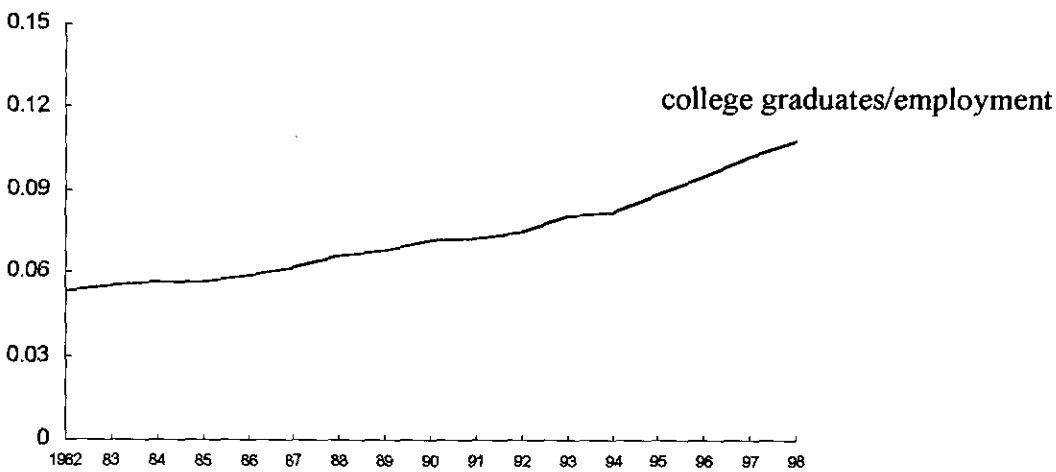

Table 1 Changes in Returns of Schooling and Wage Differentials

	(1) Returns of Schooling	(2) High School Graduates	(3) College Gradates	(3)-(2) Wage Differentials
1982	0.034	0.132	0.580	0.448
1983	0.037	0.140	0.634	0.493
1984	0.035	0.120	0.589	0.469
1985	0.033	0.122	0.592	0.470
1986	0.036	0.132	0.633	0.501
1987	0.037	0.119	0.628	0.509
1988	0.038	0.126	0.570	0.443
1989	0.038	0.107	0.602	0.494
1990	0.038	0.108	0.579	0.471
1991	0.039	0.101	0.545	0.444
1992	0.042	0.126	0.594	0.468
1993	0.043	0.135	0.583	0.448
1994	0.038	0.107	0.534	0.427
1995	0.043	0.133	0.560	0.427
1996	0.046	0.140	0.590	0.450
1997	0.045	0.131	0.560	0.429

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

Table 2 Returns to Schooling and Log Wage Differentials between College and High School Graduates, 1982-1997

Industry	Returns to schooling			Log wage gap between college and high school		
	1982	1997	1982-1997	1982	1997	1982-1997
Food and Tobacco	0.045	0.055	0.050	0.524	0.523	0.410
Textile	0.032	0.031	0.032	0.429	0.415	0.424
Apparel	0.022	0.037	0.025	0.640	0.499	0.522
Leather	0.020	0.024	0.030	0.060	0.387	0.396
Furniture	0.017	0.000	0.019	0.203	-0.170	0.331
Paper and Printing	0.030	0.053	0.039	0.415	0.384	0.413
Chemical Matter	0.052	0.060	0.056	0.590	0.480	0.451
Chemical Products	0.055	0.048	0.054	0.302	0.376	0.414
Petroleum	0.081	0.048	0.057	0.649	0.347	0.391
Non-Metallic	0.032	0.025	0.029	0.647	0.408	0.543
Basic Metal	0.038	0.035	0.042	0.357	0.440	0.405
Fabricated Metal	0.012	0.021	0.021	0.510	0.401	0.332
Machinery	0.027	0.035	0.033	0.247	0.289	0.389
Electronics	0.040	0.064	0.052	0.412	0.478	0.509
Transportation	0.031	0.033	0.036	0.230	0.291	0.409
Precision Instruments	0.034	0.046	0.042	0.295	0.251	0.522
Mean	0.035	0.039	0.038	0.437	0.366	0.434
Standard deviation	0.015	0.016	0.012	0.179	0.158	0.063

Table 3 Definition of Variables and Summary Statistics

Variables	Definition of Variables	Mean (Standard Deviation)
α_1	Returns to schooling	0.038 (0.015)
W_{hc} $(=\beta_3-\beta_1)$	Log wage differential between college and high school graduates	0.429 (0.143)
RD	R&D expenditures/sales	0.006 (0.005)
SKR	Engineers and technicians/employment	0.076 (0.034)
TFPG	Total factor productivity growth	0.016 (0.071)
PATL	Patents applied/employment	0.010 (0.014)
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)

Table 4 Regressions of Returns to Schooling on Technological Change

	(1)	(2)	(3)	(4)
Constant		0.0293 (11.06)***		
RD	0.3097 (2.84)***			
SKR		0.1157 (5.97)***		
TFPG			0.0001 (0.02)	
PATL				0.5099 (2.64)***

Note: Regressions (1), (3), and (4) are estimated using a fixed effects model. Regression (2) is estimated using a random effects model. All regressions are weighted by the inverse of the standard error of the dependent variable. Figures in parentheses are t-statistics. *** represent statistical significance at 1% level.

Table 5 Regressions of Wage Differential on Technological Change and Trade Flows

	(1)	(2)	(3)	(4)	(5)	(6)
Constant				0.1842 (23.93)***		
RD	-0.4513 (-0.35)					
SKR		-0.2999 (-1.13)				
TFPG			0.2070 (2.02)**		0.2007 (1.96)**	0.1942 (1.89)*
PATL				0.4243 (0.18)		
NEX					0.0558 (1.04)	
EX						0.0021 (0.03)
IM						-0.1163 (-1.62)

Note: Regressions (1), (2), (3), (5) and (6) are estimated using a fixed effects model. Regression (4) is estimated using a random effects model. All regressions 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.

Appendix A

Table A1 Correlation between the Different Measures of Technological Change

	RD	SKR	PATL	TFPG
RD	1.000	0.498	0.368	0.121
SKR			0.153	-0.022
PATL				-0.028
TFPG				1.000

END