Essays on the Labor Market Transitions in Taiwan

by

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To my family, who gave me their warmest support and encouragement throughout this long journey.

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ABSTRACT

Essays on the Labor Market Transitions in Taiwan

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This dissertation consists of three chapters. The first chapter studies how the expansion in post-secondary education in 1990-2000 affected the university wage premium in Taiwan. We find that the university wage premium does not seem to plummet, which implies the relative demand for university-educated workers must have increased dramatically, absorbing almost entirely the increase in relative supply. Our calculations show that the change in industrial and occupational structures explains about 20-40% of the increase in demand, while changes in the average quality of university graduates due to this expansion have little explanatory power.

The second chapter studies how trade and outsourcing affect the demand for skilled labor in Taiwan between 1981 and 2011. We incorporate a global input-output system to construct a better measure of the factor content of trade, which includes the effect of outsourcing through trade in intermediate inputs. Since we have separate input-output tables for domestically produced and imported intermediate inputs, our global input-output system does not rely on the proportionality assumption. However, despite constructing the factor content of trade with care, our results still suggest that trade and outsourcing affect little the relative demand for skilled labor. We then

explain that our results might be an underestimate: The coordination of outsourcing activities is often carried out by non-production workers, who tend to be skilled workers, but this effect is either inaccurately accounted for or excluded totally from our data.

The third chapter studies how the effect of family socio-economic status (SES) on post-secondary education attainment changed during the expansion in post-secondary education in Taiwan, and we formulate a model which separates the distribution of educational attainment, which is determined by admission quotas, and the allocation of education among people with different levels of SES, which holds fixed admission quotas and is determined by factors such as admissions process and the optimization behavior of individuals. Our point estimates suggest an increase in the effect of SES on advancing to post-secondary education, but the standard errors are very large, making the increase statistically insignificant.

CHAPTER I

The Impact of the Expansion in Post-Secondary Education on the University Wage Premium in Taiwan

1.1 Introduction

The opportunity of accessing post-secondary education used to be limited in Taiwan, but in the 1990s, the Taiwanese government started to increase the number of universities and university admissions. As a result, the number of baccalaureate recipients increased by over five times from 1990 to the 2000s (Figure 1.1), and a cross-country comparison on the population share of completing post-secondary education by age group in 2011 further indicates that this expansion is both large and fast (Table 1.1).[1] With regard to the supply of university-educated workers in Taiwan, the employment share, measured as the percentage shares of total weekly working hours, increased from about 5% before 1980 to about 20% in 2011 (Figure 1.2), and for workers with 0-4 years of potential experience, which roughly corresponds to the number of years for which workers have left school, it increased from about 5% before

[1] Table 1.1 includes people completing university education and above for Taiwan and people completing type A or advanced research programs for other countries. When we add junior colleges for Taiwan and type B tertiary education for other countries, the magnitude of the increase is still the largest for Taiwan.

1980 to more than 50% in 2011 (Figure 1.3).

One might think that the huge influx of workers with post-secondary education would make the university wage premium to fall dramatically, but the data does not seem to suggest so. Figure 1.4 plots the university wage premium, which is measured as the difference of the mean log hourly wage between workers with and without university education, after controlling for workers' demographic characteristics. As can be seen, the university wage premium does not seem to plummet. Figure 1.5 plots the university wage premium by workers' years of potential experience, and it shows that, from 1978 to 2011, the university wage premium decreased by around 15% for workers with 0-9 years of potential experience, and increased by around 10%-20% for the rest of the workers. Nevertheless, even for the least experienced workers, the university wage premium still remains high, or around 0.6, which is similar to the value in the U.S. in 2005 as reported by Goldin and Katz (2008).

The purpose of this paper is to explain the observed patterns in the relative supply and relative wage of university-educated workers as described above. We apply a supply-demand framework, and we allow less- and more-experienced workers to be imperfect substitutes in our model because the patterns of the university wage premium are different for less- and more-experienced workers. Since the number of university admission in Taiwan is highly regulated by the government, and the number of students willing to pursue post-secondary education tends to greatly exceed the number of admissions, we can view the increase in the relative supply of university-educated workers in Taiwan as exogenous. We use this model to infer the shifts in the relative demand for university-educated workers, and then quantify the extent to which several factors explain these inferred demand shifts. We also document the change in the system of post-secondary education and the composition of the student body due to the expansion, point out how this might affect the relative quality of university-educated workers, and then assess the extent to which this affects our results as robustness checks.

With regard to the literature, this paper relates to earlier studies on the development of Taiwan and Korea, such as Gindling and Sun (2002), Lin and Orazem (2003), and Lu (1993) on Taiwan, and Choi (1996) and Kim and Topel (1995) on Korea. We also provide an interesting comparison to the research using the U.S. data. Freeman (1976) studied the drop in the earnings of college graduates relative to the earnings of non-college graduates during the late 1960s and early 1970s. He concluded that this drop was mainly due to the relative increase in the number of college graduates and therefore Americans were "over-educated." However, in the 1980s, the relative earnings of college graduates in the US started to increase. Both Katz and Murphy (1992) and Card and Lemieux (2001) used a supply-demand framework to explain the decrease and then the increase of college graduates' relative earnings in the last 30 to 40 years. Bound and Johnson (1992) studied the extent to which various factors, including changes in the relative supply of college graduates, product demand, institutions, and technology, are responsible for the increase in the relative earnings of college graduates in the 1980s, and they found that the primary cause was the growth in the skill-biased technology. Goldin and Katz (2008) used the term "the race between education and technology" to describe the counterbalance between the relative supply and demand for college-educated workers. They found that during the period of 1915 to 2005, "education raced far ahead of technology" before 1980, so the college wage premium trended down, but later, "education lost the race to technology," so the college wage premium started to trend up and eventually reached back to the 1915 level during the late 2000s.

Using the terminology of Goldin and Katz (2008), our results suggest that, in contrast to the situation in the US, education and technology in Taiwan so far have reached a tie in the race: Both the relative supply and the relative demand for workers with post-secondary education have increased dramatically, and the increase in relative demand has almost entirely absorbed the increase in relative supply. The change in the industrial and occupational compositions in the labor market seems to favor university-educated workers over time, and it explains about one-third of the increase in the relative demand for university-educated workers. The results are similar after controlling for possible changes in the quality of labor force due to the expansion.

The rest of the paper is organized as follows. Section 1.2 describes the current educational system and the expansion in post-secondary education during the 1990s in Taiwan. Section 1.3 calculates the change in the relative demand for university-educated workers inferred from the changes in the relative supply and relative wage of university-educated workers, taking into account the elasticity of substitution among workers with different levels of education attainment and potential experience. Section 1.4 quantifies how the changes in industrial and occupational compositions in the labor market affect the relative demand for university-educated workers, and compares this relative demand measure with the relative demand measure generated in Section 1.3. Section 1.5 investigates the extent to which changes in the relative quality of university-educated workers affect the university wage premium. Lastly, Section 1.6 concludes and provides directions for future research.

1.2 Educational System, Expansion in Post-Secondary Education, and the Supply of University Graduates in Taiwan

1.2.1 The Current Educational System in Taiwan

Figure 1.6 illustrates the current educational system in Taiwan. The compulsory education in Taiwan takes nine years, with six years of education in elementary school and three years in junior high school. After graduating from junior high school, if students want to receive more education, they typically have to take entrance examinations to advance to a higher level of schooling. With the test scores of entrance examinations, a junior high school graduate can choose to attend senior high school, which is generally for academically-oriented students who plan to pursue post-secondary education; or a vocational senior high school or five-year junior college, which are typically for more vocationally-oriented students. Most of the students in vocational senior high schools and five-year junior colleges used to enter the labor market after graduation, but many of them now pursue post-secondary education as well.

Senior high schools and vocational senior high schools take three years, while five-year junior colleges take five years, with the first three years considered to be equivalent to vocational senior high schools. In terms of degrees awarded, senior high schools and vocational senior high schools award diplomas, while junior colleges award associate degrees, which are higher than diplomas.[2] In addition, senior high school and vocational senior high school graduates can attend two-year junior colleges (for those who graduated from senior high schools before the 1990s, there were three-year junior colleges), and they are also awarded associate degrees after finishing two-year colleges.

With regard to post-secondary education, universities and four-year colleges are mostly for academically-oriented students, and both confer bachelor degrees. Four-year colleges can be viewed as universities with fewer faculties (or disciplines and specialities). Since these institutions typically accept senior high school graduates, their joint entrance examinations focus more on academic subjects, such as Chinese, English, mathematics, history, geography, physics, chemistry, and biology. Note that *four-year colleges* are different from *junior colleges* because the former award bachelor

[2] Junior college graduates were awarded diplomas as well until 2004 when associate degree was introduced in Taiwan. However, be it junior college diploma or associate degree, both of them are still higher than senior and vocational senior high school diplomas, and employers still see them as certificates of graduation from junior colleges.

degrees, while the latter award associate degrees.

As to the post-secondary education for vocationally-oriented students, universities of technology and institutes of technology award bachelor degrees as well. Analogously, the latter can also be viewed as "smaller" universities of technology offering fewer disciplines of training. The joint entrance examinations of these institutions thus emphasize less on the academic material and more on vocational knowledge. Depending on their career objectives, students can choose to take exams in various subjects, including electronics, machinery, interior design, restaurant management, business administration, data processing, child care, tourism, home economics, and applied foreign languages.

Regardless of academic or vocational post-secondary institutions, students in Taiwan rank their preference of departments in different institutions before or after the joint entrance examinations. Then, whether they will be able to enter college, as well as which school and which *department* they will enter, are based on their scores of these examinations. Therefore, unlike the colleges in the US, in Taiwan, students' majors have been determined by the time they enter colleges.

Due to the variety of post-secondary institutions in Taiwan, throughout our paper, we will use the terms "college" and "university" interchangeably to indicate the post-secondary institutions awarding bachelor degrees (university, four-year college, university of technology, and institution of technology). In contrast, when we specify "junior college," we are referring to institutions that award associate degrees.

1.2.2 The Expansion in Post-Secondary Education in the 1990s

The vast number and the wide variety of the post-secondary educational institutions in Taiwan today did not exist until the 1990s. Before the 1990s, there was almost no institutes of technology or universities of technology, and the number of universities and four-year colleges was limited. Then, in the 1990s, in response to the public reaction to the limited opportunity to access post-secondary education, the government decided to implement a series of educational reforms, in which more spots in the post-secondary education were created. Figure 1.7 illustrates the number of post-secondary institutions from 1978 to 2010. As can be seen, the changes in the number of post-secondary institutions can be roughly divided into four periods:

- Before around 1990, the number of universities and four-year colleges was kept small, and there were almost no post-secondary institutions for students in the vocational path;
- Around 1990-1995, the number of universities and four-year colleges started to increase modestly;
- Around 1995-2000, the number of universities of technology and institutes of technology started to increase dramatically;
- In the 2000s, the number of post-secondary institutions plateaued, and vocational institutions accounted for half of the post-secondary institutions.

Comparing the first and the fourth period, we can see that after the expansion in post-secondary education in the 1990s, the number of post-secondary institutions has increased from around 20 in 1978 to more than 150 in 2010, and the structure of post-secondary institutions has shifted from mainly academic to half academic and half vocational. The proportion of baccalaureate recipients by type of post-secondary institution also reveals similar patterns. As can be seen in Figure 1.8, the proportion of the baccalaureate recipients who graduated from the institutions in the vocational path has increased dramatically since the mid-1990s and reached about 50% in the 2000s.[3]

[3] The website of the Ministry of Education has information on the number of graduates from each program in each college. Thus, from the types of colleges and the programs they offer, we can roughly categorize college graduates as being from the academic path or the vocational path. In Figure 1.8, all the normal universities and normal four-year colleges are categorized as "academic." All the

Because creating spots by building new schools is more costly, throughout the whole process of the educational reform, the government utilized existing facilities as much as possible. This utilization was done in two ways. Firstly, the government upgraded some junior colleges to four-year colleges or institutes of technology, which would later be upgraded to universities or universities of technology. Secondly, the government started to encourage and allow more private institutions to be established. Therefore, as seen in Table 1.2, the number of junior colleges drops over time, and the proportion of private post-secondary institutions has increased from around half to two-thirds.

Since the number and the admissions of *both public and private schools*, as well as other aspects of education, are highly regulated by the Ministry of Education in Taiwan, and the number of students who desire to receive post-secondary education has been far exceeding the number of spots available, when the number of universities and university admissions increase, the proportion of students entering university increases dramatically as well. Figure 1.9 shows transition rates—the proportion of junior high school, senior high school, and vocational senior high school graduates advancing to the next educational level—, which are calculated as the number of graduates who advance to the next educational level in the next academic year divided by the total number of graduates in the previous academic year.[4] As can be seen,

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universities and four-year colleges, except two-year programs in universities and four-year colleges (mostly for junior college graduates pursuing bachelor degrees), are categorized as "academic." All the institutes of technology, universities of technology, and the two-year programs in the universities and four-year colleges are categorized as "vocational."

[4] Transition rates are calculated as follows:

Transition rate of junior high school graduates =
(Number of first-year students in senior high schools, vocational senior high schools, and five-year junior colleges who graduated from junior high school in the previous academic year) ÷ (Number of junior high school graduates in the previous academic year) × 100%;

Transition rate of senior high school graduates =
(Number of first-year students in universities, two-year junior colleges, and three-year junior colleges who graduated from senior high schools in the previous academic year) ÷
(Number of senior high school graduates in the previous academic year) × 100%;

before the 1990s, the transition rate of senior high school graduates was about 40%, and the transition rate of vocational senior high school graduates was close to 0%. Then, since 1990, the transition rates of senior high school and vocational senior high school graduates have been increasing dramatically. By 2009, the transition rate of senior high school graduates increased to about 95%, and the transition rate of vocational senior high school graduates increased to about 75%.

To sum up, since the educational reform in the 1990s, the numbers of post-secondary institutions and university graduates have been increasing dramatically, and these increases are mainly driven by the increase in private vocational post-secondary institutions. In addition, because education in Taiwan is highly regulated, these increases can be considered as mainly due to the changes in the educational policy, rather than the increase in students' demand for post-secondary education, which is more likely to be affected by the labor demand for university graduates. Therefore, to investigate the effect of the expansion in post-secondary education on the labor market in Taiwan, we can treat the increase in the number of university graduates as an exogenous shift in labor supply.

1.3 Labor Supply, Labor Demand, and Wages

1.3.1 Basic Specifications: Elasticity of Substitution by Workers' Education and Potential Experience

We use the model presented by Card and Lemieux (2001) to analyze how the labor supply and demand shifts affect the university wage premium. Assume that the production function of aggregate output in year t, y_t, follows a CES (Constant

Transition rate of vocational senior high school graduates =
(Number of first-year students in universities, two-year junior colleges, and three-year junior college who graduated from vocational senior high school in the previous academic year) $\div$
(Number of vocational senior high school graduates in the previous academic year) $\times$ 100%.

Elasticity of Substitution) form:

$$y_t = (\theta_{ct} C_t^\rho + \theta_{nt} N_t^\rho)^{1/\rho}, \tag{1.1}$$
$$\rho = 1 - 1/\sigma_{Edu},$$

where σ_{Edu} is the elasticity of substitution between workers with and without university education, C_t is the aggregate supply of university-educated workers, N_t is the aggregate supply of non-university-educated workers, and θ_{ct} and θ_{nt} are the technological efficiency parameters. Also, we assume that C_t and N_t follow a CES form as well, and they are aggregates of workers across different years of potential experience:

$$C_t = [\sum_k (\beta_k C_{kt}^\eta)]^{1/\eta}, \tag{1.2}$$
$$N_t = [\sum_k (\alpha_k N_{kt}^\eta)]^{1/\eta}, \tag{1.3}$$
$$\eta = 1 - 1/\sigma_{Exp},$$

where k indexes groups of potential experience, σ_{Exp} is the elasticity of substitution between workers in different potential experience groups, assumed to be the same for workers with and without university education, and α_k and β_k are relative efficiency parameters.

If workers are paid in the way that the relative marginal products equal relative wages, after solving the first-order conditions and taking logs, we have the following equation summarizing the relationship between relative wages and relative labor supply:

$$\ln(\frac{W_{kt}^c}{W_{kt}^n}) = \ln(\frac{\theta_{ct}}{\theta_{nt}}) + \ln(\frac{\beta_k}{\alpha_k}) - (\frac{1}{\sigma_{Edu}} - \frac{1}{\sigma_{Exp}}) \ln(\frac{C_t}{N_t}) - \frac{1}{\sigma_{Exp}} \ln(\frac{C_{kt}}{N_{kt}}), \tag{1.4}$$

where W_{kt}^c and W_{kt}^n are the wage of university- and non-university-educated workers in potential experience group k during year t, respectively. Then, after arranging some terms, we obtain

$$\ln(\frac{W_{kt}^c}{W_{kt}^n}) = \ln(\frac{\theta_{ct}}{\theta_{nt}}) + \ln(\frac{\beta_k}{\alpha_k}) - \frac{1}{\sigma_{Edu}} \ln(\frac{C_t}{N_t}) - \frac{1}{\sigma_{Exp}} [\ln(\frac{C_{kt}}{N_{kt}}) - \ln(\frac{C_t}{N_t})]. \tag{1.5}$$

Equation (1.5) is almost the same as Equation (8b) in Card and Lemieux (2001), except that they had relative wages and relative supply by age groups, while we have relative wages and relative supply by potential experience groups. If labor supply is exogenous, we can estimate Equation (1.5) by running an OLS regression. Our data comes from the 1978-2011 *Manpower Utilization Survey* (MUS), which is similar to the Current Population Survey (CPS) in the U.S. Details about the MUS can be found in Appendix A.1.1.

With regard to the variables in Equation (1.5), $\ln(\theta_{ct}/\theta_{nt})$ and $\ln(\beta_k/\alpha_k)$ can be represented respectively by a time trend and dummies of potential experience groups. C_{kt} and N_{kt} are measured in the unit of weekly working hours, W_{kt}^c and W_{kt}^n are measured in the unit of hourly wages, and in order to control for the change in the composition within the university-educated and non-university-educated workforce, we run several individual-level wage regressions and use the information from these regressions to construct C_{kt}, N_{kt}, W_{kt}^c and W_{kt}^n.[5] As to C_t and N_t, we use the two-step estimation procedure as suggested by Card and Lemieux (2001) because the values of C_t and N_t depend on C_{kt}, N_{kt}, and the parameters in Equation (1.5). Appendix A.2 provides the details of how the variables in Equation (1.5) are constructed.

Years of potential experience are either grouped by five years—0-4 years, 5-9 years, ..., 35-39 years, so eight groups in total (labeled as "Five-Year Group" in the subsequent regression results); or grouped by ten years—0-9 years, 10-19 years, 20-

[5] Our data does not have information on hourly wage. Since compensation is mostly quoted as monthly instead of annually in Taiwan, the survey only asks respondents about their monthly salary. Therefore, we construct hourly wage as monthly salary divided by four and total working hours during the reference week. For robustness checks, we also used monthly salary throughout the whole analysis, and the results were similar.

29 years, and 30-39 years, so four groups in total (label as "Ten-Year Group" in the subsequent regression results). Grouping years of potential experience in these two different ways allows a higher flexibility in modeling the elasticity of substitution between more- and less-experienced workers, but, as will be seen later, both groupings generate similar results.[6]

Table 1.3 presents the estimation results of Equation (1.5) from OLS regressions. We report the robust standard errors with two-way clustering by year and potential experience, as proposed by Cameron et al. (2011), throughout this paper, since it is possible that the error term might be correlated among observations in the same year or in the same group of potential experience.[7] As can be seen, across all specifications, the coefficient of $[\ln(C_{kt}/N_{kt}) - \ln(C_t/N_t)]$, which represents $-1/\sigma_{Exp}$, is around -0.1 to -0.2, similar to what Card and Lemieux (2001) obtained, so σ_{Exp} is about 5 to 10 ($1/0.1 = 10, 1/0.2 = 5$). As to the coefficient of $\ln(C_t/N_t)$, which represents $-1/\sigma_{Edu}$, as can be seen in Columns (1) and (4), when we use a linear time trend to represent $\ln(\theta_{ct}/\theta_{nt})$, the estimate of $-1/\sigma_{Edu}$ is insignificantly different from zero and much smaller in magnitude than what Card and Lemieux (2001) and Katz and Murphy (1992) obtained, implying perfect substitutability between workers with and without university education. However, this does not seem to be plausible because,

[6] When years of potential experience is grouped by five years, the elasticity of substitution between workers with 0-4 years and 5-9 years of potential experience is assumed to be the same as that between workers with 0-4 years and 35-39 years of potential experience. In contrast, when years of potential experience are grouped by ten years, workers with 0-4 years and 5-9 years of potential experience are assumed to be perfect substitutes, but workers with 0-4 years and 35-39 years of potential experience are not. Nevertheless, both ways of grouping basically generate similar results. The only exception is that the estimate of the elasticity of substitution between more- and less-experienced workers (σ_{Exp}) tends to be slightly larger in the "Five-Year Group" regressions (i.e., the coefficient, which represents $-1/\sigma_{Exp}$, tends to be smaller in magnitude). Basically, when more-substitutable subgroups are grouped together, the estimates will be more likely to reveal the elasticity of substitution between the less-substitutable aggregated groups.

[7] In addition to two-way clustered standard errors, other standard errors, such as heteroskedastically-robust standard errors, one-way clustered standard errors by year, and one-way clustered standard errors by group of potential experience all generate similar results. Since none of the previously mentioned standard errors allow serial correlations among observations in different years *and* groups of potential experience, we also calculate the standard errors proposed by Driscoll and Kraay (1998), which can be viewed as a version of Newey-West heteroskedasticity and autocorrelation consistent (HAC) standard errors for panel data, and the results are still similar.

as discussed in the previous section, workers with and without university education seem to concentrate in different industries and occupations.

One thing worth noting is that $\ln(\theta_{ct}/\theta_{nt})$ in Taiwan might not change linearly over time. When we regress $\ln(W^c_{kt}/W^n_{kt})$ on $\ln(C_{kt}/N_{kt})$, dummies of potential experience group and year dummies in the first-stage regression, the coefficients of year dummies increase at an accelerated rate (Figure A.2 in Appendix A.2). Also, studies such as Lin and Orazem (2003) found that a linear time trend alone does not fully control for all the demand shifts in Taiwan. Therefore, in Columns (2) and (5), we use a quadratic time trend to represent $\ln(\theta_{ct}/\theta_{nt})$. As can be seen, adjusted R^2 becomes higher, indicating that adding a quadratic term fits the data better. Also, the coefficient of $\ln(C_t/N_t)$ now becomes significantly negative, and the magnitude is similar to what Card and Lemieux (2001) obtained as well, suggesting σ_{Edu} to be around 2 and 2.5 (1/0.4=2.5, 1/0.5=2). We also use a cubic time trend to represent $\ln(\theta_{ct}/\theta_{nt})$ in Columns (3) and (6) as robustness checks, but the results are similar to the ones using a quadratic time trend, and the coefficients of the cubic term are small and insignificantly different from zero.

1.3.2 Elasticity of Substitution across Experience Groups, Different by Workers' University Attainment

The elasticity of substitution across experience groups was constrained to be identical for workers both with and without university education in the previous subsection, but we can relax this constraint. Specifically, if the elasticity of substitution across experience groups is σ^c_{Exp} for workers with university education and σ^n_{Exp} for workers without university education, we obtain an analogous equation to Equation

(1.5):

$$\ln(\frac{W_{kt}^c}{W_{kt}^n}) = \ln(\frac{\theta_{ct}}{\theta_{nt}}) + \ln(\frac{\beta_k}{\alpha_k}) - \frac{1}{\sigma_{Edu}} \ln(\frac{C_t}{N_t})$$
$$- \frac{1}{\sigma_{Exp}^c}[\ln(C_{kt}) - \ln(C_t)] + \frac{1}{\sigma_{Exp}^n}[\ln(N_{kt}) - \ln(N_t)]. \quad (1.6)$$

Now, we can run OLS regressions to estimate Equation (1.6). Because C_t and N_t still depend on C_{kt} and N_{kt}, we re-construct C_t and N_t by using a modified two-step estimation procedure to take into account that the value of σ_{Exp}^c and σ_{Exp}^n might be different (the details of this procedure can also be found in Appendix A.2), while the other variables are the same as in the previous subsection.

Table 1.4 presents the regression results. The coefficient of $\ln(C_{kt}) - \ln(C_t)$ represents $-1/\sigma_{Exp}^c$, and the coefficient of $\ln(N_{kt}) - \ln(N_t)$ represents $1/\sigma_{Exp}^n$. As can be seen, across all specifications, the results suggest that $\sigma_{Exp}^c > \sigma_{Exp}^n$, and the adjusted R^2's are higher than those in Table 1.3, indicating a better fit. Therefore, in terms of model selection, we prefer the specification with non-linear time trend and based on Equation (1.6) (Columns (2) and (5) in Table 1.4), which allows the elasticity of substitution between more- and less-experienced workers to be different between university- and non-university-educated workers.

1.3.3 Relative Supply and Demand Shifts for University-Educated Workers

Now, we compare the magnitudes of the relative supply and demand shifts for university-educated workers. Equation (1.6) is the labor demand function. Based on the functional form of labor demand and using a framework similar to Goldin and

Katz (2008, Chapter 8), we first define

$$\ln(\frac{W_{kt}^c}{W_{kt}^n}) \equiv \ln(D_t^k) - \ln(S_t^k) \tag{1.7}$$

$$\ln(S_t^k) = \frac{1}{\sigma_{Edu}} \ln(\frac{C_t}{N_t}) + \frac{1}{\sigma_{Exp}^c}[\ln(C_{kt}) - \ln(C_t)] - \frac{1}{\sigma_{Exp}^n}[\ln(N_{kt}) - \ln(N_t)] \tag{1.8}$$

$$\ln(D_t^k) = \ln(\frac{W_{kt}^c}{W_{kt}^n}) + \frac{1}{\sigma_{Edu}} \ln(\frac{C_t}{N_t}) + \frac{1}{\sigma_{Exp}^c}[\ln(C_{kt}) - \ln(C_t)] - \frac{1}{\sigma_{Exp}^n}[\ln(N_{kt}) - \ln(N_t)]. \tag{1.9}$$

Equation (1.7) indicates that the university wage premium is determined by the counterbalance between $\ln(S_t^k)$ and $\ln(D_t^k)$. *Ceteris paribus*, an increase in the relative supply of university-educated workers would make the univeristy wage premium to drop, and the change in $\ln(S_t^k)$ indicates the magnitude of this drop, which is determined by the elasticity of substitution measures. However, if the magnitude of the drop in the university wage premium is smaller than the magnitude of the change in $\ln(S_t^k)$, it implies that factors other than the labor supply must have changed in a way to raise the university wage premium, and the magnitude of this raise is indicated by the change in $\ln(D_t^k)$. In other words, the change in $\ln(D_t^k)$ indicates how the *shifts* in the labor demand curve affects the university wage premium if we hold constant the labor supply.

Using the regression results from Column (5) of Table 1.4 for the value of σ_{Edu}, σ_{Exp}^c, and σ_{Exp}^n in Equations (1.8) and (1.9), Figure 1.10 plots $\ln(S_t^k) - \ln(S_{1978}^k)$ and $\ln(D_t^k) - \ln(D_{1978}^k)$, labeled as "Supply" and "Demand," respectively. Since the university wage premium trends down for less-experienced workers and trends up for more-experienced workers, as can be seen in Figure 1.10, for workers with 0-9 years of potential experience, the relative supply of university-educated workers has increased faster than the relative demand for university-educated workers, while the opposite is true for more-experienced workers.

So far, we have quantified the shift of the labor demand curve based on the changes in wages and labor supply, and we have treated this shift as the change in the relative demand for university-educated workers, without identifying the factors related to this shift. Therefore, in the following sections, we will investigate the extent to which several factors, such as the change in the industrial and occupational employment and the change in the quality of labor force due to the expansion of post-secondary education, explain the shift of the labor demand curve.

1.4 Sectoral Employment Shifts and Labor Demand

1.4.1 The Characteristics of the Labor Force and the Changes in Industrial and Occupational Compositions

We first summarize the characteristics (potential experience, educational attainment and gender) of the labor force by industry and occupation. Table 1.5 presents the effective employment shares by industry, occupation, and years of potential experience, measured as the share (averaged over the 1978-2011 period) of total weekly working hours in efficiency units.[8] The employment shares by industry between more- and less-experienced workers are similar, except that the former are concentrated in agricultural sectors, while the latter are concentrated in Manufacturing (especially High Tech), Financial/Professional Services and Information, and Other Services. As to occupations, even though one would expect to see a higher share of more-experienced workers as managers or professionals, the data suggests otherwise. Less-experienced workers are more likely to be found in white-collar occupations (Administrative, Cler-

[8] Since the occupation codes were changed in 1993, making the data systematically different before 1992 and after 1993, we take advantage of the sample rotation structure to see how occupations of those who did not change jobs were coded in 1992 and 1993. Then, we examine the extent to which the detailed occupation codes in 1992 corresponded to the following three occupation groups in 1993: Managerial and Professional; Administrative, Clerical and Sales; and Production Workers and Laborers, and use this probability to code each detailed industries before 1992 within these three categories. Besides, there were no athletes and hunters who did not change jobs between 1992 and 1993, so we code all the athletes as Managerial and Professional, and all the hunters as Production Workers and Laborers.

ical, and Sales and Managerial and Professional), while more-experienced workers are actually more likely to work in blue-collar occupations (Production Workers and Laborers).

Less-experienced workers concentrate in white-collar occupations because educational attainment has increased throughout this period. Tables 1.6 and 1.7 present the employment share by workers' university attainment. As can be seen, university-educated workers concentrate in white-collar occupations, while workers without university education concentrate in blue-collar occupations. Besides, for university-educated workers, more-experienced workers have a higher share in Managerial and Professional occupations, while for non-university-educated workers, workers with 5 to 24 years of potential experience have a higher share in Managerial and Professional occupations. With regard to industrial compositions, university-educated workers concentrate in a number of service industries (Financial/Professional Services and Information, Public Administration, and Other Services), more-experienced non-university-educated workers concentrate in Agriculture, Forestry and Fishing, and less-experienced non-university-educated workers concentrate in Low Tech and Basic Manufacturing industries. The employment shares of High Tech Manufacturing and Whole Sale and Retail Trade are similar for workers both with and without university education.

In addition to the difference in the industrial and occupational structures between workers with different levels of experience and education, Tables 1.8 provides information on gender differences. As can be seen, female workers are overall more concentrated in the service sectors. With regard to occupations, the occupational structure for male workers is more polarized, with non-university educated male workers more likely to be Production Workers and Laborers and university-educated workers concentrating in Managerial and Professional occupations. In contrast, for female workers, even though non-university-educated female workers are still more likely to be Production workers and Laborers, and university-educated female workers are still more likely to be found in Managerial and Professional occupations, more than half of the female workers actually concentrate in Administrative, Clerical and Sales occupations.

So far, we have discussed the overall demographic characteristics of the workforce by industry and occupation. Now, we turn our focus to the changes in the industrial and occupational structures over time to identify which demographic groups might benefit more from the changes in industrial and occupational compositions. Figures 1.11 and 1.12 plot the employment shares by industry from 1978 to 2011. As can be seen, the employment shares of most non-service sectors, which on average have a less-educated labor force, decrease over time, except High Tech Manufacturing, which has an upward trend, and Construction, whose employment share seems to follow the business cycles. In contrast, the employment shares of the business and service sectors, which generally have a more-educated labor force, increase over time, except that the share of Transportation, Warehousing and Communications decreases over time, and the share of Public Administration employees oscillates around three to four percent. In addition, Figure 1.13 suggests that employment moves away from blue-collar to the white-collar occupations. Therefore, the changes in the industrial and occupational compositions throughout this period seem to favor more-educated, less-experienced, and female workers.

1.4.2 Quantifying Sectoral Employment Shifts

We now use the model in Katz and Murphy (1992) to quantify the change in the sectoral employment as described previously. According to Equations (11) and (14) in Katz and Murphy (1992), we have

$$\Delta X_m^d = \frac{\Delta D_m^d}{E_m} = \sum_j \frac{E_{jm}}{E_m}\frac{\Delta E_j}{E_j} = \frac{\sum_j \alpha_{jm}\Delta E_j}{E_m}, \tag{1.10}$$

$$\Delta X_m^b = \frac{\Delta D_m^b}{E_m} = \sum_i \frac{E_{im}}{E_m}\frac{\Delta E_i}{E_i} = \frac{\sum_i \alpha_{im}\Delta E_i}{E_m}, \tag{1.11}$$

$$\Delta X_m^w = \Delta X_m^d - \Delta X_m^b,$$

where j indexes 42 industry-occupation cells (14 industries $\times$ 3 occupations = 42 industry-occupation cells), i indexes 14 industries, m indexes workers' demographic groups, E represents employment, and Δ represents changes. Katz and Murphy (1992) have proved that $\Delta D_m^d = \sum_j E_{jm}\frac{\Delta E_j}{E_j}$ ($\Delta D_m^b = \sum_i E_{im}\frac{\Delta E_i}{E_i}$) measures the demand shift due to industrial-occupational (industrial) employment shifts for workers in demographic group m, holding relative wages constant, and ΔX_m^d (ΔX_m^b) translates ΔD_m^d (ΔD_m^b) into percent changes because it equals ΔD_m^d (ΔD_m^b) divided by the employment of workers in demographic group m, E_m. Therefore, ΔX_m^d can be viewed as the overall (industry-occupation) demand shift for workers in demographic group m, ΔX_m^b as the between-industry demand shift for workers in demographic group m, and ΔX_m^w, which is equal to the difference between overall and between-industry demand shift, as the within-industry demand shift for workers in demographic group m.

The values of ΔX_m^d, ΔX_m^b, and ΔX_m^w are calculated as follows. ΔE_j and ΔE_i are the differences of employment in sector j and industry i between different years, respectively, and E_m is the employment of workers in demographic group m, averaged throughout the whole period. E is measured as effective labor input, which is calculated as weekly working hours times estimated hourly wage, normalized so that total effective labor input sums up to one in each year. To estimate hourly wage, we first regress real hourly wages on the dummies of year, gender, potential experience group, and detailed level of schooling (junior high school and below, senior high school, vocational senior high school, junior college, and university and above); the interaction terms of year and gender dummies; and all the interaction terms of gender, detailed level of schooling, and potential experience group. We only include wage and salaried workers in our regression. Then, we use the estimated regression model to calculate the estimated real hourly wage for all the employed workers, including the self-employed workers and unpaid family workers who worked at least 15 hours for family-owned business during the reference week. As to α_{jm}, we first calculate $\alpha_{jmt} = (E_{jmt}/E_{jt})$, where E_{jmt} is the effective labor input of demographic group m in sector j in year t, and E_{jt} is the effective labor input in sector j in year t, so α_{jmt} is the effective employment share of demographic group m in sector j in year t. If E_{jt} is equal to zero, α_{jmt} is defined as zero. Then, α_{jm} equals the average of α_{jmt} across t. We also generate α_{im} in an analogous way.

We first use m to index education-gender cells, and Table 1.9 presents our relative demand shift estimates. These demand shift measures are generally larger than what Katz and Murphy (1992, Table VI) obtained, which corresponds to the considerable changes in industrial and occupational compositions as illustrated in Figures 1.11, 1.12 and 1.13. As can be seen, from 1978 to 2011, the labor demand shifted to female workers and more-educated workers. Also, most of the demand changes are explained by the change in the industrial compositions (between-industry shifts).

Now, we separate the demand shifts between 1978 and 2011 into four sub-periods: 1978-1986, 1986-1994, 1994-2002, and 2002-2011, and see how the labor demand shifts within each period. As displayed in Table 1.9, the overall demand for highly-educated male and female increases, and the magnitude of this increase also grows over time. In contrast, the overall demand for less-educated male workers decreases more and more, while the overall demand for less-educated female workers increases in smaller and smaller magnitudes or decreases throughout this period. For female workers and more-educated male workers, the changes in overall demand are mainly generated from the changes in industrial compositions, and then the changes in occupational compositions within each industry gradually incorporates as well. As to less-educated male workers, the changes in overall demand are mainly due to between-industry shifts.

In addition to grouping workers by education-gender cells, we can also group workers by education-experience cells. The first eight rows of Table 1.10 report the labor demand shifts by workers' educational attainment and years of potential experience. As can be seen, the overall demand shifts away from more-experienced non-university-educated workers to less-experienced university-educated workers, and the relative demand for university-educated workers increases regardless of experience. The last two rows of Table 1.10 report the labor demand shifts by workers' university attainment, assuming more- and less-experienced workers to be perfect substitutes. As can be seen, the increase in the demand for university-educated workers has accelerated over time. Besides, across educational attainment and potential experience levels, the change in the within-industry occupational compositions has become more and more prominent in explaining the changes in labor demand.

Table 1.11 decomposes further the last two rows of Table 1.10 by industry. As can be seen, the increase in the relative demand for university-educated workers based on industrial and occupational shifts is mostly attributable to the decrease in the demand for non-university-educated workers in Agriculture, Forestry and Fishing and Low Tech Manufacturing and the increase in the demand for university-educated workers in High Tech Manufacturing, Financial/Professional Services and Information, and Other Services.

1.4.3 Labor Demand Shifts Explained by Sectoral Employment Shifts

We now compare the relative demand shift measure based on sectoral (industrial-occupational) employment shifts with the relative demand shift measure implied from relative wage and supply shifts as reported in Section 1.3.3. Based on the functional form of $\ln(D_t^k)$ as given by Equation (1.9), the change in the relative demand for university-educated workers between year t_0 and year t explained by the change in the sectoral employment, measured in the same metric as $\ln(D_t^k) - \ln(D_{t_0}^k)$, is

$$\begin{aligned}\ln(\widetilde{D}_t^k) - \ln(\widetilde{D}_{t_0}^k) =& \frac{1}{\sigma_{Edu}}[\ln(1+\Delta X_c^d) - \ln(1+\Delta X_n^d)] \\ &+ \frac{1}{\sigma_{Exp}^c}[\ln(1+\Delta X_{c,k}^d) - \ln(1+\Delta X_c^d)] \\ &- \frac{1}{\sigma_{Exp}^n}[\ln(1+\Delta X_{n,k}^d) - \ln(1+\Delta X_n^d)],\end{aligned}$$

where demographic group indices "c, k" and "n, k" respectively represent university- and non-university-educated workers in potential experience group k, and "c" and "n" respectively represent university- and non-university-educated workers as a whole. The first eight rows in Table 1.10 provide values of $\ln(1+\Delta X_{c,k}^d)$ and $\ln(1+\Delta X_{n,k}^d)$. As to $\ln(1+\Delta X_c^d)$ and $\ln(1+\Delta X_n^d)$, because we should take into account the elasticity of substitution between more- and less-experienced workers, their values are not provided by the last two rows of Table 1.10. Instead, since log linearizing Equations (1.2) and (1.3) around values in year t_0 yields

$$\begin{aligned}\ln(C_t) - \ln(C_{t_0}) =& \sum_k \frac{\beta_k C_{kt_0}^{\eta^c}}{\sum_k(\beta_k C_{kt_0}^{\eta^c})}[\ln(C_{kt}) - \ln(C_{k,t_0})] \\ \ln(N_t) - \ln(N_{t_0}) =& \sum_k \frac{\alpha_k N_{kt_0}^{\eta^n}}{\sum_k(\alpha_k N_{kt_0}^{\eta^n})}[\ln(N_{kt}) - \ln(N_{k,t_0})],\end{aligned}$$

we obtain

$$\ln(1+\Delta X_c^d) = \sum_k \frac{\beta_k C_{kt_0}^{\eta^c}}{\sum_k(\beta_k C_{kt_0}^{\eta^c})}[\ln(1+\Delta X_{c,k}^d)]$$

$$\ln(1+\Delta X_n^d) = \sum_k \frac{\alpha_k N_{kt_0}^{\eta^n}}{\sum_k(\alpha_k N_{kt_0}^{\eta^n})}[\ln(1+\Delta X_{n,k}^d)].$$

Table 1.12 reports the values of $\ln(D_t^k) - \ln(D_{t_0}^k)$ and $\ln(\widetilde{D}_t^k) - \ln(\widetilde{D}_{t_0}^k)$. As can be seen, both demand shift measures increased between 1978 and 2011, and the rate of increase accelerated since the mid-1990s. Also, between 1978 and 2011, sectoral employment shifts explained about 20% of the increase in the relative demand implied from relative wage and relative supply shifts for less-experienced university-educated workers and 40% for more-experienced university-educated workers, and sectoral employment shifts explained more after the mid-1990s than before.

To sum up, the results in this section suggest that the shifts in the industrial and occupational structures have favored more-educated workers and female workers. Between-industry shifts dominated first, but the importance of within-industry shifts has been increasing as well. These shifts explain about one-third of the change in the university wage premium due to the increase in the relative demand for university-educated workers.

1.5 Quality of Labor Force

One might wonder whether the observed increase in the (unexplained) relative demand for university-educated workers is due to the change in the relative "quality" of university-educated workers. After all, this expansion of post-secondary education allows students from the vocational path, who had little chance to attend university before the expansion, to pursue post-secondary education. Also, it is likely that less academically accomplished students who would not have had access to higher education now are able to enter university. Since the productivity of the workers who can only enter university under the expansion might be different from those who would enter university regardless of the expansion, we adjust for the measurement of the efficiency unit of labor in this section as a robustness check. This exercise also allows us to investigate the extent to which the change in the quality of university-educated workers affects the university wage premium.

1.5.1 Controlling for Tracking: Proportion of Academic and Vocational Graduates

As stated in Section 1.2, one of the main features of the educational reform in the 1990s was the establishment of institutes and universities of technology, making it easier for students in the vocational track to pursue higher education. To understand how this change affects university wage premium, we need information on the labor market outcomes of university graduates from the academic and vocational tracks (hereafter “academic graduates” and “vocational graduates,” respectively). Because the MUS does not specify whether a university graduate is an academic or a vocational graduate, we incorporate information from other datasets which allow us to distinguish university graduates by tracks: the *Taiwan Integrated Postsecondary Education Database* (TIPED) and the *Panel Study of Family Dynamics* (PSFD). TIPED surveys college students and recent graduates, while PSFD, a survey similar to the PSID in the US, surveys individuals born in 1935 and later. Details about the TIPED and the PSFD can be found respectively in Appendices A.1.2 and A.1.3, while the information on the labor market outcomes of academic and vocational graduates obtained from these datasets can be found in Appendix A.3.

To quantify the extent to which tracking affects university wage premium, we first construct the relative supply and wage measures of university-educated workers in the unit of academic-graduate equivalents. Specifically, define W^a_{kt} and C^a_{kt} respectively as the wage and the labor supply of university-educated workers, measured in the unit of academic-graduate equivalents. Since the MUS does not distinguish university-educated workers by tracks, W^a_{kt} is constructed by the following steps:

$$\begin{aligned} W^c_{kt} &= pW^a_{kt} + (1-p)W^v_{kt} \\ &= pW^a_{kt} + (1-p)\tau W^a_{kt} \\ \Rightarrow W^a_{kt} &= \frac{W^c_{kt}}{p + \tau(1-p)}, \end{aligned}$$

where W^c_{kt} is the mean wage of university-educated workers, obtained from the MUS; W^a_{kt} and W^v_{kt} represent the mean wage of academic and vocational graduates, respectively; p is the proportion of academic graduates to the whole university graduates; and τ is the average earnings of vocational graduates relative to that of academic graduates. With regard to C^a_{kt},

$$\begin{aligned} C^a_{kt} &= [(pC_{kt})^\psi + \tau((1-p)C_{kt})^\psi]^{\frac{1}{\psi}}, \\ \psi &= 1 - 1/\sigma_{Acad}, \end{aligned} \tag{1.12}$$

where C_{kt} is directly available from the MUS, and σ_{Acad} is the elasticity of substitution between vocational and academic graduates.[9] If vocational and academic graduates are perfect substitutes ($\sigma_{Acad} = \infty$, or $\psi = 1$), Equation (1.12) degenerates to the weighted-sum of the effective supply of academic and vocational graduates, or

$$C^a_{kt} = pC_{kt} + (1-p)\tau C_{kt}. \tag{1.13}$$

Also, the aggregate supply of university-educated workers as a whole, measured in

[9] As suggested in Appendix A.3, the occupational structure of vocational graduates is closer to academic graduates than to non-university-educated workers, so we aggregate vocational graduates with academic graduates, instead of non-university-educated workers, which is what Equation (1.12) and the rest of the model imply.

the unit of academic-graduate equivalents, is

$$C_t^a = [\sum_k (\beta_k C_{kt}^{a\eta^c})]^{1/\eta^c}$$

$$\eta^c = 1 - 1/\sigma_{Exp}^c.$$

To construct academic-graduate-equivalent labor supply and wage measures, we need to know the values of p and τ. Information on p can be found in Figure 1.8, while τ is set to be 1, 0.95, 0.9, 0.85, 0.8, 0.75, or 0.7 because, according to Table A.3 in Appendix A.3, a vocational graduate earns about 10%-30% less than an academic graduate does. In addition, if vocational and academic graduates are not perfect substitutes, we need information on ψ. Ideally, if we had information on the wage gap between vocational and academic graduates in earlier years, we could obtain an estimate of ψ. However, TIPED did not start until 2004, and the sample size of vocational graduates among older cohorts and in earlier years are too small in PSFD. Therefore, we choose different values of ψ to see whether our results are sensitive to the choice of ψ. Given that production was not greatly hindered at the time when vocational graduates did not exist, vocational and academic graduates should be at least highly substitutable, so σ_{Acad} should not be too small, which means ψ should not be too small, either. Thus, we set ψ to be 1, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, or 0.3.

Now, applying the specification of Equation (1.6), and replacing W_{kt}^c with W_{kt}^a, C_{kt} with C_{kt}^a, and C_t with C_t^a, which is constructed by using the two-step approach as mentioned before, we have

$$\begin{aligned}\ln(\frac{W_{kt}^a}{W_{kt}^n}) =& \ln(\frac{\theta_{ct}}{\theta_{nt}}) + \ln(\frac{\beta_k}{\alpha_k}) - \frac{1}{\sigma_{Edu}} \ln(\frac{C_t^a}{N_t}) \\ & - \frac{1}{\sigma_{Exp}^c}[\ln(C_{kt}^a) - \ln(C_t^a)] + \frac{1}{\sigma_{Exp}^n}[\ln(N_{kt}) - \ln(N_t)]. \qquad (1.14)\end{aligned}$$

As to the extent to which tracking affects the relative demand for university-educated workers, since, combining Equations (1.8), (1.9), and (1.14), we obtain

$$\begin{aligned}
&\ln(\frac{W_{kt}^a}{W_{kt}^n}) + \ln(W_{kt}^c) - \ln(W_{kt}^c) \\
=&\ln(\frac{\theta_{ct}}{\theta_{nt}}) + \ln(\frac{\beta_k}{\alpha_k}) - \ln(S_t^k) \\
+&\frac{1}{\sigma_{Edu}}\ln(\frac{C_t}{N_t}) + \frac{1}{\sigma_{Exp}^c}[\ln(C_{kt}) - \ln(C_t)] - \frac{1}{\sigma_{Exp}^n}[\ln(N_{kt}) - \ln(N_t)] \\
-&\frac{1}{\sigma_{Edu}}\ln(\frac{C_t^a}{N_t}) - \frac{1}{\sigma_{Exp}^c}[\ln(C_{kt}^a) - \ln(C_t^a)] + \frac{1}{\sigma_{Exp}^n}[\ln(N_{kt}) - \ln(N_t)],
\end{aligned}$$

we can define the part of demand shift explained by tracking as

$$\begin{aligned}
\ln(T_t^k) \equiv&\ln(W_{kt}^c) - \ln(W_{kt}^a) \\
&+\frac{1}{\sigma_{Edu}}[\ln(C_t) - \ln(C_t^a)] + \frac{1}{\sigma_{Exp}^c}\{[\ln(C_{kt}) - \ln(C_t)] - [\ln(C_{kt}^a) - \ln(C_t^a)]\} \\
&=\ln(W_{kt}^c) - \ln(W_{kt}^a) \\
&+(\frac{1}{\sigma_{Edu}} - \frac{1}{\sigma_{Exp}^c})[\ln(C_t) - \ln(C_t^a)] + \frac{1}{\sigma_{Exp}^c}[\ln(C_{kt}) - \ln(C_{kt}^a)]. \qquad (1.15)
\end{aligned}$$

In other words, tracking affects the relative demand for university-educated workers through wages, captured by the first term, $\ln(W_{kt}^c) - \ln(W_{kt}^a)$, and supply, captured by $(\frac{1}{\sigma_{Edu}} - \frac{1}{\sigma_{Exp}^c})[\ln(C_t) - \ln(C_t^a)] + \frac{1}{\sigma_{Exp}^c}[\ln(C_{kt}) - \ln(C_{kt}^a)]$. Imagine a situation in which the total working hours of university-educated workers, C_{kt} and C_t, and the wage rate of academic and vocational graduates, W_{kt}^a and W_{kt}^v, stay fixed, while the proportion of academic graduates, p, decreases. This would make $\ln(W_{kt}^c) - \ln(W_{kt}^a)$ to decrease because $\ln(W_{kt}^c)$ decreases when p decreases, which goes in the opposite direction to the perceived increase in the relative demand for university-educated workers. In contrast, if academic and vocational graduates are perfect substitutes ($\psi = 1$) and $\tau < 1$, $(\frac{1}{\sigma_{Edu}} - \frac{1}{\sigma_{Exp}^c})[\ln(C_t) - \ln(C_t^a)] + \frac{1}{\sigma_{Exp}^c}[\ln(C_{kt}) - \ln(C_{kt}^a)]$ would increase because a decrease in p would make $\ln(C_{kt}^a)$, and thus $\ln(C_t^a)$, to decrease, which is consistent to the perceived increase in the relative demand for university-educated workers.[10]

To quantify the change in $\ln(T_t^k)$, we first estimate σ_{Edu}, σ_{Exp}^c and σ_{Exp}^n by running an OLS regression based on Equation (1.14), and the results under selected parameterizations are presented in Tables 1.13 and 1.14. $\tau = 1$ means that vocational graduates are assumed to earn as much as academic graduates do, so Column (1) in Tables 1.13 and 1.14 are the same as Columns (2) and (5) in Table 1.4, while $\tau = 0.75$ means that vocational graduates are assumed to earn 75% as academic graduates do. As can be seen, the results are quite similar across different values of τ and ψ. The parameterizations not shown in the tables also generate similar results. Using the estimates as reported in Table 1.14, Table 1.15 presents total relative demand shifts for university-educated workers, $\ln(D_t^k) - \ln(D_{t_0}^k)$, and the part of demand shifts explained by tracking, $\ln(T_t^k) - \ln(T_{t_0}^k)$. As can be seen, tracking explains little the increase in the relative demand for university-educated workers: tracking either has a small positive or a negative effect on the relative demand for university-educated workers.

1.5.1.1 Varying the Wage Gap between Vocational and Academic Graduates with the Proportion of Academic Graduates

One might argue that the wage gap between academic and vocational graduates might be changing over time. For example, because the increase in the number of vocational post-secondary institutions was both dramatic and rapid, it is possible that vocational graduates who graduated earlier were similar to academic graduates, and thus earned roughly as much as academic graduates did, while vocational graduates who graduated after the expansion earned considerably less than academic graduates. Therefore, we take this into account by allowing τ to change with p.

For simplicity, we assume the relationship between τ and p can be summarized

[10] However, if academic and vocational graduates are not perfect substitutes ($\psi < 1$), C_{kt}^a actually will increase when p decreases and p is close enough to 1.

by the following linear function:

$$\tau = \frac{1-\tau_{min}}{0.5}p + \frac{\tau_{min}-0.5}{0.5}, \tag{1.16}$$

and Figure 1.14 illustrates a graphical representation of Equation (1.16). τ_{min} corresponds to the wage gap between vocational and academic graduates in recent years when the proportion of academic graduates decreases to around half, so we set τ_{min} to be 1, 0.95, 0.9, 0.85, 0.8, 0.75, or 0.7, which corresponds to the values obtained from TIPED and PSFD.

Tables 1.16 and 1.17 present our regression results under selected parameterizations. The parameterizations not shown in the tables also generate similar results. As can be seen, the results still do not differ much. Table 1.18 again presents total relative demand shifts for university-educated workers and the part of demand shifts explained by tracking. As can be seen, tracking still has little effect on the increase in the relative demand for university-educated workers.

1.5.2 Controlling for Selection: Mean Ability of Workers with and without University Education

In this section, we reconstruct a measure of labor supply which controls for the change in workers' average ability. We assume that the government sets university admissions quota, and people compete for university admissions based on their ability, so the university-educated have a higher ability than the non-university-educated. As a result, when the number of university admissions increases, the mean ability of both university-educated and non-university-educated workers will decrease, but not necessarily in the same magnitude. Therefore, the mean ability of university-educated workers might either increase or decrease *relative* to the mean ability of workers without university education.

Specifically, we use the following model, adapted from Carneiro and Lee (2011), to re-construct an ability-adjusted measure of relative labor supply. First, assume that

$$A \sim N(0, \sigma_A^2)$$
$$Z = \frac{A}{\sigma_A},$$

where A is ability, and Z is a standardized version of A. Assume that university enrollment depends on Z. Then, given the proportion of people allowed to enter university, the critical value of Z, c, is determined. Thus, the average abilities of those admitted and not admitted into university are

$$E(A|Z > c) = \sigma_A \lambda_+(c),$$

and

$$E(A|Z < c) = \sigma_A \lambda_-(c),$$

respectively, where

$$\lambda_+(c) = \frac{\phi(c)}{1 - \Phi(c)}$$
$$\lambda_-(c) = -\frac{\phi(c)}{\Phi(c)}.$$

From the equations above, we can see that when university enrollment increases, c decreases, so both $E(A|Z > c)$ and $E(A|Z < c)$ decrease.

Suppose the wage rate of workers with and without university education are as follows:

$$
\begin{aligned}
\ln(W_{kt}^c) &= \ln(\Pi_{kt}^c) + A \\
\ln(W_{kt}^n) &= \ln(\Pi_{kt}^n) + A.
\end{aligned}
$$

We standardize A so that σ_A^2 equals the variance of wages, after controlling for potential experience, detailed education level, and the interaction term between gender and year. Thus, the mean wage of workers with and without university education are

$$
\begin{aligned}
E(\ln(W_{kt}^c)) &= \ln(\Pi_{kt}^c) + E(A|Z > c_{kt}) = \ln(\Pi_{kt}^c) + \sigma_A \lambda_+(c_{kt}) \\
E(\ln(W_{kt}^n)) &= \ln(\Pi_{kt}^n) + E(A|Z < c_{kt}) = \ln(\Pi_{kt}^n) + \sigma_A \lambda_-(c_{kt}),
\end{aligned}
\tag{1.17}
$$

where c_{kt} is the critical value of Z for the cohort in potential experience group k in year t. Therefore, when c_{kt} decreases, the mean wage of university-educated and non-university-educated workers should both decrease.

As to the production function, suppose we can rewrite the production function as follows:

$$y_t = (\theta_{ct} C_t'^{\rho} + \theta_{nt} N_t'^{\rho})^{1/\rho}, \tag{1.18}$$

$$C_t' = [\sum_k (\beta_k C_{kt}'^{\eta^c})]^{1/\eta^c}, \tag{1.19}$$

$$N_t' = [\sum_k (\alpha_k N_{kt}'^{\eta^n})]^{1/\eta^n}, \tag{1.20}$$

$$
\begin{aligned}
\eta^c &= 1 - 1/\sigma_{Exp}^c, \\
\eta^n &= 1 - 1/\sigma_{Exp}^n, \\
\rho &= 1 - 1/\sigma_{Edu}.
\end{aligned}
$$

C_t', N_t', C_{kt}', and N_{kt}' represent quality-adjusted effective labor supply. Since Equations (1.18), (1.19), and (1.20) have similar functional forms as Equations (1.1), (1.2), and

(1.3), combining first-order conditions and assuming

$$\Pi^c_{kt} = \frac{\partial y_t}{\partial C'_t}\frac{\partial C'_t}{\partial C'_{kt}}$$
$$\Pi^n_{kt} = \frac{\partial y_t}{\partial N'_t}\frac{\partial N'_t}{\partial N'_{kt}},$$

we obtain:

$$\begin{aligned}\ln(\frac{\Pi^c_{kt}}{\Pi^n_{kt}}) =& \ln(\frac{\theta_{ct}}{\theta_{nt}}) + \ln(\frac{\beta_k}{\alpha_k}) - \frac{1}{\sigma_{Edu}}\ln(\frac{C'_t}{N'_t}) \\ & -\frac{1}{\sigma^c_{Exp}}[\ln(C'_{kt}) - \ln(C'_t)] + \frac{1}{\sigma^n_{Exp}}[\ln(N'_{kt}) - \ln(N'_t)].\end{aligned} \tag{1.21}$$

Suppose the relationship between the raw and the quality-adjusted effective supply is as follows:

$$\begin{aligned}C'_{kt} =& C_{kt}Q^c_{kt} \\ N'_{kt} =& N_{kt}Q^n_{kt},\end{aligned}$$

where Q^c_{kt} and Q^n_{kt} are the average quality of university-educated and non-university-educated workers, respectively. Specifically,

$$\begin{aligned}Q^c_{kt} =& E(\exp(A)|Z > c_{kt}) = \frac{\exp(\frac{\sigma^2_A}{2})\Phi(\sigma_A - c_{kt})}{\Phi(-c_{kt})} \\ Q^n_{kt} =& E(\exp(A)|Z < c_{kt}) = \frac{\exp(\frac{\sigma^2_A}{2})\Phi(c_{kt} - \sigma_A)}{\Phi(c_{kt})},\end{aligned}$$

which are derived from the truncated means of log-normal distribution because $\exp(A)$ is log-normally distributed.

Now, combining Equations (1.17) and (1.21), we obtain

$$\begin{aligned}
&\ln(\frac{W^c_{kt}}{W^n_{kt}}) - \sigma_A(\lambda_+(c_{kt}) - \lambda_-(c_{kt})) \\
=&\ln(\frac{\theta_{ct}}{\theta_{nt}}) + \ln(\frac{\beta_k}{\alpha_k}) - \frac{1}{\sigma_{Edu}}\ln(\frac{C'_t}{N'_t}) \\
-&\frac{1}{\sigma^c_{Exp}}[\ln(C_{kt}) + \ln(Q^c_{kt}) - \ln(C'_t)] + \frac{1}{\sigma^n_{Exp}}[\ln(N_{kt}) + \ln(Q^n_{kt}) - \ln(N'_t)],
\end{aligned} \tag{1.22}$$

and based on Equation (1.22), the part of demand shift explained by the change in the quality of labor force due to selection is

$$\begin{aligned}
&\ln(H^k_t) \\
\equiv&\sigma_A(\lambda_+(c_{kt}) - \lambda_-(c_{kt})) + \frac{1}{\sigma_{Edu}}[\ln(\frac{C_t}{N_t}) - \ln(\frac{C'_t}{N'_t})] \\
+&\frac{1}{\sigma^c_{Exp}}\{[\ln(C_{kt}) - \ln(C_t)] - [\ln(C'_{kt}) - \ln(C'_t)]\} \\
-&\frac{1}{\sigma^n_{Exp}}\{[\ln(N_{kt}) - \ln(N_t)] - [\ln(N'_{kt}) - \ln(N'_t)]\}.
\end{aligned} \tag{1.23}$$

Again, the change in the selection into university affects the relative demand for university-educated workers through wages, captured by the first term, $\sigma_A(\lambda_+(c_{kt}) - \lambda_-(c_{kt}))$, and supply, captured by the rest of the terms in the right-hand side of Equation (1.23). The first term decreases when admission into university increases, while the rest of the terms might increase or decrease, depending on the counterbalance between the change in the quality-adjusted effective supply of university-educated and non-university-educated workers.

To estimate Equation (1.22), $\ln(\theta_{ct}/\theta_{nt})$ is again represented by a linear or a quadratic time trend, $\ln(\beta_k/\alpha_k)$ is again represented by dummies of potential experience groups, $\ln(C'_t)$ and $\ln(N'_t)$ are constructed by using the two-step procedure as before, and c_{kt} is calculated from the proportion of university-educated workers in experience group k in year t. Then, we combine all the pieces and run an OLS regression. After estimating Equation (1.22), we use Equation (1.23) to calculate $\ln(H_t^k)$.

Table 1.19 presents the regression results based on Equation (1.22). As can be seen, the results do not change much from the base-line specification (Columns (2) and (5) in Table 1.4), except that the magnitude of the coefficient of $\ln(C'_{kt})-\ln(C'_t)$ seems to decrease, which indicates that more- and less-experienced university-educated workers are close to perfect substitutes. To evaluate the extent to which this difference affects predicted wage patterns, Figure 1.15 plots the actual and the predicted values of $\ln(W^c_{kt}/W^n_{kt})$, where "Predicted, No Selection" uses the specification of Column (5) in Table 1.4, and "Predicted, With Selection" uses the specification of Column (2) in Table 1.19. As can be seen, the predicted values of $\ln(W^c_{kt}/W^n_{kt})$ are quite similar regardless of whether we control for workers' mean ability. Table 1.20 reports the change in the relative demand for university-educated workers and the part of demand shift explained by the change in the selection into university, applying the estimates reported in Column (4) of Table 1.19 as elasticity of substitution measures. As can be seen, the change in the selection into university does not explain much the increase in the relative demand for university-educated workers.

1.6 Conclusion

In this paper, we have investigated the effect of the expansion in post-secondary education since the 1990s on the labor market outcomes in Taiwan. Since the educational reform in the 1990s, the number of university graduates has increased dramatically, and the share of university-educated workers in the workforce has increased as well. However, the university wage premium does not seem to plummet, which implies the relative demand for university-educated workers must have not only increased but also increased at an accelerated rate. We find that the change in the sectoral employment is consistent to this implication, and sectoral employment explains about one-third of the relative demand for university-educated workers inferred from changes in relative wages and supply. Changes in the industrial composition dominated throughout the whole period, but the changes in occupational compositions within each industry gradually revealed its importance in the 2000s. In contrast, the possible changes in the quality of the labor force due to the expansion, such as the increase in the share of university graduates from the vocational path and the decrease in the mean "ability" of workers with and without university education, do not seem to explain the patterns of the university wage premium much.

After controlling for demand shifts, our estimates suggest that the elasticity of substitution between workers with and without university education is about 2 to 2.5, and the elasticity of substitution between less- and more-experienced workers is about 10 for university-educated workers and about 5 for non-university-educated workers.

In contrast to the situation in the U.S., where the university wage premium increased since 1980, the university wage premium in Taiwan stayed relatively stable during the past three decades, and the concept of "the race between education and technology" as proposed by Goldin and Katz (2008), or the counterbalance between the relative demand and the relative supply of university-educated workers, seems to explain the difference between the U.S. and Taiwan quite well. The structure of sectoral employment shifted toward favoring university-educated workers in both places, but the relative supply of university-educated workers in the U.S. did not increase as much nor as rapidly as Taiwan did. Therefore, the expansion in the post-secondary education in Taiwan can be viewed as a showcase of how education policy can be used to provide the industry with the kind of labor it needs. The Taiwanese case also illustrates how education policy might help mitigate the inequality between more- and less-educated workers.

With regard to the directions for future research, it is worth identifying other relevant factors of the increase in the relative demand for university-educated workers. One of the possible candidates might be the changes in the patterns of trade and foreign direct investment (FDI). The trade share in Taiwan has been staying at around 40-60% of GDP for three decades, but the trade patterns have shifted substantially from exporting basic manufacturing products to exporting electronics and machinery. Also, restrictions on FDI, especially outward FDI to China, have been relaxed gradually since 1987, and the value of outward FDI has increased dramatically in the 2000s. Therefore, it is worth investigating the effects of trade and FDI on the relative demand for university-educated workers and the university wage premium.

In addition to wage gaps, it is also worth studying the change in the *level* of the real wage rate in Taiwan, which trended up between the late 1970s and the mid-1990s but stagnated afterwards. Formulating a model which combines possible factors that affect labor supply and demand, such as the expansion in post-secondary education, trade and FDI, might potentially shed light on understanding the change in the level of the real wage rate as well.

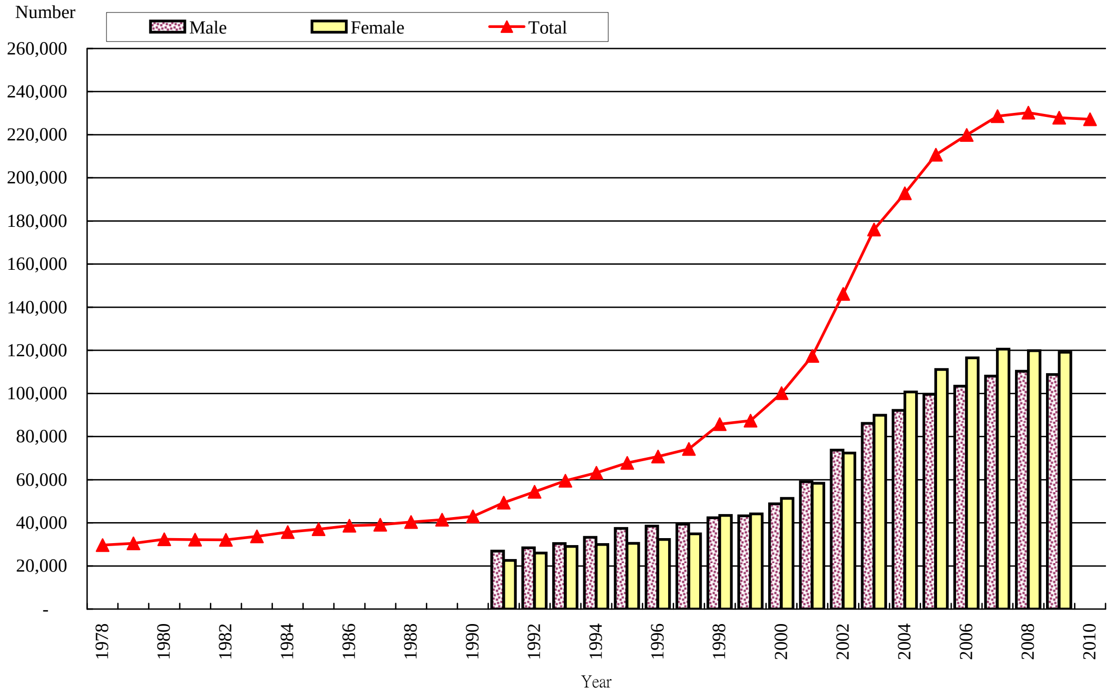


Figure 1.1: Number of Bachelor Recipients

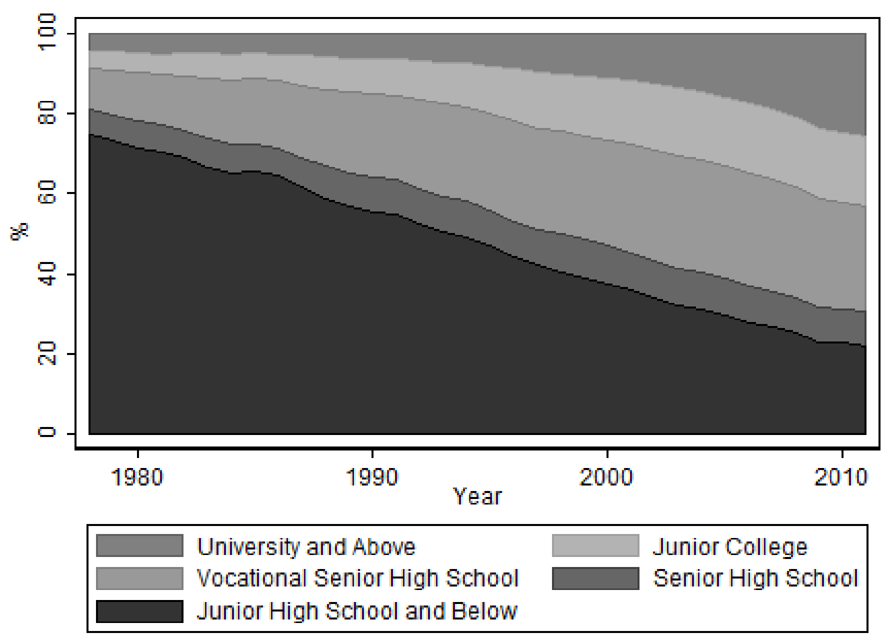


Figure 1.2: Employment Shares by Educational Attainment and Year

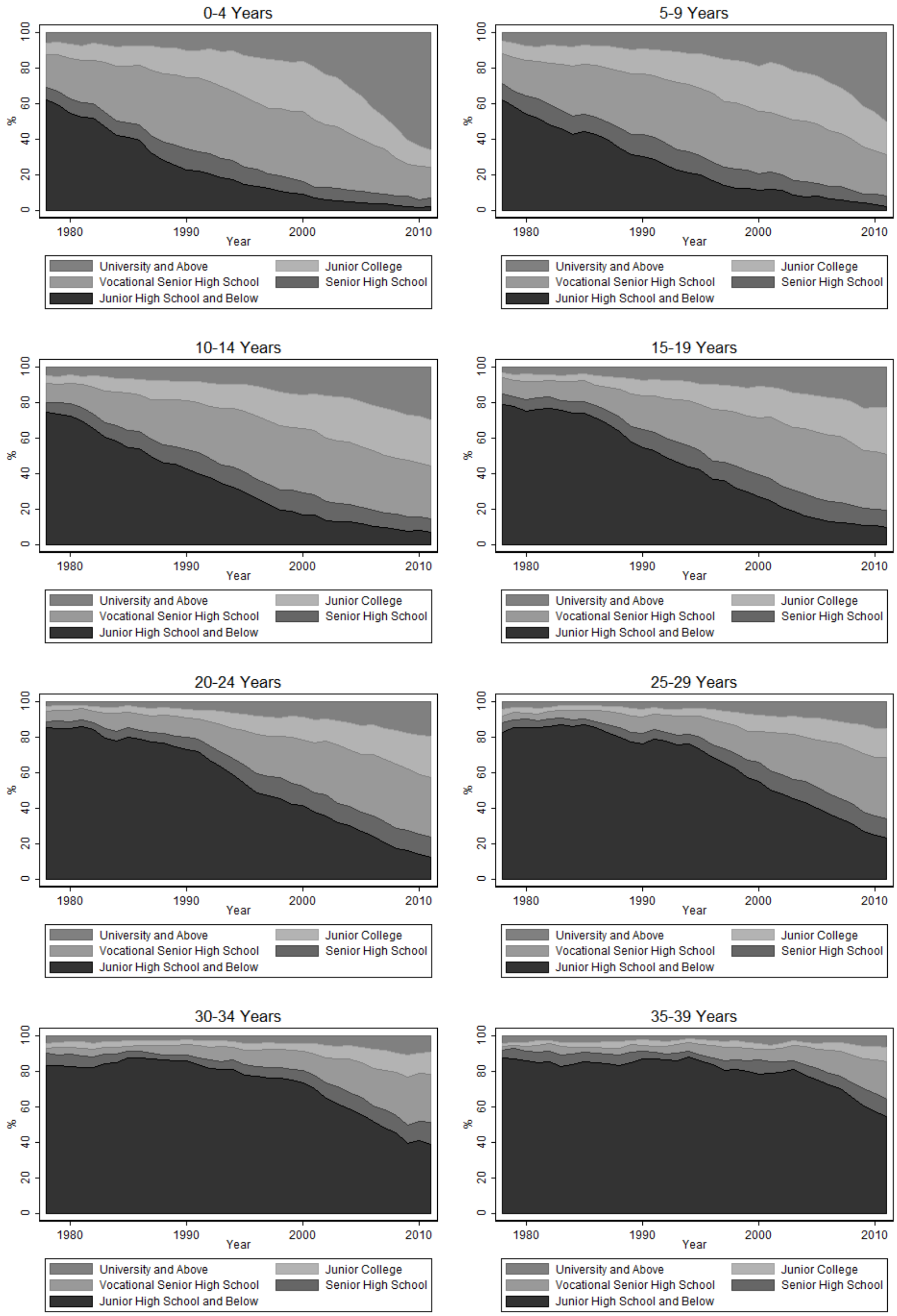


Figure 1.3: Employment Shares by Educational Attainment, Year and Years of Potential Experience

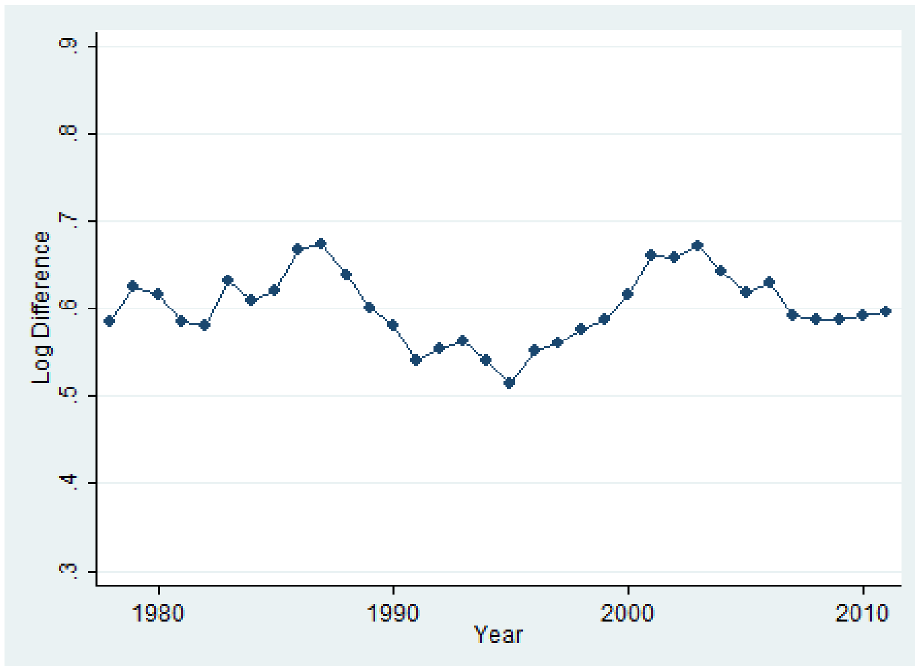
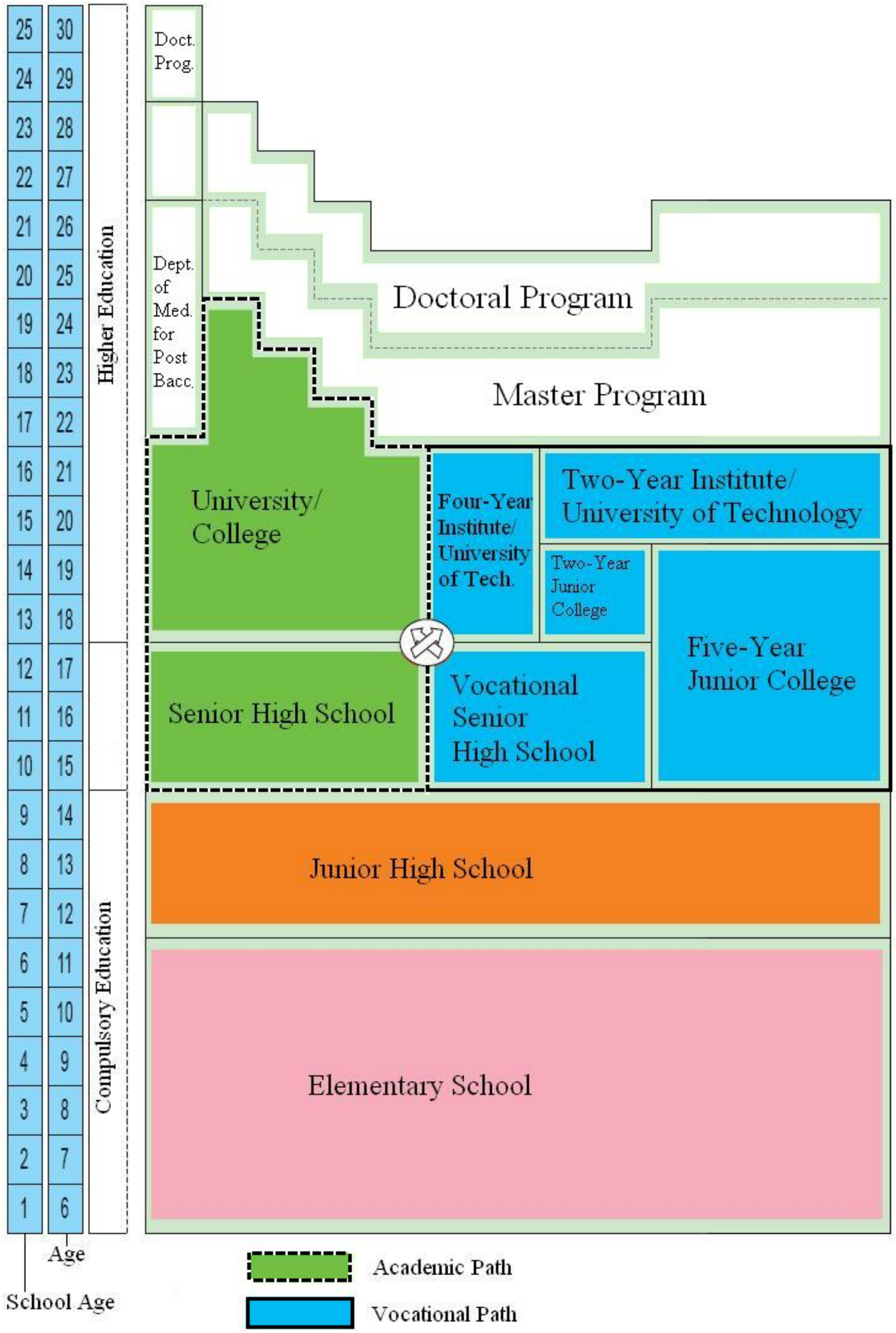


Figure 1.4: University Wage Premium

Note: University wage premium is the difference of log hourly wage between university-educated and non-university-educated workers after controlling for workers' demographic characteristics. Specifically, we first regress log hourly wage on dummies of potential experience group, detailed educational attainment, and the whole interaction terms between gender and year dummies. We run separate regressions for university-educated and non-university-educated workers, and only wage and salaried workers are included in the wage regressions. Then, the university wage premium is calculated as the difference in the coefficients of year dummies between the two wage regressions.

Figure 1.5: University Wage Premium by Years of Potential Experience

Note: University wage premium is the difference of log hourly wage between university-educated and non-university-educated workers after controlling for workers' demographic characteristics. Specifically, we first regress log hourly wage on dummies of detailed educational attainment and the whole interaction terms between gender and year dummies. We run separate regressions by workers' university attainment and group of potential experience, so we have eight wage regressions in total, and only wage and salaried workers are included in the wage regressions. Then, the university wage premium is calculated as the difference in the coefficients of year dummies between the wage regressions for university-educated and non-university-educated workers in corresponding potential experience groups.



Source: Adapted from Ministry of Education, Taiwan.

Figure 1.6: The Current Educational System in Taiwan

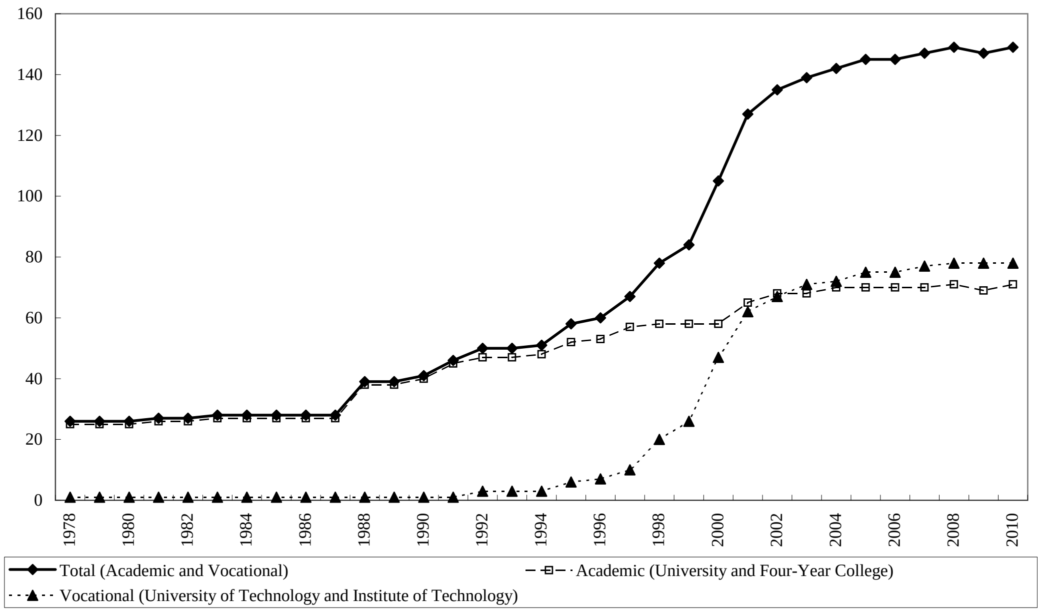


Figure 1.7: The Number of Post-Secondary Institutions

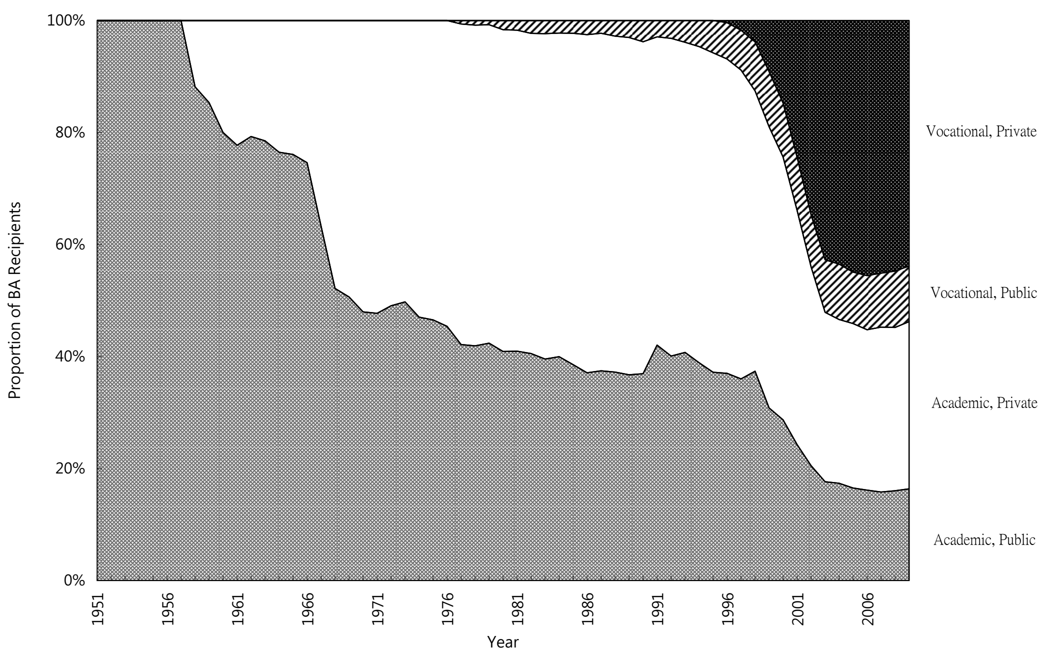


Figure 1.8: Proportion of BA Recipients Graduated from Academic and Vocational Paths

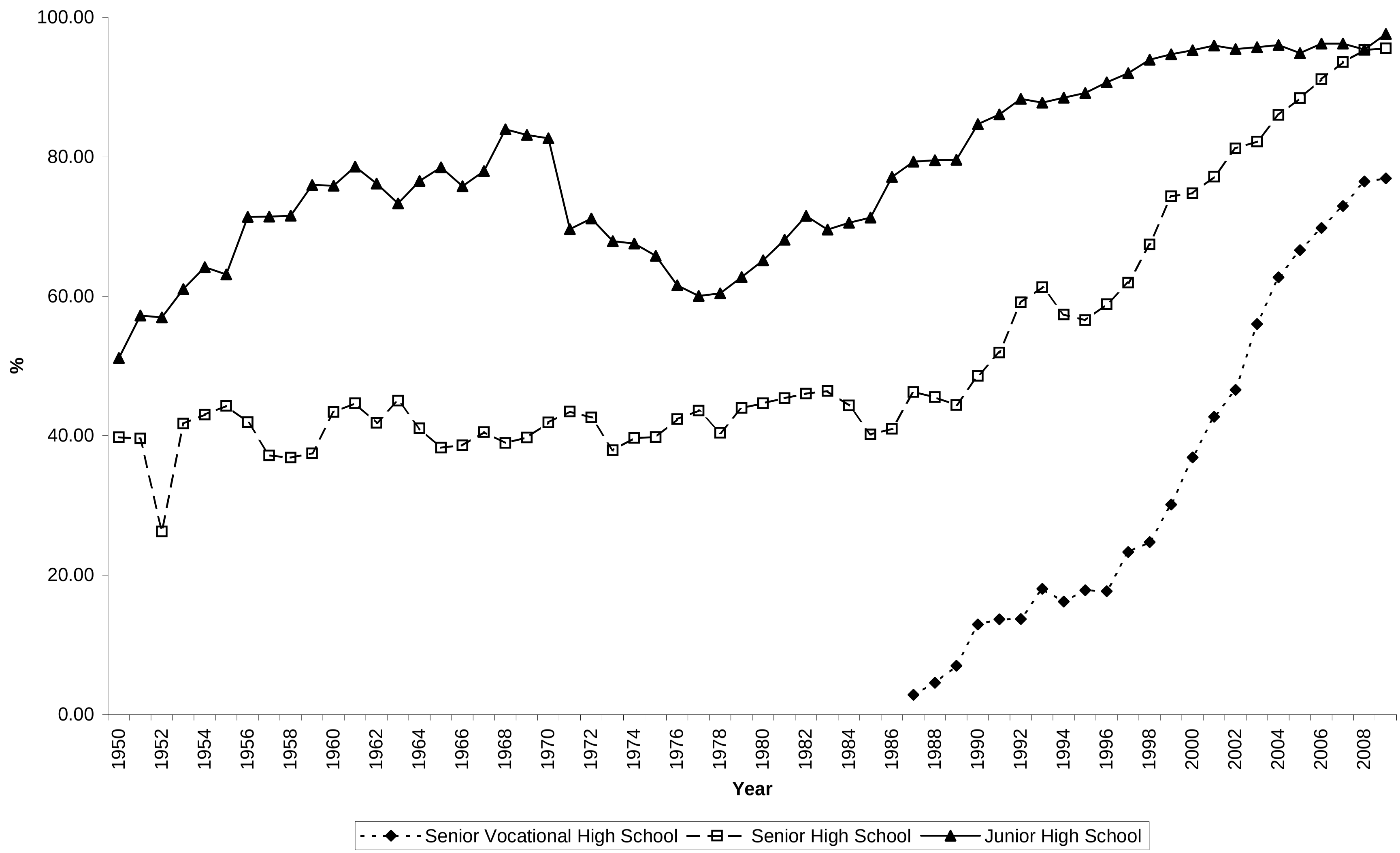


Figure 1.9: Transition Rates of Graduates Advancing to the Next Level of Schooling

Note: “Supply”$= \ln(S_t^k) - \ln(S_{1978}^k)$; “Demand”$= \ln(D_t^k) - \ln(D_{1978}^k)$.

Figure 1.10: Relative Supply and Demand Shifts for University-Educated Workers

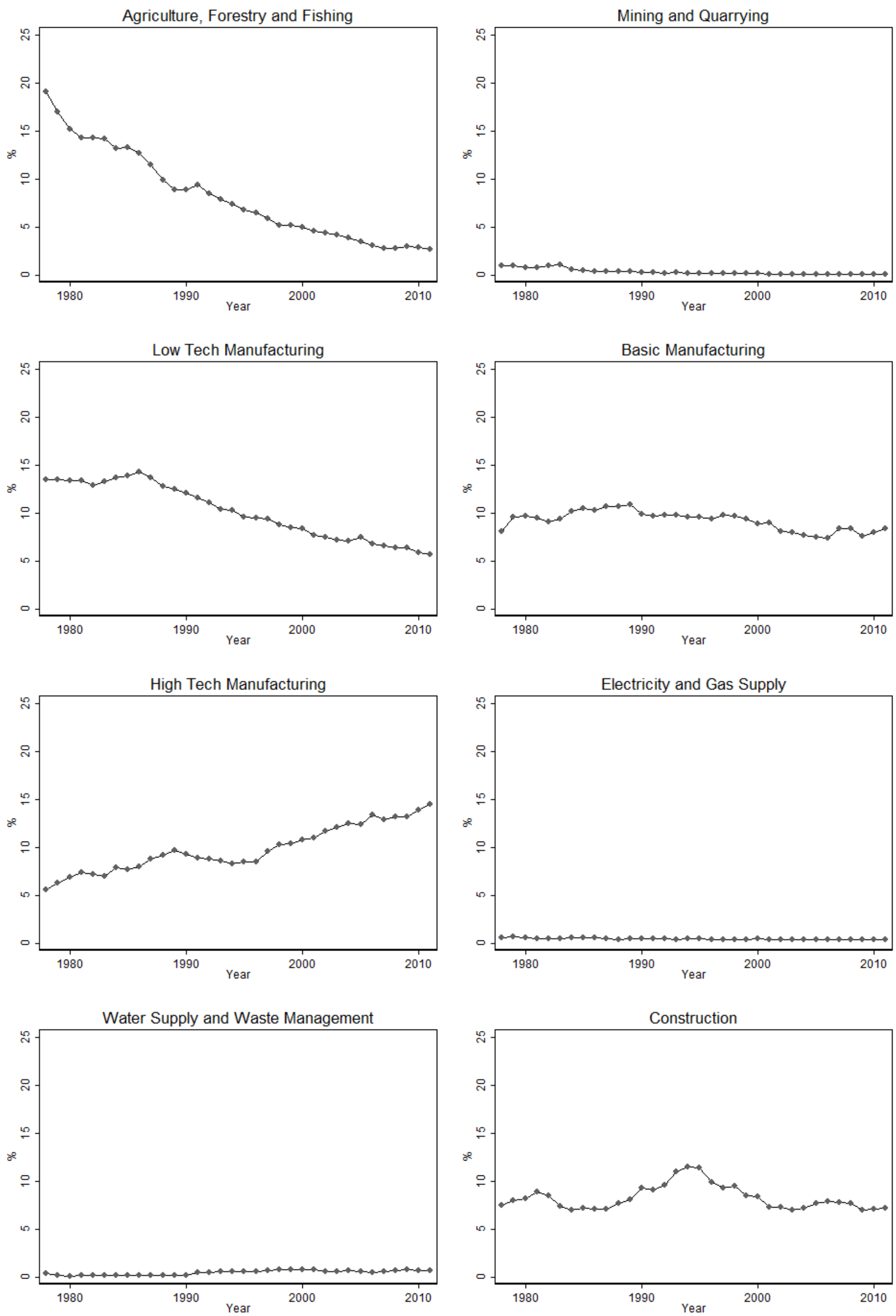


Figure 1.11: Effective Employment Shares in Agricultural, Manufacturing and Construction Industries

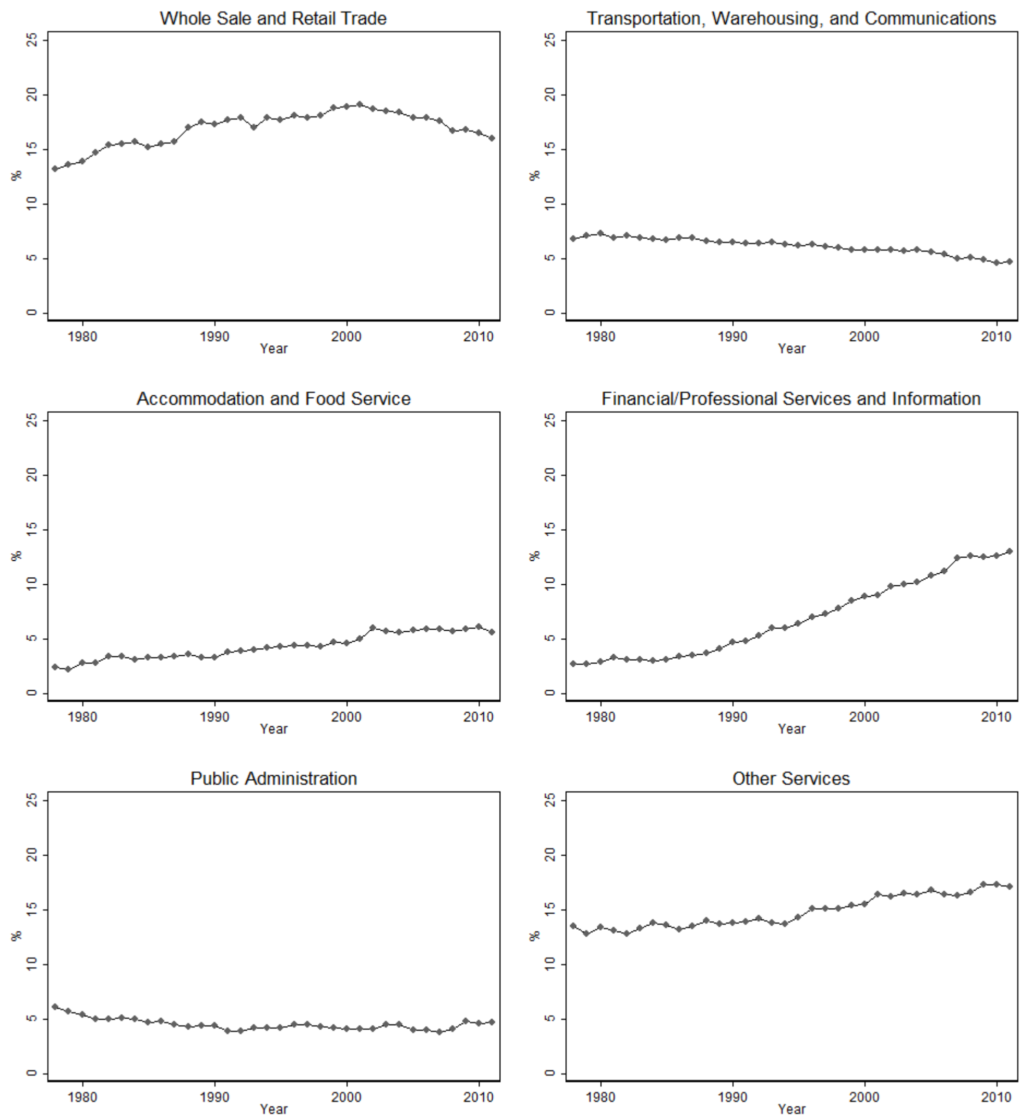


Figure 1.12: Effective Employment Shares in Business and Service Industries

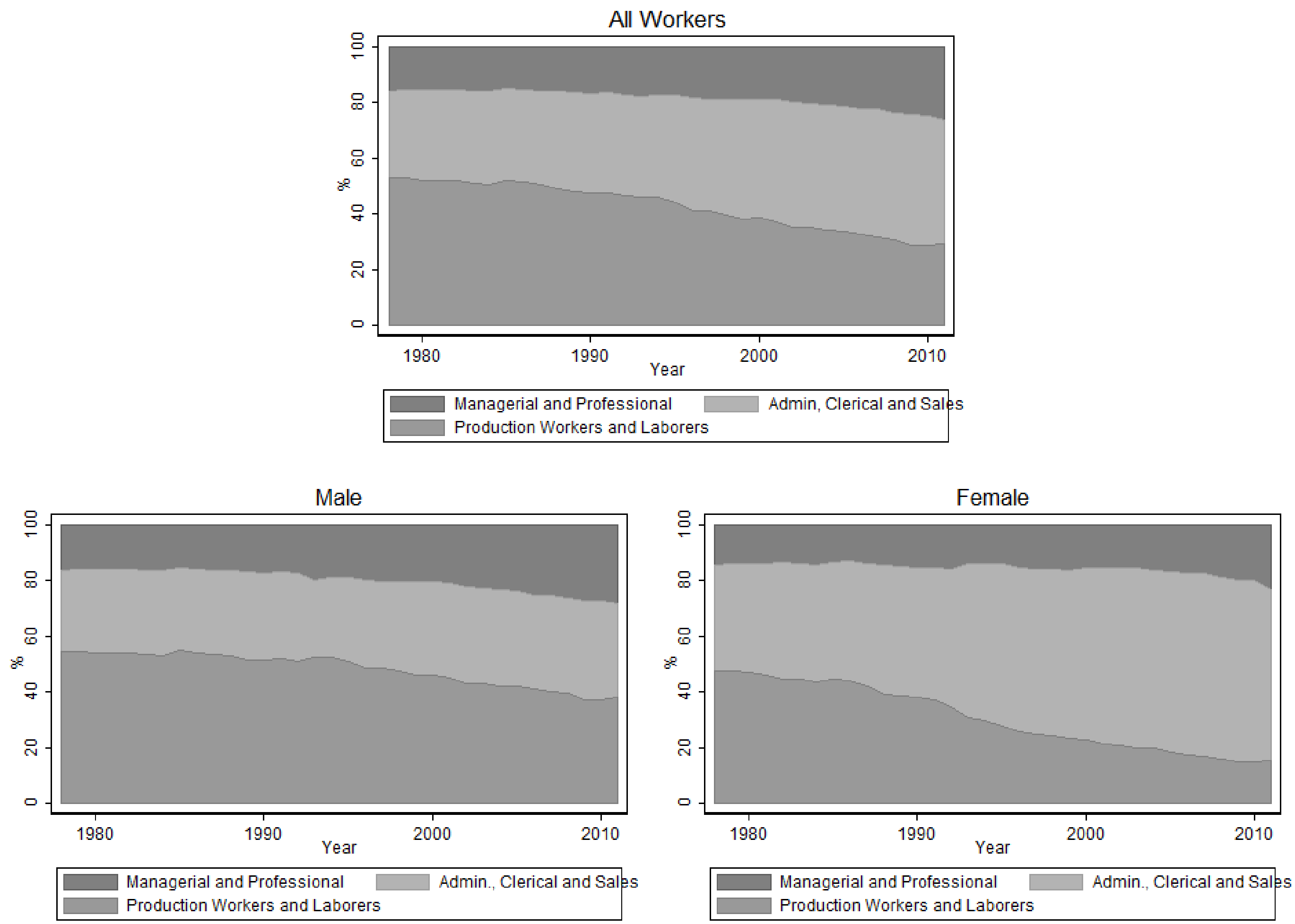


Figure 1.13: Effective Employment Shares by Occupation

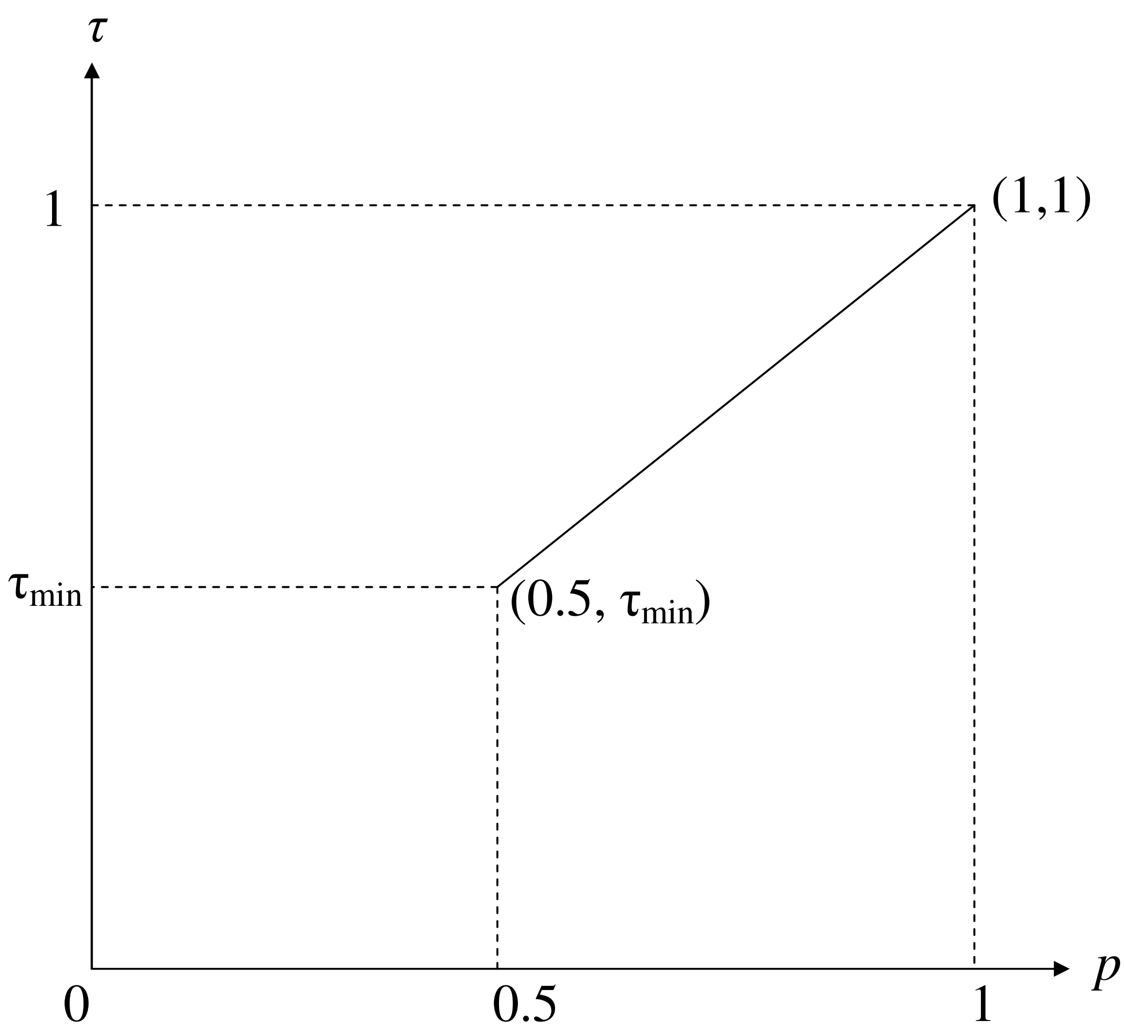


Figure 1.14: The Relationship between τ and p

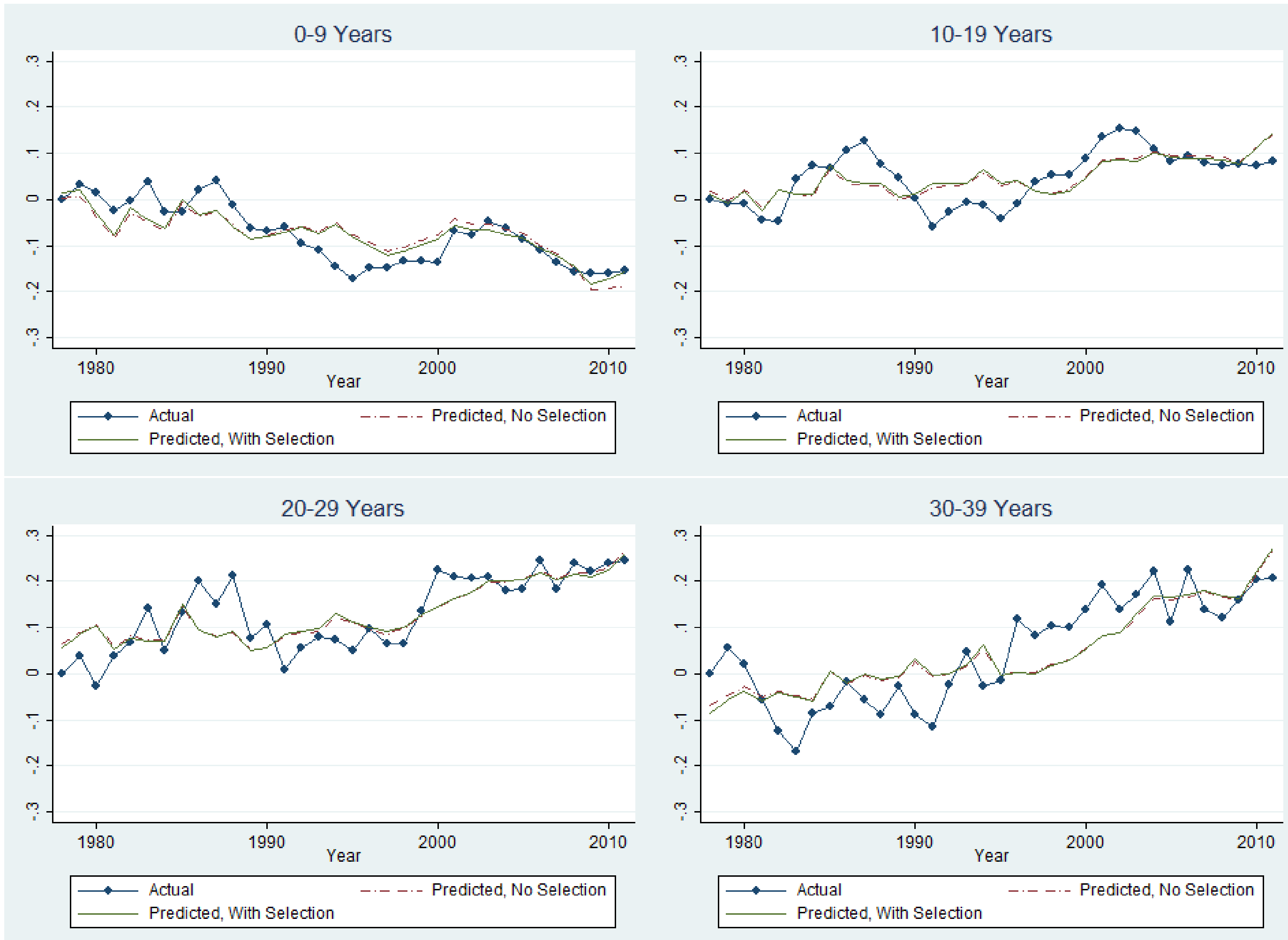


Figure 1.15: Actual versus Predicted University Wage Premium ($\ln(W^c_{kt}/W^n_{kt})$), Controlling for Selection

Table 1.1: Population Share of Completing Post-Secondary Education by Age Group, 2011

	Age Groups				
Unit: %	25-64	25-34	35-44	45-54	55-64
Taiwan	24	43	23	14	12
Korea	28	39	35	22	11
Japan	26	35	26	27	18
Canada	27	31	32	23	22
UK	30	39	32	24	22
USA	32	33	34	30	31

Source: Table 1-2-4, *International Comparison of Education Statistical Indicators*, 2013 Edition, Ministry of Education of Taiwan; Table A1.3a., *Education at a Glance 2013: OECD Indicators*.
"University and above" for Taiwan; "Tertiary: type A and advanced research programs" for other countries.

Table 1.2: Number of Post-Secondary Institutions and Junior Colleges

	Academic Path				Vocational Path					
	University		Four-Year College		University of Technology		Institute of Technology		Junior College	
Year	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private
1987	9	7	5	6	0	0	1	0	21	56
1992	13	8	12	14	0	0	3	0	13	60
1993	13	8	12	14	0	0	3	0	14	60
1994	13	8	12	15	0	0	3	0	14	60
1995	15	8	12	17	0	0	5	1	13	59
1996	16	8	12	17	0	0	6	1	16	58
1997	16	8	15	18	0	0	6	4	14	56
1998	16	17	15	10	4	1	6	9	10	51
1999	16	17	15	10	5	1	7	13	6	47
2000	16	21	15	6	5	2	10	30	4	32
2001	19	23	14	9	6	5	10	41	4	19
2002	21	24	12	11	6	6	11	44	3	16
2003	21	25	12	10	6	9	11	45	3	12
2004	24	26	11	9	6	11	10	45	3	13
2005	26	27	9	8	8	14	8	45	3	11
2006	32	28	3	7	9	20	7	39	3	14
2007	32	30	3	5	9	23	8	37	3	13
2008	32	31	3	5	10	27	7	34	3	12
2009	32	32	1	4	10	28	7	33	3	12
2010	32	32	2	5	10	31	7	30	3	12

Note: Before 1992, there was only one post-secondary institution in the vocational path.

Table 1.3: OLS Regression of the University Wage Premium

Grouping of Potential Experience:	Five-Year Group			Ten-Year Group		
Dependent Variable: $\ln(W^c_{kt}/W^n_{kt})$	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(C_t/N_t)$	0.082	-0.439	-0.410	0.074	-0.488	-0.460
	(0.080)	(0.109)	(0.114)	(0.107)	(0.067)	(0.084)
$\ln(C_{kt}/N_{kt}) - \ln(C_t/N_t)$	-0.138	-0.142	-0.142	-0.185	-0.191	-0.193
	(0.052)	(0.053)	(0.053)	(0.040)	(0.041)	(0.037)
$t/10$	-0.012	0.008	-0.066	-0.008	0.013	-0.055
	(0.050)	(0.0488)	(0.122)	(0.067)	(0.065)	(0.172)
$(t/10)^2$		0.073	0.119		0.079	0.121
		(0.011)	(0.068)		(0.012)	(0.098)
$(t/10)^3$			-0.010			-0.009
			(0.014)			(0.020)
Observations	272	272	272	136	136	136
Adjusted R^2	0.628	0.658	0.660	0.652	0.702	0.703

Dummies for potential experience groups are included in the regression. In Columns (1)-(3) (Five-Year Group), years of potential experience are grouped as 0-4 years, 5-9 years, ..., 35-39 years; in Columns (4)-(6) (Ten-Year Group), years of potential experience are grouped as 0-9 years, 10-19 years, 20-29 years, 30-39 years. t is year index, re-scaled so that $t = 1, 2, 3, ...$, $t^2 = 1, 4, 9, ...$, and $t^3 = 1, 8, 27, ...$ Two-way clustering standard errors by year (t) and group of potential experience (k) are in parentheses.

Table 1.4: OLS Regression of the University Wage Premium, $\sigma^c_{Exp} \neq \sigma^n_{Exp}$

Grouping of Potential Experience:	Five-Year Group			Ten-Year Group		
Dependent Variable: $\ln(W^c_{kt}/W^n_{kt})$	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(C_t/N_t)$	0.066	-0.426	-0.401	0.056	-0.474	-0.450
	(0.066)	(0.119)	(0.125)	(0.078)	(0.084)	(0.110)
$\ln(C_{kt}) - \ln(C_t)$	-0.092	-0.098	-0.099	-0.135	-0.144	-0.145
	(0.028)	(0.029)	(0.030)	(0.018)	(0.022)	(0.028)
$-[\ln(N_{kt}) - \ln(N_t)]$	-0.231	-0.231	-0.231	-0.280	-0.281	-0.281
	(0.039)	(0.040)	(0.039)	(0.016)	(0.021)	(0.017)
$t/10$	-0.001	0.015	-0.049	0.003	0.019	-0.038
	(0.039)	(0.037)	(0.132)	(0.045)	(0.045)	(0.173)
$(t/10)^2$		0.070	0.110		0.075	0.111
		(0.013)	(0.082)		(0.007)	(0.108)
$(t/10)^3$			-0.008			-0.007
			(0.017)			(0.023)
Observations	272	272	272	136	136	136
Adjusted R^2	0.673	0.700	0.701	0.703	0.748	0.748

Dummies for potential experience groups are included in the regression. In Columns (1)-(3) (Five-Year Group), years of potential experience are grouped as 0-4 years, 5-9 years, ..., 35-39 years; in Columns (4)-(6) (Ten-Year Group), years of potential experience are grouped as 0-9 years, 10-19 years, 20-29 years, 30-39 years. t is year index, re-scaled so that $t = 1, 2, 3, ...$, $t^2 = 1, 4, 9, ...$, and and $t^3 = 1, 8, 27, ...$ Two-way clustering standard errors by year (t) and group of potential experience (k) are in parentheses.

Table 1.5: Average Employment Shares by Industry, Occupation and Potential Experience

Years of Potential Experience:	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39
Industry								
Agriculture, Forestry, and Fishing	2.70	3.78	5.16	6.73	9.08	11.55	15.28	20.20
Mining and Quarrying	0.10	0.13	0.18	0.24	0.39	0.54	0.58	0.68
Manufacturing*								
Low Tech	11.88	10.56	10.14	9.72	9.96	9.51	9.00	8.59
Basic	9.47	9.58	9.84	9.34	8.92	8.86	7.87	7.35
High Tech	15.63	14.29	11.47	9.46	7.97	6.51	5.65	4.50
Electricity and Gas Supply	0.17	0.30	0.35	0.41	0.51	0.62	0.58	0.63
Water Supply and Waste Management	0.16	0.26	0.30	0.38	0.49	0.62	0.79	0.87
Construction	5.23	7.04	8.56	9.19	9.24	9.22	8.68	7.45
Whole Sale and Retail Trade	16.48	17.04	16.90	17.29	17.26	16.87	16.48	15.92
Transportation, Warehousing, and Communications	3.37	4.88	6.07	6.79	7.07	6.95	7.11	6.47
Accommodation and Food Services	4.61	3.84	3.66	3.90	4.35	4.72	5.05	4.98
Financial/Professional Services and Information	8.84	8.81	8.01	7.07	6.23	5.16	4.73	4.02
Public Administration	3.37	3.84	4.38	4.50	4.33	4.66	5.08	5.56
Other Services**	17.99	15.66	14.98	14.97	14.20	14.21	13.14	12.80
Occupation								
Managerial and Professional	18.14	19.84	20.10	20.42	19.15	17.71	15.96	14.13
Administrative, Clerical, and Sales	44.62	43.02	40.15	38.20	36.92	35.69	34.83	33.22
Production Workers and Laborers	37.24	37.14	39.75	41.38	43.93	46.60	49.22	52.65

* Low tech manufacturing includes food, tobacco, textile, apparel, leather, wood product, bamboo product, paper manufacturing and printing. Basic manufacturing includes petroleum, chemical, plastic product, rubber product, nonmetallic mineral product, and mineral product manufacturing. High tech manufacturing includes electronic product, computer product, machinery, and transportation equipment manufacturing.
** Other services include education, health care, social assistance, arts, entertainment, recreation, and all the other service industries not included elsewhere.

Table 1.6: Average Employment Shares by Industry, Occupation and Potential Experience, University-Educated Workers

Years of Potential Experience:	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39
Industry								
Agriculture, Forestry, and Fishing	0.56	0.46	0.55	0.65	1.03	0.95	1.42	2.07
Mining and Quarrying	0.39	0.38	0.58	0.60	0.60	0.84	0.77	1.54
Manufacturing*								
Low Tech	6.12	5.09	4.97	4.71	4.90	4.35	4.71	4.99
Basic	5.46	5.74	5.79	4.91	4.95	5.19	5.50	4.86
High Tech	14.49	13.47	10.19	8.21	6.72	4.56	3.64	3.61
Electricity and Gas Supply	0.40	0.50	0.62	0.83	1.27	1.78	1.54	3.10
Water Supply and Waste Management	0.29	0.33	0.38	0.30	0.39	0.40	1.23	0.96
Construction	2.69	3.24	2.98	3.44	2.93	3.04	3.07	3.62
Whole Sale and Retail Trade	14.55	13.52	13.83	14.07	13.27	11.92	11.71	11.78
Transportation, Warehousing, and Communications	4.36	4.59	4.72	5.04	5.35	5.53	7.43	5.45
Accommodation and Food Services	1.59	1.27	1.04	1.05	1.15	1.43	2.20	1.93
Financial/Professional Services and Information	16.20	15.98	14.68	13.20	13.41	11.05	11.83	10.58
Public Administration	5.91	7.81	8.64	9.25	10.12	12.26	13.78	14.77
Other Services**	27.53	28.02	31.75	34.87	35.59	38.72	35.31	38.54
Occupation								
Managerial and Professional	42.27	47.81	53.29	57.40	57.95	58.95	58.30	59.24
Administrative, Clerical, and Sales	50.15	46.70	42.05	38.46	38.03	37.04	36.79	36.10
Production Workers and Laborers	7.58	5.49	4.66	4.14	4.02	4.01	5.06	5.46

* Low tech manufacturing includes food, tobacco, textile, apparel, leather, wood product, bamboo product, paper manufacturing and printing. Basic manufacturing includes petroleum, chemical, plastic product, rubber product, nonmetallic mineral product, and mineral product manufacturing. High tech manufacturing includes electronic product, computer product, machinery, and transportation equipment manufacturing.
** Other services include education, health care, social assistance, arts, entertainment, recreation, and all the other service industries not included elsewhere.

Table 1.7: Average Employment Shares by Industry, Occupation and Potential Experience, Non-University-Educated Workers

Years of Potential Experience:	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39
Industry								
Agriculture, Forestry, and Fishing	3.26	4.53	6.05	7.80	10.16	12.87	16.82	22.04
Mining and Quarrying	0.10	0.13	0.18	0.25	0.42	0.58	0.64	0.74
Manufacturing*								
Low Tech	13.01	11.80	11.26	10.71	10.75	10.20	9.52	8.97
Basic	10.61	10.81	10.89	10.31	9.68	9.43	8.18	7.61
High Tech	15.41	14.14	11.56	9.62	8.22	6.82	5.92	4.64
Electricity and Gas Supply	0.15	0.25	0.29	0.36	0.42	0.51	0.51	0.53
Water Supply and Waste Management	0.17	0.27	0.34	0.43	0.54	0.69	0.84	0.99
Construction	6.09	8.16	9.94	10.45	10.39	10.15	9.40	7.86
Whole Sale and Retail Trade	17.78	18.49	17.94	18.21	18.12	17.60	17.00	16.29
Transportation, Warehousing, and Communications	3.14	4.97	6.41	7.19	7.38	7.17	7.04	6.61
Accommodation and Food Services	6.19	4.85	4.50	4.67	5.06	5.30	5.52	5.34
Financial/Professional Services and Information	5.74	6.30	6.11	5.59	4.92	4.29	3.98	3.38
Public Administration	2.75	2.90	3.47	3.62	3.45	3.63	4.04	4.67
Other Services**	15.61	12.39	11.05	10.79	10.48	10.74	10.62	10.43
Occupation								
Managerial and Professional	9.83	11.28	11.72	12.36	12.33	11.81	11.00	9.87
Administrative, Clerical, and Sales	42.83	42.08	40.05	38.53	37.16	35.62	34.62	32.93
Production Workers and Laborers	47.35	46.63	48.23	49.11	50.50	52.57	54.38	57.21

* Low tech manufacturing includes food, tobacco, textile, apparel, leather, wood product, bamboo product, paper manufacturing and printing. Basic manufacturing includes petroleum, chemical, plastic product, rubber product, nonmetallic mineral product, and mineral product manufacturing. High tech manufacturing includes electronic product, computer product, machinery, and transportation equipment manufacturing.
** Other services include education, health care, social assistance, arts, entertainment, recreation, and all the other service industries not included elsewhere.

Table 1.8: Average Employment Shares by Industry, Occupation, Education and Gender

	Male		Female	
	Non-University	Univ. and Above	Non-University	Univ. and Above
Industry				
Agriculture, Forestry, and Fishing	10.69	0.80	6.51	0.16
Mining and Quarrying	0.43	0.20	0.11	0.24
Manufacturing*				
Low Tech	9.55	5.30	14.97	4.06
Basic	11.28	6.47	7.20	2.75
High Tech	9.24	11.39	10.73	5.62
Electricity and Gas Supply	0.49	0.97	0.10	0.23
Water Supply and Waste Management	0.59	0.30	0.31	0.22
Construction	12.49	3.74	2.33	1.28
Whole Sale and Retail Trade	16.57	13.67	20.16	13.03
Transportation, Warehousing, and Communications	8.07	5.43	2.45	3.98
Accommodation and Food Services	4.13	1.05	6.94	1.33
Financial/Professional Services and Information	4.38	14.32	7.14	13.07
Public Administration	3.79	9.93	3.10	8.22
Other Services**	8.31	26.48	17.96	46.09
Occupation				
Managerial and Professional	12.37	55.86	9.67	46.24
Administrative, Clerical, and Sales	30.71	38.12	54.57	50.81
Production Workers and Laborers	56.92	6.02	35.77	2.96

* Low tech manufacturing includes food, tobacco, textile, apparel, leather, wood product, bamboo product, paper manufacturing and printing. Basic manufacturing includes petroleum, chemical, plastic product, rubber product, nonmetallic mineral product, and mineral product manufacturing. High tech manufacturing includes electronic product, computer product, machinery, and transportation equipment manufacturing.
** Other services include education, health care, social assistance, arts, entertainment, recreation, and all the other service industries not included above.

Table 1.9: Demand Shift Measures Based on Industrial and Occupational Shifts, 1978-2011

	Between Industry					Within Industry					Overall (Industry and Occupation)				
Unit=100%*	78-86	86-94	94-02	02-11	78-11	78-86	86-94	94-02	02-11	78-11	78-86	86-94	94-02	02-11	78-11
By Gender and Educational Level:															
Males															
Jr. HS & Below	-7.64	-3.65	-13.24	-5.94	-30.48	2.22	-0.72	-3.94	-4.84	-7.28	-5.42	-4.36	-17.18	-10.79	-37.75
Sr. HS	1.96	0.55	-1.33	-2.38	-1.20	0.56	-0.26	-0.68	-1.91	-2.29	2.52	0.29	-2.01	-4.29	-3.49
Sr. Voc. HS	1.75	0.34	-2.54	-0.63	-1.08	1.15	-0.68	-1.89	-3.22	-4.64	2.90	-0.34	-4.43	-3.85	-5.72
Jr. College	3.83	3.73	5.08	4.66	17.31	-2.17	1.84	3.35	6.61	9.63	1.66	5.57	8.43	11.27	26.93
Univ. & Above	3.50	5.96	11.94	8.86	30.25	-4.52	2.95	4.01	13.81	16.25	-1.03	8.91	15.95	22.67	46.50
Females															
Jr. HS & Below	-0.42	-10.36	-2.15	-5.28	-18.21	3.02	-1.17	-1.79	-7.07	-7.02	2.60	-11.53	-3.94	-12.35	-25.22
Sr. HS	6.48	2.60	10.26	1.94	21.28	0.51	-0.96	2.71	-4.46	-2.21	6.99	1.64	12.97	-2.53	19.07
Sr. Voc. HS	7.62	3.35	10.21	2.73	23.91	0.07	-1.82	3.75	-4.07	-2.07	7.69	1.53	13.96	-1.34	21.85
Jr. College	4.15	5.54	12.37	5.64	27.70	-3.37	-0.74	4.50	4.34	4.73	0.78	4.80	16.87	9.99	32.43
Univ. & Above	2.04	5.42	14.27	7.20	28.94	-4.44	1.48	2.86	8.67	8.56	-2.40	6.90	17.12	15.87	37.49

* The reported numbers are in the form of $\ln(1 + \Delta X_m) \times 100\%$, where $\Delta X_m = \Sigma_j \alpha_{jm}(\Delta E_j / E_m)$, or the demand shift measures for group m, as shown in Equations (1.10) and (1.11).

Table 1.10: Demand Shift Measures Based on Industrial and Occupational Shifts, 1978-2011

	Between Industry					Within Industry					Overall (Industry and Occupation)				
Unit=100%	78-86	86-94	94-02	02-11	78-11	78-86	86-94	94-02	02-11	78-11	78-86	86-94	94-02	02-11	78-11
By Educational Level and Years of Potential Experience:															
Non-University															
0-9 Years	6.20	2.06	3.23	1.97	13.47	1.15	-1.07	-0.48	-3.66	-4.07	7.35	0.99	2.75	-1.69	9.40
10-19 Years	2.16	1.21	-1.92	-0.79	0.65	0.82	-0.42	-0.66	-2.35	-2.60	2.98	0.78	-2.58	-3.14	-1.95
20-29 Years	-2.66	-2.01	-5.25	-3.49	-13.42	0.78	-0.26	-1.06	-2.26	-2.82	-1.88	-2.28	-6.31	-5.75	-16.23
30-39 Years	-11.62	-8.73	-8.18	-5.84	-34.37	1.17	-0.47	-1.13	-2.46	-2.89	-10.45	-9.20	-9.31	-8.30	-37.26
University and Above															
0-9 Years	5.63	7.08	14.77	9.85	37.34	-3.93	1.99	4.71	11.39	14.16	1.70	9.07	19.48	21.24	51.50
10-19 Years	3.02	6.09	12.83	8.42	30.36	-4.69	2.56	3.50	12.83	14.20	-1.67	8.65	16.33	21.25	44.56
20-29 Years	0.92	4.29	10.75	6.81	22.76	-4.92	2.98	2.76	12.54	13.36	-4.00	7.27	13.51	19.35	36.12
30-39 Years	-1.33	3.53	9.41	6.00	17.61	-4.87	2.72	2.50	11.51	11.86	-6.20	6.25	11.91	17.51	29.47
By Educational Level:															
Non-Univ.	-0.66	-1.25	-2.74	-1.79	-6.44	0.95	-0.54	-0.81	-2.65	-3.05	0.29	-1.79	-3.55	-4.44	-9.49
Univ. & Above	3.03	5.79	12.70	8.32	29.84	-4.50	2.47	3.65	12.15	13.78	-1.47	8.26	16.35	20.47	43.62

* The reported numbers are in the form of $\ln(1 + \Delta X_m) \times 100\%$, where $\Delta X_m = \Sigma_j \alpha_{jm}(\Delta E_j / E_m)$, or the demand shift measures for group m, as shown in Equations (1.10) and (1.11).

Table 1.11: Demand Shift Measures Based on Industrial and Occupational Shifts, By Educational Level and Industry, 1978-2011

	Between Industry					Within Industry					Overall (Industry and Occupation)				
Unit=100%	78-86	86-94	94-02	02-11	78-11	78-86	86-94	94-02	02-11	78-11	78-86	86-94	94-02	02-11	78-11
Non-University															
Agriculture, Forestry and Fishing	-7.73	-6.37	-3.55	-2.07	-19.72	0.06	0.06	0.00	-0.01	0.12	-7.67	-6.31	-3.55	-2.07	-19.6
Mining and Quarrying	-0.60	-0.27	-0.08	-0.07	-1.04	0.02	0.00	0.00	0.00	0.01	-0.59	-0.28	-0.08	-0.08	-1.03
Low Tech Manufacturing	0.92	-4.50	-3.02	-2.05	-8.64	0.09	-0.20	-0.10	-0.12	-0.33	1.01	-4.70	-3.11	-2.17	-8.97
Basic Manufacturing	2.34	-0.73	-1.73	0.34	0.23	0.14	-0.02	-0.14	-0.14	-0.16	2.48	-0.75	-1.87	0.20	0.07
High Tech Manufacturing	2.38	0.31	3.35	2.85	8.89	0.10	-0.07	-0.32	-0.85	-1.15	2.47	0.24	3.03	1.99	7.74
Electricity and Gas Supply	-0.04	-0.09	-0.09	0.02	-0.20	0.01	-0.02	-0.01	-0.02	-0.04	-0.03	-0.11	-0.10	0.00	-0.23
Water Supply and Waste Management	-0.22	0.44	0.03	0.08	0.34	0.01	0.03	-0.01	0.00	0.03	-0.20	0.47	0.02	0.08	0.37
Construction	-0.48	5.02	-4.85	-0.12	-0.43	-0.04	0.00	-0.20	-0.05	-0.30	-0.52	5.02	-5.05	-0.17	-0.73
Whole Sale and Retail Trade	2.38	2.51	0.83	-2.80	2.92	0.05	-0.16	0.12	-0.06	-0.04	2.43	2.35	0.95	-2.86	2.87
Transportation, Warehousing, and Communications	0.04	-0.56	-0.58	-1.19	-2.28	0.01	-0.01	-0.12	-0.06	-0.18	0.05	-0.57	-0.70	-1.25	-2.46
Accommodation and Food Services	1.04	1.03	2.03	-0.39	3.71	0.03	0.00	0.01	-0.02	0.03	1.07	1.03	2.04	-0.41	3.74
Financial/Professional Services and Information	0.50	1.98	2.95	2.40	7.83	0.04	0.02	-0.09	-0.16	-0.19	0.55	2.00	2.86	2.23	7.64
Public Administration	-1.06	-0.53	-0.09	0.48	-1.19	-0.05	-0.13	-0.01	-0.04	-0.23	-1.11	-0.65	-0.10	0.44	-1.42
Other Services	-0.29	0.37	1.96	0.66	2.70	0.49	-0.05	0.06	-1.11	-0.62	0.20	0.32	2.01	-0.45	2.08
University and Above															
Agriculture, Forestry and Fishing	-0.62	-0.51	-0.29	-0.17	-1.59	-0.26	-0.29	-0.01	0.03	-0.54	-0.88	-0.81	-0.30	-0.14	-2.13
Mining and Quarrying	-0.17	-0.08	-0.02	-0.02	-0.30	-0.04	0.02	0.01	0.01	0.00	-0.21	-0.06	-0.01	-0.01	-0.30
Low Tech Manufacturing	0.46	-2.22	-1.49	-1.01	-4.26	-0.42	0.93	0.45	0.58	1.53	0.03	-1.29	-1.04	-0.43	-2.73
Basic Manufacturing	1.25	-0.38	-0.92	0.18	0.13	-0.65	0.08	0.63	0.64	0.71	0.60	-0.30	-0.28	0.82	0.84
High Tech Manufacturing	2.35	0.31	3.31	2.81	8.78	-0.45	0.33	1.51	3.98	5.37	1.90	0.64	4.82	6.79	14.15
Electricity and Gas Supply	-0.07	-0.16	-0.16	0.04	-0.35	-0.04	0.07	0.04	0.09	0.17	-0.10	-0.09	-0.12	0.13	-0.18
Water Supply and Waste Management	-0.15	0.30	0.02	0.06	0.23	-0.06	-0.14	0.05	-0.01	-0.15	-0.21	0.16	0.08	0.05	0.08
Construction	-0.15	1.65	-1.58	-0.04	-0.12	0.20	0.00	0.94	0.24	1.39	0.05	1.65	-0.64	0.21	1.27
Whole Sale and Retail Trade	1.78	1.88	0.63	-2.10	2.19	-0.25	0.74	-0.55	0.26	0.19	1.53	2.62	0.07	-1.84	2.38
Transportation, Warehousing, and Communications	0.03	-0.43	-0.44	-0.91	-1.75	-0.07	0.04	0.57	0.28	0.82	-0.04	-0.39	0.13	-0.62	-0.92
Accommodation and Food Services	0.26	0.25	0.50	-0.10	0.92	-0.15	0.00	-0.07	0.08	-0.13	0.10	0.26	0.43	-0.02	0.78
Financial/Professional Services and Information	1.38	5.44	8.09	6.58	21.50	-0.21	-0.08	0.40	0.76	0.88	1.18	5.36	8.49	7.34	22.37
Public Administration	-2.57	-1.27	-0.21	1.15	-2.90	0.25	0.59	0.04	0.18	1.06	-2.32	-0.68	-0.17	1.34	-1.84
Other Services	-0.80	0.98	5.26	1.77	7.22	-2.30	0.22	-0.28	5.17	2.80	-3.10	1.20	4.98	6.94	10.02

Low tech manufacturing includes food, tobacco, textile, apparel, leather, wood product, bamboo product, paper manufacturing and printing. Basic manufacturing includes petroleum, chemical, plastic product, rubber product, nonmetallic mineral product, and mineral product manufacturing. High tech manufacturing includes electronic product, computer product, machinery, and transportation equipment manufacturing. Other services include education, health care, social assistance, arts, entertainment, recreation, and all the other service industries not included above. The reported numbers are in the form of $\ln(1+\Delta X_m)\times 100\%$, where $\Delta X_m = \Sigma_j \alpha_{jm}(\Delta E_j/E_m)$, or the demand shift measures for group k, as shown in Equations (1.10) and (1.11). The summation of the numbers here is not exactly the same as the last two rows in Table 1.10 because summation of logs does not equal log of summations.

Table 1.12: Relative Demand Shifts for University-Educated Workers Implied from Relative Wage and Supply Shifts, $\ln(D_t^k) - \ln(D_{t_0}^k)$, and Implied from Sectoral Employment Shifts, $\ln(\widetilde{D}_t^k) - \ln(\widetilde{D}_{t_0}^k)$

Unit=100%	1978-1986	1986-1994	1994-2002	2002-2011	1978-2011
$\ln(D_t^k) - \ln(D_{t_0}^k)$					
0-9 Years	13.60	1.67	34.03	47.33	96.62
10-19 Years	16.45	3.15	40.04	29.21	88.84
20-29 Years	24.51	1.72	34.80	36.63	97.67
30-39 Years	1.18	8.40	40.12	30.44	80.14
$\ln(\widetilde{D}_t^k) - \ln(\widetilde{D}_{t_0}^k)$					
0-9 Years	-2.50	4.08	8.13	11.17	20.54
10-19 Years	-1.76	4.08	9.17	11.58	22.73
20-29 Years	-0.73	4.74	9.82	12.04	25.53
30-39 Years	1.36	6.54	10.43	12.49	30.48

Table 1.13: OLS Regression of the University Wage Premium, Controlling for Tracking, Altering the Elasticity of Substitution between Academic and Vocational Graduates, Five-Year Group

	$\psi = 1$ ($\sigma_{Acad} = \infty$)		$\psi = 0.9$ ($\sigma_{Acad} = 10$)		$\psi = 0.6$ ($\sigma_{Acad} = 2.5$)		$\psi = 0.3$ ($\sigma_{Acad} = 1.43$)	
Dependent Variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln(W_{kt}^a/W_{kt}^n)$	$\tau = 1$	$\tau = 0.75$	$\tau = 1$	$\tau = 0.75$	$\tau = 1$	$\tau = 0.75$	$\tau = 1$	$\tau = 0.75$
$\ln(C_t^a/N_t)$	-0.426	-0.398	-0.433	-0.404	-0.447	-0.420	-0.383	-0.392
	(0.119)	(0.119)	(0.118)	(0.116)	(0.120)	(0.110)	(0.141)	(0.114)
$\ln(C_{kt}^a) - \ln(C_t^a)$	-0.098	-0.069	-0.098	-0.069	-0.096	-0.069	-0.069	-0.058
	(0.029)	(0.030)	(0.029)	(0.030)	(0.027)	(0.028)	(0.020)	(0.023)
$-[\ln(N_{kt}) - \ln(N_t)]$	-0.231	-0.159	-0.228	-0.157	-0.216	-0.150	-0.210	-0.146
	(0.040)	(0.036)	(0.039)	(0.035)	(0.036)	(0.032)	(0.041)	(0.033)
$t/10$	0.015	0.008	0.012	0.007	0.014	0.008	0.124	0.092
	(0.037)	(0.041)	(0.036)	(0.041)	(0.036)	(0.041)	(0.074)	(0.063)
$(t/10)^2$	0.070	0.069	0.073	0.071	0.084	0.080	0.072	0.076
	(0.013)	(0.012)	(0.013)	(0.012)	(0.016)	(0.013)	(0.019)	(0.013)
Observations	272	272	272	272	272	272	272	272
Adjusted R^2	0.700	0.669	0.702	0.670	0.708	0.674	0.705	0.676

Dummies for potential experience groups are included in the regression. Years of potential experience are grouped as 0-4 years, 5-9 years, ..., 35-39 years. t is year index, re-scaled so that $t = 1, 2, 3, ...$ and $t^2 = 1, 4, 9, ...$ Two-way clustering standard errors by year (t) and group of potential experience (k) are in parentheses.

Table 1.14: OLS Regression of the University Wage Premium, Controlling for Tracking, Altering the Elasticity of Substitution between Academic and Vocational Graduates, Ten-Year Group

	$\psi = 1$ ($\sigma_{Acad} = \infty$)		$\psi = 0.9$ ($\sigma_{Acad} = 10$)		$\psi = 0.6$ ($\sigma_{Acad} = 2.5$)		$\psi = 0.3$ ($\sigma_{Acad} = 1.43$)	
Dependent Variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln(W^a_{kt}/W^n_{kt})$	$\tau = 1$	$\tau = 0.75$	$\tau = 1$	$\tau = 0.75$	$\tau = 1$	$\tau = 0.75$	$\tau = 1$	$\tau = 0.75$
$\ln(C^a_t/N_t)$	-0.474	-0.447	-0.482	-0.454	-0.500	-0.472	-0.397	-0.408
	(0.084)	(0.088)	(0.083)	(0.082)	(0.102)	(0.076)	(0.145)	(0.112)
$\ln(C^a_{kt}) - \ln(C^a_t)$	-0.144	-0.113	-0.141	-0.111	-0.133	-0.106	-0.098	-0.088
	(0.022)	(0.030)	(0.022)	(0.030)	(0.020)	(0.027)	(0.012)	(0.017)
$-[\ln(N_{kt}) - \ln(N_t)]$	-0.281	-0.203	-0.274	-0.198	-0.250	-0.182	-0.257	-0.184
	(0.021)	(0.015)	(0.021)	(0.014)	(0.021)	(0.014)	(0.026)	(0.017)
$t/10$	0.019	0.013	0.017	0.012	0.020	0.013	0.115	0.086
	(0.045)	(0.053)	(0.045)	(0.053)	(0.044)	(0.055)	(0.078)	(0.074)
$(t/10)^2$	0.075	0.074	0.079	0.077	0.091	0.087	0.076	0.080
	(0.007)	(0.011)	(0.007)	(0.010)	(0.011)	(0.008)	(0.018)	(0.012)
Observations	136	136	136	136	136	136	136	136
Adjusted R^2	0.748	0.698	0.749	0.699	0.757	0.705	0.760	0.713

Dummies for potential experience groups are included in the regression. Years of potential experience are grouped as 0-9 years, 10-19 years, 20-29 years, 30-39 years. t is year index, re-scaled so that $t = 1, 2, 3, ...$ and $t^2 = 1, 4, 9, ...$ Two-way clustering standard errors by year (t) and group of potential experience (k) are in parentheses.

Table 1.15: Relative Demand Shifts for University-Educated Workers Implied from Relative Wage and Supply Shifts, $\ln(D_t^k) - \ln(D_{t_0}^k)$, and Implied from Tracking, $\ln(T_t^k) - \ln(T_{t_0}^k)$

Unit=100%	1978-1986	1986-1994	1994-2002	2002-2011	1978-2011
$\tau = 0.75, \psi = 1$					
(Table 1.14, Column (2))					
$\ln(D_t^k) - \ln(D_{t_0}^k)$					
0-9 Years	12.06	-0.32	31.56	40.21	83.51
10-19 Years	16.85	2.43	38.42	27.01	84.71
20-29 Years	24.44	1.48	34.05	35.47	95.43
30-39 Years	1.53	8.37	39.05	31.83	80.78
$\ln(T_t^k) - \ln(T_{t_0}^k)$					
0-9 Years	-0.24	-0.26	-1.68	-7.75	-9.93
10-19 Years	0.04	-0.16	-0.06	-0.18	-0.36
20-29 Years	0.04	0.07	0.17	1.25	1.53
30-39 Years	0.04	0.07	0.30	1.56	1.97
$\tau = 1, \psi = 0.9$					
(Table 1.14, Column (3))					
$\ln(D_t^k) - \ln(D_{t_0}^k)$					
0-9 Years	13.64	1.79	34.31	47.51	97.25
10-19 Years	16.68	3.40	40.39	29.81	90.28
20-29 Years	24.65	2.03	35.24	37.33	99.26
30-39 Years	1.36	8.68	40.54	31.37	81.95
$\ln(T_t^k) - \ln(T_{t_0}^k)$					
0-9 Years	-0.24	-0.26	-0.79	-1.40	-2.69
10-19 Years	-0.12	-0.27	-0.53	-1.26	-2.18
20-29 Years	-0.12	-0.17	-0.49	-1.05	-1.82
30-39 Years	-0.12	-0.17	-0.42	-0.97	-1.67
$\tau = 0.75, \psi = 0.9$					
(Table 1.14, Column (4))					
$\ln(D_t^k) - \ln(D_{t_0}^k)$					
0-9 Years	12.11	-0.19	31.81	40.42	84.15
10-19 Years	17.01	2.64	38.72	27.52	85.90
20-29 Years	24.56	1.73	34.41	36.04	96.74
30-39 Years	1.68	8.61	39.40	32.55	82.25
$\ln(T_t^k) - \ln(T_{t_0}^k)$					
0-9 Years	-0.40	-0.44	-2.22	-8.76	-11.82
10-19 Years	-0.04	-0.35	-0.44	-1.07	-1.90
20-29 Years	-0.04	-0.05	-0.18	0.50	0.21
30-39 Years	-0.04	-0.05	-0.01	0.86	0.75

Table 1.16: OLS Regression of the University Wage Premium, Controlling for Tracking, Varying τ, Five-Year Group

	$\psi = 1$ ($\sigma_{Acad} = \infty$)		$\psi = 0.9$ ($\sigma_{Acad} = 10$)		$\psi = 0.6$ ($\sigma_{Acad} = 2.5$)		$\psi = 0.3$ ($\sigma_{Acad} = 1.43$)	
Dependent Variable: $\ln(W^a_{kt}/W^n_{kt})$	(1) $\tau_{min} = 0.9$	(2) $\tau_{min} = 0.75$	(3) $\tau_{min} = 0.9$	(4) $\tau_{min} = 0.75$	(5) $\tau_{min} = 0.9$	(6) $\tau_{min} = 0.75$	(7) $\tau_{min} = 0.9$	(8) $\tau_{min} = 0.75$
$\ln(C^a_t/N_t)$	-0.409	-0.383	-0.416	-0.388	-0.429	-0.394	-0.373	-0.324
	(0.118)	(0.119)	(0.117)	(0.117)	(0.117)	(0.117)	(0.131)	(0.121)
$\ln(C^a_{kt}) - \ln(C^a_t)$	-0.087	-0.069	-0.087	-0.070	-0.087	-0.073	-0.064	-0.057
	(0.029)	(0.030)	(0.029)	(0.030)	(0.028)	(0.029)	(0.020)	(0.022)
$-[\ln(N_{kt}) - \ln(N_t)]$	-0.204	-0.159	-0.201	-0.158	-0.192	-0.153	-0.190	-0.156
	(0.037)	(0.033)	(0.036)	(0.033)	(0.034)	(0.031)	(0.038)	(0.036)
$t/10$	0.011	0.005	0.009	0.004	0.014	0.011	0.128	0.114
	(0.040)	(0.044)	(0.039)	(0.044)	(0.040)	(0.046)	(0.079)	(0.086)
$(t/10)^2$	0.068	0.067	0.071	0.069	0.081	0.075	0.067	0.057
	(0.012)	(0.012)	(0.012)	(0.012)	(0.014)	(0.013)	(0.014)	(0.009)
Observations	272	272	272	272	272	272	272	272
Adjusted R^2	0.686	0.662	0.687	0.663	0.693	0.668	0.691	0.667

Dummies for potential experience groups are included in the regression. Years of potential experience are grouped as 0-4 years, 5-9 years, ..., 35-39 years. t is year index, re-scaled so that $t = 1, 2, 3, ...$ and $t^2 = 1, 4, 9, ...$ Two-way clustering standard errors by year (t) and group of potential experience (k) are in parentheses.

Table 1.17: OLS Regression of the University Wage Premium, Controlling for Tracking, Varying τ, Ten-Year Group

	$\psi = 1$ ($\sigma_{Acad} = \infty$)		$\psi = 0.9$ ($\sigma_{Acad} = 10$)		$\psi = 0.6$ ($\sigma_{Acad} = 2.5$)		$\psi = 0.3$ ($\sigma_{Acad} = 1.43$)	
Dependent Variable: $\ln(W^a_{kt}/W^n_{kt})$	(1) $\tau_{min} = 0.9$	(2) $\tau_{min} = 0.75$	(3) $\tau_{min} = 0.9$	(4) $\tau_{min} = 0.75$	(5) $\tau_{min} = 0.9$	(6) $\tau_{min} = 0.75$	(7) $\tau_{min} = 0.9$	(8) $\tau_{min} = 0.75$
$\ln(C^a_t/N_t)$	-0.458	-0.432	-0.465	-0.438	-0.482	-0.447	-0.380	-0.328
	(0.086)	(0.092)	(0.084)	(0.089)	(0.094)	(0.090)	(0.128)	(0.096)
$\ln(C^a_{kt}) - \ln(C^a_t)$	-0.133	-0.118	-0.132	-0.117	-0.125	-0.115	-0.0948	-0.091
	(0.026)	(0.032)	(0.025)	(0.031)	(0.022)	(0.024)	(0.013)	(0.013)
$-[\ln(N_{kt}) - \ln(N_t)]$	-0.255	-0.213	-0.249	-0.208	-0.229	-0.196	-0.240	-0.213
	(0.019)	(0.017)	(0.018)	(0.017)	(0.018)	(0.017)	(0.023)	(0.020)
$t/10$	0.016	0.010	0.014	0.010	0.020	0.018	0.116	0.102
	(0.050)	(0.058)	(0.050)	(0.058)	(0.051)	(0.060)	(0.082)	(0.079)
$(t/10)^2$	0.074	0.072	0.077	0.075	0.088	0.082	0.070	0.060
	(0.008)	(0.010)	(0.007)	(0.010)	(0.008)	(0.009)	(0.013)	(0.011)
Observations	136	136	136	136	136	136	136	136
Adjusted R^2	0.729	0.697	0.730	0.698	0.737	0.706	0.742	0.713

Dummies for potential experience groups are included in the regression. Years of potential experience are grouped as 0-9 years, 10-19 years, 20-29 years, and 30-39 years. t is year index, re-scaled so that $t = 1, 2, 3, ...$ and $t^2 = 1, 4, 9, ...$ Two-way clustering standard errors by year (t) and group of potential experience (k) are in parentheses.

Table 1.18: Relative Demand Shifts for University-Educated Workers Implied from Relative Wage and Supply Shifts, $\ln(D_t^k) - \ln(D_{t_0}^k)$, and Implied from Tracking, $\ln(T_t^k) - \ln(T_{t_0}^k)$, Varying τ

Unit=100%	1978-1986	1986-1994	1994-2002	2002-2011	1978-2011
$\tau_{min} = 0.75, \psi = 1$					
(Table 1.17, Column (2))					
$\ln(D_t^k) - \ln(D_{t_0}^k)$					
0-9 Years	11.98	-0.65	30.99	39.75	82.08
10-19 Years	16.55	1.96	37.73	25.88	82.11
20-29 Years	24.12	0.98	33.26	34.20	92.57
30-39 Years	1.16	7.73	38.33	30.22	77.45
$\ln(T_t^k) - \ln(T_{t_0}^k)$					
0-9 Years	-0.01	-0.02	-0.49	-9.90	-10.42
10-19 Years	0.0011	-0.0011	0.04	1.16	1.20
20-29 Years	0.0011	0.0036	0.07	1.63	1.70
30-39 Years	0.0011	0.0036	0.07	1.65	1.73
$\tau_{min} = 0.75, \psi = 0.9$					
(Table 1.17, Column (4))					
$\ln(D_t^k) - \ln(D_{t_0}^k)$					
0-9 Years	12.02	-0.55	31.20	39.93	82.60
10-19 Years	16.72	2.15	37.98	26.31	83.15
20-29 Years	24.20	1.22	33.58	34.69	93.70
30-39 Years	1.26	7.90	38.65	30.85	78.66
$\ln(T_t^k) - \ln(T_{t_0}^k)$					
0-9 Years	-0.22	-0.25	-1.14	-10.76	-12.37
10-19 Years	-0.11	-0.24	-0.42	0.30	-0.47
20-29 Years	-0.11	-0.15	-0.36	0.92	0.30
30-39 Years	-0.11	-0.15	-0.30	1.01	0.45

Table 1.19: OLS Regression of the University Wage Premium, Controlling for Selection

Grouping of Potential Experience:	Five-Year Group	Ten-Year Group
Dependent Variable:		
$\ln(W^c_{kt}/W^n_{kt}) - \sigma_A(\lambda_+(c_{kt}) - \lambda_-(c_{kt}))$	(1)	(2)
$\ln(C'_t/N'_t)$	-0.392	-0.447
	(0.143)	(0.101)
$\ln(C'_{kt}) - \ln(C'_t)$	0.002	-0.046
	(0.034)	(0.020)
$-[\ln(N'_{kt}) - \ln(N'_t)]$	-0.188	-0.232
	(0.040)	(0.018)
$t/10$	0.032	0.034
	(0.034)	(0.035)
$(t/10)^2$	0.069	0.075
	(0.014)	(0.008)
Observations	272	136
Adjusted R^2	0.765	0.809

Dummies for potential experience groups are included in the regression. In Column (1) (Five-Year Group), years of potential experience are grouped as 0-4 years, 5-9 years, ..., 35-39 years; in Column (2) (Ten-Year Group), years of potential experience are grouped as 0-9 years, 10-19 years, 20-29 years, 30-39 years. t is year index, re-scaled so that $t = 1, 2, 3, ...$ and $t^2 = 1, 4, 9, ...$ Two-way clustering standard errors by year (t) and group of potential experience (k) are in parentheses.

Table 1.20: Relative Demand Shifts for University-Educated Workers Implied from Relative Wage and Supply Shifts, $\ln(D^k_t) - \ln(D^k_{t_0})$, and Explained by Selection into University, $\ln(H^k_t) - \ln(H^k_{t_0})$

Unit=100%	1978-1986	1986-1994	1994-2002	2002-2011	1978-2011
$\ln(D^k_t) - \ln(D^k_{t_0})$					
0-9 Years	12.08	1.45	31.91	40.46	85.90
10-19 Years	13.05	1.60	39.66	28.12	82.43
20-29 Years	28.15	-2.78	32.92	35.92	94.22
30-39 Years	5.23	13.87	35.91	31.50	86.51
$\ln(H^k_t) - \ln(H^k_{t_0})$					
0-9 Years	-3.53	-2.39	-4.14	-3.93	-13.99
10-19 Years	-3.14	-2.96	-2.63	-1.97	-10.70
20-29 Years	3.26	-5.07	-3.75	-2.60	-8.16
30-39 Years	4.55	4.79	-5.95	-0.23	3.17

CHAPTER II

Trade, Outsourcing, and the Demand for Skilled Labor in Taiwan, 1981-2011

2.1 Introduction

Between 1981 and 2011, the employment share and the relative supply of skilled labor trended up in Taiwan, but the skill premium did not trend down (Figure 2.1), which suggests that the relative demand for skilled labor must have increased. Also, trade as a share of GDP in Taiwan increased from around 40% to 60%, Taiwan shifted from exporting basic manufacturing products to exporting high-tech manufacturing products, and China became one of Taiwan's main trading partners. Given that trade is an integral part of the Taiwanese economy, in this paper, we study the extent to which the change in the composition of trading commodities and trading partners is accountable for the shifts in the relative demand for skilled labor in Taiwan.

Earlier studies on the impact of trade on the skill premium in the U.S. suggested that the effect was small. The relative demand for skilled labor started to increase in the 1980s in the U.S., and it was also a period when the imports of unskilled-labor-intensive manufacturing products increased. However, most studies on the U.S. labor market as a whole, such as Katz and Murphy (1992), Bound and Johnson (1992), Berman et al. (1994), and Borjas et al. (1997), found that the effect of trade on the relative demand for skilled labor was at most modest, even though the effect may be large for certain local labor markets (Autor et al., forthcoming). With regard to this small effect, Krugman (2008) argued that intermediate products with different skill intensities were often produced in different countries, so the effect of trade would be bigger if these studies had taken the vertical integration among countries into account, but he also admitted that more finely disaggregated data by sector would be needed to prove this claim.

In contrast, earlier studies on other places suggested mixed results. For example, Wood (1997) summarized that during the 1960s and 1970s in East Asia, including Taiwan, openness to trade increased and the skill premium decreased, while in Latin America during the 1980s and 1990s, openness to trade and the skill premium both increased, and he concluded that this difference might be better explained by the difference between the two periods, rather than the difference between the two regions. Robbins (1996) compared nine countries across Asia and Latin America, including Taiwan, between the 1970s and the mid-1990s, and concluded that opening to trade would increase the relative demand for skilled workers. Lu (1993) found that trade patterns explained quite well the decrease in the labor demand for less-educated women in Taiwan in 1978-1990, but not as much for other workers. Chen and Hsu (2001) found that exporting to OECD and non-OECD countries had opposite effects on the skill premium in Taiwan in 1979-1998 for male workers with no more than ten years of working experience. These papers provided thorough documentation on the development of Taiwan as well as other developing countries before the mid-1990s, but given that the Taiwanese economy has also changed dramatically for the past two decades, an update to these results would be beneficial.

In this paper, we provide more current information and update earlier studies on Taiwan as mentioned before, and our results may also provide insights to the aforementioned U.S. literature. Specifically, following the methodology used in the

U.S. literature, we use a supply-demand framework to quantify the relative demand for skilled labor explained by trade. However, to construct a better measure of the factor content of trade, we build a global input-output system to take into account the demand for intermediate goods implied from observed trade flows. By construction, this factor content of trade measure includes the kind of outsourcing as described by Feenstra and Hanson (1996), or the import of intermediate inputs by domestic firms, and it also addresses the concerns raised by Krugman (2008) about the prevalence of vertical integration among countries. Moreover, one advantage of using the Taiwanese data is that our global input-output system does not rely on the proportionality assumption, which assumes the proportion of imported intermediate input is the same for all industries, because we have separate input-output tables for domestically produced and imported intermediate inputs. Depending on data availability, the number of industries in our system ranges from around 25 to 90.

Despite constructing the factor content of trade with care, our results still suggest that trade has little effect on the relative demand for skilled labor, or, at least trade does not greatly affect the relative demand for skilled labor through the between-industry channel. Even though our data might not be disaggregated enough, either, as Krugman (2008) discussed about the U.S. data — after all, sectors are not necessarily defined by skill intensity in the data — this is still an interesting finding. First of all, unlike the U.S., where trade accounts for only about 10% of the GDP, trade is more important for the Taiwanese economy, so it is surprising that we also find a small effect for Taiwan. In addition, we have taken into account trade in intermediate inputs as much as we can, so it is interesting that the effect is still small. These results suggest that we should instead look for the other factors which would increase the relative demand for skilled labor *within* each industry.

We provide directions for future research by documenting the patterns of outsourcing and explaining how it might increase the relative demand for skilled labor within each industry. The prevalence of outsourcing increased dramatically in the 2000s for almost all industries, and since coordinating outsourcing activities requires non-production workers, who are more likely to be skilled workers, outsourcing may be accountable for the increase in the relative demand for skilled labor within each industry.

The rest of the paper is organized as follows. Section 2.2 documents the data used throughout this paper. Section 2.3 summarizes the patterns of trade and employment between 1981 and 2011. Section 2.4 calculates the factor content of trade and quantifies the relative demand for skilled labor explained by trade. Section 2.5 provides directions for future research by documenting the patterns of outsourcing. Lastly, Section 2.6 concludes.

2.2 Data

2.2.1 Trade Data and Input-Output Tables

Most of the trade data we use in this paper are based on the *Monthly Statistics of Exports and Imports*, released by the Ministry of Finance of Taiwan. The statistics are organized by the 2-digit Standard International Trade Classification (SITC), revision 2 or revision 3, and include several 3-digit sub-commodities which are crucial to the Taiwanese economy. Since the information on these sub-commodities are not available in earlier years of data, we use Comtrade, in which Taiwan is listed as "Other Asia, n.e.s.," and the NBER-United Nations Trade Data to calculate the proportion of these sub-commodities to the corresponding 2-digit commodities, and then use these proportions to recover the trade volumes of sub-commodities. We also use Comtrade when we draw graphs illustrating trade shares by commodities *and* trading partners. All these data are based on customs records and thus do not include trade in services. Throughout this paper, we use the terms "tradable sector" and "non-tradable sector."

The former includes mostly the industries in the primary and secondary sectors and appears in the customs-record-based trade data, while the latter includes mostly the tertiary sector and does not appear in such trade data.

Input-output tables of Taiwan are generated by the Directorate-General of Budget, Accounting and Statistics (DGBAS). There are separate tables for domestic intermediate goods, imported intermediate goods, and all intermediate goods combined, and imports are valued in C.I.F. prices. Both the matrices of coefficients and the transaction tables, or the tables used for generating national accounting statistics and the coefficients in input-output tables, are available, tables are $C \times C$ (both the columns and the rows list commodities), and about 120-160 commodities are included. Tables are available in years 1981, 1984, 1986, 1989, 1991, 1994, 1996, 1999, 2001, 2004, and 2006, but we do not always use all the tables throughout the paper. First, since firm-level censuses are performed every five years (1981, 1986, 1991, 1996, 2001, and 2006), and tables generated in census years tend to be more accurate, off-census-year tables are sometimes discarded. Second, tables before 1991 are sometimes not used because these tables do not separate electronic parts and components out as a distinct category.

In addition to the trade data based on customs records as mentioned before, transaction tables provide one other version of trade data. They are generated from customs records and balance of payments, so they include trade in commodities and services. Since trade data from transaction tables and the data on employment are both generated by the DGBAS, the industrial classifications in these two datasets are more compatible. This compatibility allows us to have as many as 91 industries when we calculate the factor content of trade, instead of having at most 28 industries when we use the other trade data. Therefore, even though we will mostly use the trade data based on customs records to summarize trade patterns, we will use both versions of trade data to calculate the factor content of trade in Section 2.4.

2.2.2 Employment Data

We use the 1981-2011 *Manpower Utilization Survey* (MUS) and the 1987-2011 *Employees' Earnings Survey* (EES), both administered by the DGBAS, to obtain information on employment. The MUS surveys individuals every May, while the EES is a monthly firm-level survey. The MUS is similar to the Current Population Survey in the U.S., so it provides detailed information on individual workers, but the industry of electronic parts and components, which is essential to the development of the Taiwanese economy, was not a distinct category in the MUS until 2002. In contrast, the EES uses a more refined industrial classification and includes the industry of electronic parts and components as a distinct category, but the information on individual workers is not as exhaustive. It only provides information on the number of workers, total working hours, and total wage bills in each firm, and workers are only separated into two categories based on occupation. Also, firms in the agricultural sector and some service sectors are not surveyed in the EES, and employers, self-employed workers, and unpaid family workers working in family businesses are not included. Given that both surveys have their advantages and limitations, we use both throughout this paper.

We define skilled labor either by workers' educational attainment or by occupation. The first definition of skilled labor is university-educated workers, often labeled as "University-Educated" throughout the paper. This definition is used only when we use the MUS data because the EES does not provide information on workers' educational attainment. The second definition of skilled labor is those who work in the managerial and professional occupations, often labeled as "Managerial and Professional" throughout the paper, and it is used both when we use the MUS and the EES data. Since the EES separates workers into only two occupational categories, we consider one of the two categories as managerial and professional when we use the EES data. As to the MUS, the coding scheme of occupations has changed since

1993 in the way that occupations are grouped into nine broad categories roughly corresponding to skill intensities, coded as 1-9, so we consider occupation codes 1-4 as managerial and professional.[1]

We use the 1993-2011 MUS data to examining the mapping between education and occupation. Figure 2.2 illustrates the relationship between the proportion of university-educated workers and the occupation code in 1993-2011. As can be seen, the mapping between educational attainment and the new occupational coding scheme are matched quite well, and the proportion of university-educated workers is much lower for occupation codes 5-9 than occupation codes 1-4. Figure 2.3 displays the distribution of occupations in tradable and non-tradable sectors, and the vertical axis represents the proportion of workers in each occupation. As can be seen, the distribution of occupations in the tradable sector is more polarized, while the distribution of occupations in the non-tradable sector concentrates more in the middle. This suggests that the distinction between skilled and unskilled occupations might be less clear in the non-tradable sector than in the tradable sector.

We now describe how we generate relative labor supply and relative wage measures throughout the paper. When we use the EES, we treat total monthly wage bill as total effective monthly working hours and use this measure as effective labor supply, while hourly wage is calculated as total monthly wage bill divided by total monthly working hours. We calculate labor supply and hourly wage measures separately for skilled and unskilled workers, take logs, and then take difference between skilled and unskilled workers. These differences are the relative supply and the relative wage of skilled labor when we use the EES data.

In contrast, since the MUS provide more information on individual workers, we

[1] The definition of the occupation code in the 1993-2011 MUS is as follows: 1 represents Legislators, Senior Officials and Managers; 2 represents Professionals; 3 represents Technicians and Associate Professionals; 4 represents Clerical Support Workers; 5 represents Service and Sales Workers; 6 represents Skilled Agricultural, Forestry and Fishery Workers; 7 represents Craft and Related Trades Workers; 8 represents Plant and Machine Operators and Assemblers; and 9 represents Elementary Laborers.

control for several aspects of workers' characteristics when we use the MUS. Specifically, we first regress log hourly wage on dummies of potential experience group (0-4 years, 5-9 years, ..., 35-39 years), detailed educational attainment (junior high school and below, senior high school, vocational senior high school, junior college, university), and the whole interaction terms between gender and year dummies. These regressions are run separately for skilled and unskilled workers, and only wage and salaried workers are included in the regressions. Then, the skill premium is calculated as the difference in the coefficients of year dummies between the two wage regressions. As to the relative labor supply, we first use the aforementioned regressions to predict the log hourly wage for all the employed workers, including wage and salaried workers, self-employed workers, and unpaid family workers working at least 15 hours during the reference week, and we set all the year dummies to be zero. Then, we calculate the weighted sum of weekly working hours for skilled and unskilled workers, using the exponential of the predicted log hourly wages as the weight. Finally, we take logs and then take difference to generate the relative supply of skilled labor.

2.3 Trade Patterns, Input-Output System, and Employment

2.3.1 Gross Trade Patterns

Trade has always been an integral part of the Taiwanese economy, but the importance of trade increased further in the 2000s. Figure 2.4 illustrates the trade volume of Taiwan as a share of GDP. As can be seen, both export and import stayed at around 40% as a share of GDP before 2000, trended upward in the 2000s, and then reached around 60% in the late 2000s and early 2010s.

With regard to the share of trading commodities, as can be seen in Figure 2.5, the main export commodities of Taiwan have changed from basic manufacturing products (Food, Beverages, Tobacco, Wood and Paper Products; Garments, Apparel, Footwear, and Leather Products) to high-tech manufacturing products (Electronic Parts and Components; Computers, Electronics, Optical and Precision Instruments; and Machinery, Power-Generating Machinery, Household Appliances), and the export share of Electronic Parts and Components has increased from negligible in 1981 to about 20% in 2011. In contrast, the composition of import commodities stays relatively stable. Besides, Taiwan seems to have moved up its position in the supply chain in terms of export commodities. Figures 2.6 and 2.7 plot net import as a share of gross output by commodities. As can be seen, Taiwan has shifted from exporting Garments, Apparel, Footwear, and Leather Products to exporting Textiles and from a net importer to a net exporter of Electronic Parts and Components.

Part of the changes in trading commodities might be related to the change in the relative importance of trading partners. As illustrated in Figure 2.8, even though Japan and the U.S. remain important trading partners of Taiwan, China has been Taiwan's main trading partner since around 2000. The share of export to China has increased from negligible before 2000 to about 20% in 2012, the share of import from China has increased steadily since 1990 and reached about 15% in 2012, and the trade surplus from China has exceeded the trade surplus from the U.S. since the early 2000s. Figures 2.9 and 2.10 illustrate export and import shares by trading partners and commodities. As can be seen, the patterns of export to China and Hong Kong are similar: an increase in the export share of Electronic Parts and Components, and a decrease in the export share of Textiles. With regard to the exports to Japan, the export share was the largest for food and beverages in the 1980s and 1990s, while the export share of high-tech manufacturing products was the largest in the 2000s. As to the exports to the US, the most noticeable change is the decrease in the export share of apparels. In contrast, the pattern of imports does not change much over time.

To sum up, during the past three decades, the importance of trade to the Taiwanese economy has increased, the pattern of export has changed more dramatically than the pattern of import, and Taiwan has shifted from exporting basic manufacturing products to exporting high-tech products and from exporting final goods to intermediate products. In addition, the trade share with China was small in the 1980s, but China has become one of Taiwan's main trading partners in the 2000s.

2.3.2 Input-Output System and Imported Intermediate Input

We first summarize the magnitudes of intermediate input and imported intermediate input. Table 2.1 presents the proportion of intermediate input to gross output by sector. As can be seen, the proportion of intermediate input to gross output ranged around 0.5-0.6 for the whole economy, ranged around 0.35-0.4 for the non-tradable sector, and increased from around 0.7 to 0.8 for the tradable sector between 1981 and 2006. Table 2.2 summarizes the proportion of imported intermediate input to the total value of intermediate input. As can be seen, the proportion of imported intermediate input for the whole economy has increased between 1981 and 2006, and the tradable sector seems to be more responsible for this increase. In short, intermediate input is an integral part of production, and the importance of imported intermediate input has increased over time.

Now, we turn our focus to imported intermediate input within more detailed industrial categories. Since producing one unit of output requires domestic and imported intermediate inputs, which also require domestic and imported intermediate inputs, and so on, we include the intermediate input of intermediate inputs in our calculations. Assume that the economy consists of J industries, and A is a $J \times J$ matrix representing the input-output table of Taiwan, so the element of the j-th row and i-th column of A, $A(j, i)$, represents the amount of industry-j goods required as intermediate input to produce one unit of output in industry i. Also, assume $A = B_{11} + B_{12}$, where 1 represents Taiwan and 2 represents the rest of the world, and the elements of j-th row and i-th column of B_{11} and B_{12}, $B_{11}(j, i)$ and $B_{12}(j, i)$, represent the amount of domestic and imported industry-j goods required as intermediate input to produce one unit of output in industry i, respectively. Besides, define Y_i as a $J \times 1$ vector with the i-th element to be one and the other elements to be zero.

Figure 2.11 illustrates the relationship among output, intermediate input, and the intermediate input of intermediate inputs, with domestic intermediate inputs colored as yellow and imported intermediate inputs uncolored. Concerning simplicity and data availability, Figure 2.11 assumes that the rest of the world has the same input-output tables as Taiwan does. To produce one unit of output in industry i, we need $B_{11}Y_i$ units of domestic intermediate input and $B_{12}Y_i$ units of imported intermediate input. In addition, producing $B_{11}Y_i$ requires $B_{11}B_{11}Y_i$ units of domestic intermediate input and $B_{12}B_{11}Y_i$ units of imported intermediate input, producing $B_{12}Y_i$ requires $B_{11}B_{12}Y_i$ units of domestic intermediate input and $B_{12}B_{12}Y_i$ units of imported intermediate input, producing $B_{11}B_{11}Y_i$, $B_{11}B_{12}Y_i$, $B_{12}B_{11}Y_i$, and $B_{12}B_{12}Y_i$ all require domestic and imported intermediate inputs as listed in Figure 2.11, and so on. Therefore, the sum of all the domestic intermediate inputs required to produce one unit of output in industry i is $B_{11}(I - A)^{-1}Y_i$, and the sum of all the imported intermediate inputs required to produce one unit of output in industry i is $B_{12}(I - A)^{-1}Y_i$.

Table 2.3 summarizes the amount of imported intermediate input required to produce one unit of output in each industry, excluding the amount of imported Mining and Quarrying products used as intermediate inputs. In other words, the values in Table 2.3 represent the sum of all elements in vector $B_{12}(I - A)^{-1}Y_i$ subtracting the amount of imported Mining and Quarrying products used as intermediate input. For example, in 1981, the total amount of imported intermediate input required for producing one unit of output in Textiles, excluding the amount of imported Mining and Quarrying products used as intermediate input for the production of Textiles, was 0.3760. Since imported Mining and Quarrying products are indispensable inputs of production in Taiwan, we exclude those so that the values in Table 2.3 are not affected too much by the price of imported Mining and Quarrying products. As can be seen in Table 2.3, across all industries, the amount of imported intermediate input required to produce one unit of output increased between 1981 and 2006, and the tradable sector tends to use more imported intermediate input than the non-tradable sector.[2]

In addition to imported intermediate input as a whole, we now focus on different types of imported products used as intermediate inputs. Table 2.4 presents the amount of different types of imported intermediate input used for producing one unit of high-tech manufacturing products. Columns under "Amount of Intermediate Input" represent the sum of corresponding elements in vector $B_{12}(I-A)^{-1}Y_i$, and columns under "Proportion to Total Intermediate Input" represent the corresponding elements in $B_{12}(I-A)^{-1}Y_i$ divided by the corresponding elements in $B_{11}(I-A)^{-1}Y_i+B_{12}(I-A)^{-1}Y_i$. For example, producing one unit of Electronic Parts and Components in 1991 required 0.7581 units of imported intermediate input, which included 0.0790 units of imported Mining and Quarrying products; also, imported intermediate input consisted of 38.35% of the total amount of intermediate input, and imported Mining and Quarrying products consisted of 60.12% of all the Mining and Quarrying products used as intermediate input. As can be seen in Table 2.4, the quantity of imported intermediate input and its proportion to total intermediate input have increased over time. However, the use of imported Electronic Parts and Components as intermediate input increased in the 1990s and decreased in the 2000s, while the use of imported Computers, Electronics, Optics, and Precision Equipment as intermediate input decreased in the 1990s and then increased in the 2000s. Table 2.5 provides similar information for the textiles and garments industry. As can be

[2] If the amount of imported Mining and Quarrying products used as intermediate input was included in Table 2.3, the values in Table 2.3 for all industries would follow the trend of the price of imported Mining and Quarrying products, which decreased between 1981 and 1986, increased slightly between 1986 and 2001, and increased dramatically between 2001 and 2006.

seen, the use of imported Textiles as an intermediate product has increased and then decreased over time, while the use of imported Garments, Apparel, Footwear, and Leather Products as intermediate products have either increased or decreased and then increased over time. Therefore, in addition to the change in export commodities as discussed in the previous subsection, Tables 2.4 and 2.5 also suggest that Taiwan seems to move up its position in the supply chain in terms of the usage of imported intermediate inputs throughout the production process. Similar patterns can also be found in other industries in the tradable sector (not reported).

2.3.3 Employment by Industry and Skill Intensity

Before analyzing the source of the increase in the employment of skilled labor, we first document employment shares by industry. Employment shares are measured as shares of total effective working hours. The upper panel of Figure 2.12 plots the employment share of the Agriculture, Forestry and Fishing sector, which trends downward over time. Since the EES does not survey the Agriculture, Forestry and Fishing sector, Figures 2.13 and 2.14 respectively plot the employment shares of industries in the manufacturing and the services sectors to the whole non-agricultural sector, and the discrepancy between the plots based on the MUS and the EES is attributable to different sampling frames between the two surveys, such as individual-level versus firm-level surveys and the inclusion of employers, self-employed workers, and unpaid family workers working in family businesses.[3] As can be seen in Figure

[3] The slight difference between "MUS, University-Educated" and "MUS, Managerial and Professional" is mostly attributable to the difference in the weights used for the construction of effective hours. To construct effective hours, we first regress log hourly wage on dummies of potential experience groups (0-4 years, 5-9 years, ..., 35-39 years), dummies of educational attainment (junior high school and below, senior high school, vocational senior high school, junior college, university and above), and the whole interactions between gender and year dummies. Only wage and salaried workers are included in the regression, and we run separate regressions for skilled and unskilled labor. Then, setting all the year dummies to be zero, we predict the log hourly wage for all the employed workers, and we use the exponential of predicted log hourly wage to be the weight applied to working hours. Since the regression results are not identical, the plots of "MUS, University-Educated" and "MUS, Managerial and Professional" are slightly different as well.

2.13, the employment shares of most of the industries in the manufacturing sector have decreased over time, except that the employment share of high-tech manufacturing increased between the mid-1990s and 2011. According to the upper panel of Figure 2.15, among industries in the high-tech sector, the industry of Electronic Parts and Components has the largest increase in employment shares. With regard to the services sector, as can be seen in Figure 2.14, the employment shares of Financial Services, Professional Services, and Social Services have increased over time.

Then, we focus on the proportion of skilled labor in each industry, which are plotted in the lower panel of Figure 2.12 and all of Figures 2.16 and 2.17. As can be seen, even though the results for the services sector are not as consistent across surveys as they are for the manufacturing sector because the distinction between skilled and unskilled workers might be less clear in the services sector, we can still see some general patterns across these plots. Some industries, such as Financial Services, Professional Services, and Social Services, tend to have higher proportion of skilled labor than other industries, but the proportion of skilled labor has also increased within each industry. Also, in the manufacturing sector, the rate of increase in the proportion of skilled labor is the most rapid in High-Tech Manufacturing, in which the industry of Computers, Electronics, Optics and Precision Equipment has the highest rate of increase (lower panel of Figure 2.15).

We now analyze further the change in the employment of skilled labor as described above by using the decomposition method presented in Berman et al. (1994) and Murphy and Welch (1993), and we will use more refined industry classifications than the one we used for the plots as illustrated before. Specifically, the change in the proportion of skilled workers in the whole labor force between year τ and year t,

$f_t - f_\tau$, can be decomposed as follows:

$$\begin{aligned} f_t - f_\tau &= \sum_i \frac{(f_{i\tau} + f_{it})}{2}(s_{it} - s_{i\tau}) + \sum_i \frac{(s_{i\tau} + s_{it})}{2}(f_{it} - f_{i\tau}) \\ &= \sum_i [\frac{(f_{i\tau} + f_{it})}{2} - \frac{(f_\tau + f_t)}{2}](s_{it} - s_{i\tau}) + \sum_i \frac{(s_{i\tau} + s_{it})}{2}(f_{it} - f_{i\tau}), \end{aligned}$$

where f_{it} and $f_{i\tau}$ represent the proportion of skilled workers in industry i in year t and year τ, respectively, and s_{it} and $s_{i\tau}$ represent the proportion of workers employed in industry i in year t and year τ, respectively. The first term, $\sum_i \frac{(f_{i\tau}+f_{it})}{2}(s_{it} - s_{i\tau})$ or $\sum_i[\frac{(f_{i\tau}+f_{it})}{2} - \frac{(f_\tau+f_t)}{2}](s_{it} - s_{i\tau})$, measures the change in the proportion of skilled labor for the whole labor force due to the change in the industrial composition, holding the proportion of skilled labor in each industry fixed, so it can be considered as "between-industry" shifts of the employment of skilled labor. The second term, $\sum_i \frac{(s_{i\tau}+s_{it})}{2}(f_{it} - f_{i\tau})$, measures the change in the proportion of skilled labor for the whole labor force due to the change in the proportion of skilled labor in each industry, holding the industrial composition fixed, so it can be considered as "within-industry" shifts of the employment of skilled labor.

Employment is measured as effective working hours. Also, in terms of the measurement of between-industry shifts, we report $[\frac{(f_{i\tau}+f_{it})}{2} - \frac{(f_\tau+f_t)}{2}](s_{it} - s_{i\tau})$ because it is easier to interpret: it is positive when industry i expands and employs more skilled labor than average or when industry i shrinks and employs less skilled labor than average. This choice does not matter at the aggregate level because $\sum_i \frac{(f_{i\tau}+f_{it})}{2}(s_{it} - s_{i\tau})$ equals $\sum_i[\frac{(f_{i\tau}+f_{it})}{2} - \frac{(f_\tau+f_t)}{2}](s_{it} - s_{i\tau})$.

Table 2.6 displays the results of decomposition using the EES data. To make it easier to compare among industries, we use only 18 industries in the tradable sector and 10 industry in the non-tradable sector to generate Table 2.6, but using a more refined industrial classification (68 industries in the tradable sector and 23 industries in the non-tradable sector) also generate similar magnitudes in the between-industry and with-industry shifts at the aggregate level. As can be seen, between 1981 and 2011, the proportion of managerial and professional workers in the whole labor force has increased by about 20% (6.2348%+14.5896%=20.8244%). Within-industry shifts are larger than between-industry shifts, but between-industry shifts still account for around 30% of the whole increase in the proportion of managerial and professional workers (6.2348/20.8244=0.2994). Among industries in the tradable sector, the industries with larger contributions to the between-industry shifts are Textiles; Garments, Apparel, Footwear, Leather Products; and Electronic Parts and Components. The first two industries had larger contributions in 1987-1995, while the third industry had a larger contribution in 2003-2011. This is consistent with the patterns of the expansion in the high-tech industry and the shrinkage of the textile and garments industry as discussed before. As to within-industry shifts, the industries with larger contributions to the within-industry shifts are Electronic Parts and Components; Computers, Electronics, Optics, Precision Equipment; and Garments, Apparel, Footwear, Leather Products. We also compare the results between different datasets and definitions of skilled labor in Table 2.7, where Panel (a) reports the results using the MUS, while Panel (b) reports the results using the EES. (The period covered in Table 2.7 is 1993-2011.) As can be seen, the results for the tradable sector are quite similar across datasets and definitions of skilled labor. Besides, as reported in Panel (a), the industry of Agriculture, Forestry, and Fishing also makes a large contribution to the between-industry shifts.

With regard to the non-tradable sector, the results are less consistent. Part of the inconsistency arises from whether we define skilled labor by workers' educational attainment or occupation. As can be seen in Table 2.7(a), even though the between-industry shifts are similar across definitions of skilled labor, the within-industry shifts are larger if we define skilled labor as university-educated workers. This might be related to the expansion in post-secondary education since the mid-1990s because university graduates tend to work in the services sector, and younger university graduates are more likely to hold entry-level or non-managerial positions than older university graduates. The other part of the inconsistency arises from the difference between MUS and EES in terms of sampling frames and distinctions between skilled and unskilled occupations, which is revealed by the difference between Panels (a) and (b) in Table 2.7. However, we can still identify the industries with larger contributions to the change in the proportion of skilled workers. According to Tables 2.6 and 2.7, these industries include Medical Services; Social Services; Financial Services; Professional Services; Transportation, Warehousing, Communications; and Construction.

To summarize, between 1981 and 2011, in terms of gross trade, Taiwan has shifted from exporting basic manufacturing products to exporting high-tech manufacturing products. With regard to the usage of imported intermediate input, the dependence of imported intermediate input has increased over time, but the dependence of upstream imported products used as intermediate input, such as electronic parts and components, increased first and then decreased. As to employment, the employment shares of the industries which tend to employ more skilled labor, such as electronic parts and components, financial services, professional services, and social services, have increased over time, even though the proportion of skilled workers has also increased in all industries. We will investigate further how trade affects the relative demand for skilled labor in the following section.

2.4 Trade and the Demand for Skilled Labor

2.4.1 Traditional Factor-Proportions Approach

In this section, we use the factor-proportions approach to study the impact of trade flows on skill premium. This approach involves allocating trade volumes to skilled and unskilled labor by industry, aggregating these allocations across industries, and then analyzing how these aggregated allocations affect the skill premium. Similar procedures can be found in, for example, Katz and Murphy (1992) and Borjas et al. (1997).

Assume that production involves two inputs, skilled labor and unskilled labor, and that the production function follows a CES (Constant Elasticity of Substitution) form:

$$
\begin{aligned}
Y_t &= (\theta_{Ct} C_t^r + \theta_{Nt} N_t^r)^{1/r}, \qquad (2.1)\\
r &= 1 - 1/\sigma,
\end{aligned}
$$

where t indexes year; σ is the elasticity of substitution between skilled and unskilled labor; C and N represent the supply of skilled and unskilled labor, respectively, measured in effective working hours; and θ_{Ct} and θ_{Nt} are technological efficiency parameters. If workers are paid in the way that relative marginal products equal relative wages, after solving the first-order conditions and taking logs, we obtain the following equation:

$$
\ln(\frac{W_t^C}{W_t^N}) = \ln(\frac{\theta_{Ct}}{\theta_{Nt}}) - \frac{1}{\sigma}\ln(\frac{C_t}{N_t}). \qquad (2.2)
$$

Based on Equation (2.2), we first define

$$
\begin{aligned}
\ln(S_t) &= \frac{1}{\sigma}\ln(\frac{C_t}{N_t}) \qquad (2.3)\\
\ln(D_t) &= \ln(\frac{W_t^C}{W_t^N}) + \frac{1}{\sigma}\ln(\frac{C_t}{N_t}). \qquad (2.4)
\end{aligned}
$$

Then, combining Equations (2.3) and (2.4), we obtain

$$
\ln(\frac{W_t^C}{W_t^N}) = \ln(D_t) - \ln(S_t). \qquad (2.5)
$$

In other words, the change in the skill premium is determined by the counterbalance between the changes in the relative demand for skilled labor, $\ln(D_t)$, and the changes in the relative supply of skilled labor, $\ln(S_t)$.

We now quantify the extent to which $\ln(D_t)$ is explained by trade flows. To do so, we first define the employment of skilled and unskilled labor contained in net trade flows, T_t^C and T_t^N, as follows:

$$T_t^C = \sum_i a_i^C L_{it} \frac{I_{it}}{Y_{it}} \tag{2.6}$$

$$T_t^N = \sum_i (1 - a_i^C) L_{it} \frac{I_{it}}{Y_{it}}, \tag{2.7}$$

where i indexes industry; L_{it}, I_{it}, and Y_{it} represent employment, net import, and gross output, respectively, of industry i in year t; and a_i^C represents the employment share of skilled labor in industry i, averaged over a few years around t, and how the average is calculated depends on data availability and will be discussed in detail later. Then, we define the "implicit supply" of skilled and unskilled labor, C_t' and N_t', as

$$C_t' = C_t + T_t^C$$

$$N_t' = N_t + T_t^N,$$

we define the changes in the skill premium due to the changes in the relative implicit supply of skilled labor as

$$\ln(S_t') = \frac{1}{\sigma} \ln(\frac{C_t'}{N_t'}), \tag{2.8}$$

and we define trade contributions to the changes in the skill premium as

$$\ln(T_t) = -[\ln(S_t') - \ln(S_t)].$$

We define $\ln(T_t)$ this way so that it goes in the same direction as $\ln(D_t)$. An increase in the import of skill-intensive goods implies a decrease in the relative demand for skilled labor, or an increase in the relative implicit supply of skilled labor, $\ln(S_t')$, so $\ln(T_t)$ should decrease. Likewise, an increase in the export of skill-intensive goods implies an increase in the relative demand for skilled labor, or a decrease in the relative implicit supply of skilled labor, so $\ln(T_t)$ should increase.

If we decompose Equation (2.5) as follows,

$$\ln(\frac{W_t^C}{W_t^N}) = [\ln(D_t) - \ln(T_t)] + \ln(T_t) - \ln(S_t), \tag{2.9}$$

we can see that skill premium is determined by the changes due to labor supply, $\ln(S_t)$, the changes due to trade, $\ln(T_t)$, and the changes in unexplained labor demand factors, $[\ln(D_t) - \ln(T_t)]$. Therefore, we can compare the magnitude of $\ln(D_t)$ and $\ln(T_t)$ to study the extent to which trade explains the changes in labor demand.

To calculate $\ln(T_t)$ and $\ln(D_t)$, we need information on σ, which can be obtained from running an OLS regression to estimate Equation (2.2). Table 2.8 displays the regression results. We use polynomial time trends (Columns (1)-(12)) or polynomial time trends and month dummies (Columns (13)-(16)) to represent $\ln(\theta_{Ct}/\theta_{Nt})$. As can be seen, across specifications, datasets, and definitions of skilled labor, after sufficient detrending, $1/\sigma$ ranges from around 0.3 to 0.5, which suggests the elasticity of substitution between skilled and unskilled workers is around 2 to 3.3.

Table 2.9 illustrates the change in $\ln(D_t)$ and $\ln(T_t)$ over time. Based on the regressions results as displayed in Table 2.8, we assume $1/\sigma \in [0.3, 0.5]$, but the results are very similar across different values of σ, so we only report the results for $1/\sigma = 0.5$. "MUS, University-Educated" and "MUS, Managerial and Professional" include 25 industries (15 in the tradable sector and 10 in the non-tradable sector), while "EES, Managerial and Professional" uses the EES data in May and includes 28 industries (18 in the tradable sector and 10 in the non-tradable sector). The trade data for these rows are from the *Monthly Statistics of Exports and Imports*, Comtrade, and the NBER-United Nations Trade Data, which do not have information on trade in the non-tradable sector. Since these data are available for every year, we calculate the change between two adjacent years, using the average in the employment share of skilled labor in industry i over these two adjacent years to construct a_i^C, and then sum up all the changes according to the periods specified in the table. "EES, Managerial and Professional, Trade Data from Transaction Tables" also uses the EES data in May, but it includes 91 industries (68 in the tradable sector and 23 in the non-tradable sector), and the trade data for this row comes from transaction tables, which includes trade in commodities and services. Since we only use the transaction tables of years 1991, 1996, 2001, and 2006, we calculate directly the changes between 1991 and 1996, between 1996 and 2001, and between 2001 and 2006 and construct a_i^C by averaging the employment share of skilled labor in industry i over the whole five-year periods as specified in the table. As can be seen in Table 2.9, the explanatory power of trade was larger in 1991-1996 when we define skilled labor as university-educated workers, and larger in years 2001-2006 when we define skilled labor as workers in managerial and professional occupations. Trade can explain as much as 9% of the relative demand for skilled labor in years 2001-2006, but over the past three decades, $\ln(T_t)$ stayed relatively fixed, and the magnitude was negligible compared with the increase in $\ln(D_t)$. Therefore, trade has little effect overall on the relative demand for skilled labor.

2.4.2 Including Intermediate Inputs Implied from Trade Flows

The traditional factor-proportions approach only takes into account how changes in gross trade flows affect the skill premium, so it does not include the effect of intermediate inputs embedded in gross trade flows. Therefore, we include these indirect effects in this section.

2.4.2.1 Setup

Following Trefler and Zhu (2010), we construct a global input-output system with J goods (or industries) and two countries, Taiwan and the world. First, we construct separate input-output tables by source of inputs

$$B_{mn} = \begin{bmatrix} B_{mn}(1,1) & B_{mn}(1,2) & \dots & B_{mn}(1,J) \\ B_{mn}(2,1) & B_{mn}(2,2) & \dots & B_{mn}(2,J) \\ \vdots & \vdots & \ddots & \vdots \\ B_{mn}(J,1) & B_{mn}(J,2) & \dots & B_{mn}(J,J) \end{bmatrix},$$

where $B_{mn}(i,j)$ is the amount of good i made in country m used to produce one unit of good j in country n, and B_{mn} is a $J \times J$ input-output matrix. In short, country m produces intermediate inputs and country n produces final outputs. Then, we construct a global input-output system, which can be characterized by the following $2J \times 2J$ matrix:

$$B = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix},$$

where 1 represents Taiwan and 2 represents the world.

After constructing the global input-output system, we can calculate the amount of intermediate inputs required to generate final outputs for trading. First, define

$$G = \begin{bmatrix} -X \\ M \end{bmatrix} = \begin{bmatrix} -X_1 \\ -X_2 \\ \vdots \\ -X_J \\ M_1 \\ M_2 \\ \vdots \\ M_J \end{bmatrix}$$

where X_i is the export of good i from Taiwan, M_i is the the import of good i to Taiwan, X and M are $J \times 1$ vectors summarizing the export and import of Taiwan by industry, respectively, and G is a $2J \times 1$ vector summarizing gross trade volumes of Taiwan. In other words, X and M are the final outputs for trading made by Taiwan and the world, respectively.

In order to generate G, we not only have to produce G, but also have to produce intermediate inputs BG, which requires intermediate inputs B^2G, and so on. Therefore, the total amount of production required to generate G, is

$$G + BG + B^2G + ... = \sum_{k=0}^{\infty} B^k G = (I - B)^{-1} G,$$

where I is a $2J \times 2J$ identity matrix. $(I - B)^{-1}G$ is a $2J \times 1$ vector, where the first J elements are negative and represent the amount of intermediate and final output that each industry in Taiwan has to produce and export to the world, while the last J elements are positive and represent the amount of intermediate and final output that each industry in the world has to produce and export to Taiwan.

After obtaining the amount of output required for given trade flows, we now allocate these outputs to skilled and unskilled labor. First, define

$$D_m^C(i) = \frac{a_{i,m}^C L_{i,m}}{Y_{i,m}}$$
$$D_m^N(i) = \frac{(1-a_{i,m}^C)L_{i,m}}{Y_{i,m}},$$

where $a_{i,m}^C$ represents the proportion of skilled labor in industry i in country m, averaged over time and in the same way as in Section 2.4.1, and $L_{i,m}$ and $Y_{i,m}$ represent the amount of employment and gross output of industry i in country m, respectively. Therefore, $D_m^C(i)$ and $D_m^N(i)$ correspond to the amount of skilled and unskilled workers required to produce one unit of gross output in industry i in country m, respectively. Then, we further define the direct factor requirement matrix, D, as

$$D = \begin{bmatrix} D_1 & D_2 \end{bmatrix} = \begin{bmatrix} D_1^C(1) & D_1^C(2) & \dots & D_1^C(J) & D_2^C(1) & D_2^C(2) & \dots & D_2^C(J) \\ D_1^N(1) & D_1^N(2) & \dots & D_1^N(J) & D_2^N(1) & D_2^N(2) & \dots & D_2^N(J) \end{bmatrix},$$

so the implicit supply of skilled and unskilled labor contained in trade flows are summarized as

$$\begin{bmatrix} T^C \\ T^N \end{bmatrix} = D(I-B)^{-1}G. \tag{2.10}$$

Note that T^C and T^N degenerate to Equations (2.6) and (2.7) in the previous section when $B = 0$, or when production does not require intermediate inputs.

The last step is to replace Equation (2.10) with Equations (2.6) and(2.7) and then recalculate Equation (2.9).

2.4.2.2 Implementation of the Global Input-Output System

Implementing the global input-output system usually requires gathering information on bilateral trade flows and the input-output tables of as many countries as possible. For example, Trefler and Zhu (2010) used the global input-output system to test Vanek's factor content of trade prediction (Vanek, 1968), and Johnson and Noguera (2012) and the joint OECD-WTO Trade in Value-Added (TiVA) Initiative used the global input-output system to calculate trade in value-added by country. However, since our purpose is to study how the change in trade flows affects the skill premium in Taiwan, what we actually need is the *counterfactual* amount of skilled and unskilled labor which would be used in Taiwan if all the imports were made domestically. Therefore, we assume that the world has the same production process as Taiwan does ($B_{12} = B_{21}$, $B_{11} = B_{22}$, $D_1 = D_2$), so we only need information on B_{11}, B_{12}, and D_1.

The construction of B usually requires the proportionality assumption, i.e., the proportion of imported intermediate input i to the total value of intermediate input i, inferred from gross trade flows and gross output, is the same for all industries. However, since the DGBAS generates separate input-output tables for domestic and imported intermediate inputs by tracking the source and the flows of inputs and outputs, B_{11} and B_{12} (and thus, B_{22} and B_{21}) are directly available and do not rely on the proportionality assumption.

The input-output tables of 2004 are not used because they generate huge negative import and export values for several industries, and 2004 was not an census year. When we use customs-record-based trade data and the MUS, we use all the input-output tables, except the tables of 2004, to construct B and D, and each table is used for two to three years, except that the tables of 2001 are used for years 2000-2003 and the tables of 2006 are used for years 2004-2011. When we use customs-record-based trade data and the EES, we use the input-output tables of year 1991 and after, except the tables of 2004, to construct B and D because tables before 1991 do not separate "Electronic Parts and Components" out as a distinct category, and each table is used for two to three years, except that the tables of 2001 are used for years 2000-2003, the tables of 2006 are used for years 2004-2011, and the tables of 1991 are used for years 1987-1992. When trade data comes from transaction tables, we use the input-output tables of 1991, 1996, 2001, and 2006.

Our global input-output system sometimes generates negative export values for Mining and Quarrying. This is because Taiwan has little natural resources and we assume the world has the same production process as Taiwan does. The negative export of Mining and Quarrying essentially indicates that if the world was like Taiwan, some natural resources would have to be given to Taiwan from outside of the global input-output system to carry out production.

Before constructing trade contributions to the changes in the skill premium based on $D(I-B)^{-1}G$, Figure 2.18 illustrates the trade shares based on $(I-B)^{-1}G$. As can be seen, apart from negative exports in Mining and Quarrying, which is not included in Figure 2.18, our global input-output system generates positive exports and imports for most of the industries. Also, the trends in Figure 2.18 are similar to the trends of gross trade as illustrated in Figure 2.5, except that the import share of Electronic Parts and Components is lower in Figure 2.18. Besides, the output of the non-tradable sector required for generating trade in the tradeable sector accounts for about 10-15% of trade volumes and does not vary much over time.

We now use Equation (2.10) to recalculate the factor content of trade, and then calculate the shifts in the relative demand for skilled labor explained by trade in final and intermediate goods, and the results are reported in Table 2.10. As can be seen, the results are similar as before, and the magnitude of the change in $\ln(T_t)$ is still negligible compared with that of $\ln(D_t)$. Therefore, after taking into account the intermediate inputs embedded in gross trade flows, the effect of trade on the relative demand for skilled labor is still small.

2.5 Outsourcing, Triangular Trade, and Coordinations

The results in the previous section suggest that trade has a small effect on the relative demand for skilled labor, at least at the between-industry level. Even though earlier studies on the U.S. labor market also found that the effect of trade on the relative demand for skilled labor was small, it is interesting that we also find similar results for Taiwan. First, trade is an integral part of the Taiwanese economy: Trade accounts for 40-60% of the Taiwanese GDP but only around 10% of the U.S. GDP. Second, our global input-output system includes the effect of imported intermediate inputs, which Feenstra and Hanson (1996) view as a form of outsourcing, and it also implies that countries export and import intermediate inputs back and forth, so it captures at least to some degree the essence of vertical integration among countries as described by Krugman (2008).

Conceptually, outsourcing affects the relative demand for skilled labor through two channels. The first channel is the flow of physical goods, and our calculations already take this channel into account. For example, an increase in outsourcing may imply a decrease in the export of physical goods produced by the manufacturing sector. If disproportionately more unskilled workers are employed in the manufacturing sector, the decrease in export will hurt unskilled workers more severely, and our calculations include this effect. Also, within the manufacturing sector, if unskilled-labor-intensive industries have higher prevalence in outsourcing, unskilled workers will also be hurt more severely, and this is also included in our calculations.

The second channel is the coordinations required to perform outsourcing. However, our calculations so far either do not include at all or do not precisely quantify the demand for workers carrying out the coordinations. One extreme form of outsourcing which illustrates the importance of coordinations is triangular trade. Triangular trade means Taiwanese firms fulfill orders placed by firms in country A by ordering goods from firms in country B and then directly exporting those goods from country B to country A. Thus, no physical production is carried out in Taiwan, and these goods never go through the Taiwanese customs, but at least some non-production workers have to be employed to carry out the coordinations.

The following example illustrates how our calculations in the previous section might underestimate the effect of trade on the relative demand for skilled labor. We use triangular trade as an example, but the same logic also applies to outsourcing in general because triangular trade essentially means 100% of production is performed abroad, while outsourcing means some proportion of production is performed abroad. Imagine a Taiwanese shoes company which used to fulfill foreign orders mostly by making their own shoes and exporting from Taiwan in the past, but now, it fulfills most of its foreign orders by triangular trade: requesting suppliers in, for example, China, to make those shoes and export directly to the destination country. If we use the trade data based on customs records, since triangular trade does not show up in the Taiwanese customs record, the data will suggest that export has decreased, and we will allocate the harm due to this decrease proportionately to skilled and unskilled workers in our calculations. However, benefits from triangular trade are not allocated to workers, and since workers carrying out triangular trade are more likely to be non-production workers, who are more likely to be skilled workers, this will underestimate the benefits of skilled labor furthermore. Incorporating the global input-output system in our calculations does not really solve this issue, either. Suppose the production process of, and thus the required intermediate input for, physically making a pair of shoes in Taiwan remains the same. If triangular trade does not require any intermediate inputs, the coefficients in the input-output tables will stay the same. Even if triangular trade also requires some intermediate inputs, since physical production tends to require much more intermediate inputs than services, the coefficients in the input-output tables will not change much.

If we use the trade data from transaction tables, the profit of triangular trade will be included as part of net exports, so the benefits of triangular trade will be allocated to workers in our calculations. However, it is still very likely that we will allocate too few of the benefits to skilled labor relative to unskilled labor because the data does not distinguish coordination from physical production, especially in later years when a larger proportion of net export is generated from triangular trade. This is related to the issue of data aggregation as described by Krugman (2008), but with a different flavor. To address the issue we face here, the ideal dataset should be disaggregated at the right dimension: It should separate the shoes company into at least two sub-sectors, one represents coordination and the other represents physical production, instead of fitting the whole shoes company into one category, no matter how exhaustively refined the industrial classification is.

We now document the patterns of outsourcing in the past three decades. First, we compare the difference between the amounts of export orders and customs export, and the information on export orders is based on the firm-level surveys conducted by the Ministry of Economic Affairs (MOEA) of Taiwan. As can be seen in Figure 2.19, the difference between these two amounts was very small before 2000, but the amount of export orders started to exceed the amount of customs export since around 2000, and the gap between these two amounts widened dramatically in the 2000s. The MOEA also asked firms in the same surveys the proportion of foreign production they used in order to fulfill the export orders they received, and as also plotted in Figure 2.19, this proportion increased dramatically in the 2000s. These patterns suggest that more and more export orders were fulfilled by outsourcing in the 2000s, sometimes without having part or even all of the merchandise exporting through the Taiwanese customs.

Second, the DGBAS released aggregated statistics on triangular trade based on the firm-level censuses in 2006 and 2011, and the results are summarized in Table

2.11. By definition, only the manufacturing and the wholesale/retail industries perform triangular trade, so Table 2.11 reports the number of firms, the proportion of firms performing triangular trade, and the profit margins in the manufacturing and the wholesale/retail industries. As can be seen, the proportion of firms performing triangular trade increased between 2006 and 2011, and the margin between sales revenue and the cost of purchasing from abroad could be large. The DGBAS found that the profit margin of triangular trade accounted for about 3.3%-4% of the Taiwanese GDP in recent years.

Third, even though it is not necessary to hold ownership of foreign firms in order to outsource production abroad, at least part of the outward FDI (Foreign Direct Investment) from Taiwan to other countries might be used to facilitate outsourcing. Figure 2.20 plots the amount of outward FDI from Taiwan to other countries approved by the Investment Commission of MOEA. As can be seen, the amount of outward FDI from Taiwan to other countries, especially to China, measured as a proportion to GDP, increased in the 1990s and then more dramatically in the 2000s. The patterns in U.S. dollars are similar.

Figures 2.19 and 2.20 both suggest that outsourcing increased more dramatically in the early 2000s. According to the MOEA and the DGBAS, the prevalence of outsourcing increased for almost every manufacturing industry, and based on the employment patterns documented in Section 2.3.3, it is true that disproportionately more unskilled workers are employed in the manufacturing sector, so this suggests that the relative demand for skilled labor should increase at the between-industry level when non-manufacturing sector is included in our calculations. However, within the manufacturing sector, it is actually the high-tech manufacturing, the most skilled-labor-intensive industry in the manufacturing sector, that had the largest increase and the highest prevalence in outsourcing in the 2000s, and this would make the relative demand for skilled labor to *decrease* at the between-industry level. The counterbalance between these two forces might explain why, in the previous section, even though the effect of trade and outsourcing on the relative demand for skilled labor was slightly larger between 2001 and 2006, it could only explain at most 9% of the increase in the relative demand for skilled labor.

Besides, since it requires non-production workers, who tend to be skilled workers, to coordinate outsourcing activities, this suggests that the relative demand for skilled labor might have increased *within* each industry when outsourcing increased. Therefore, quantifying this within-industry effect is worthwhile for future research.

2.6 Conclusion

During the past three decades, the importance of trade to the Taiwanese economy increased, China became one of Taiwan's main trading partners, Taiwan moved up its position in the supply chain in terms of trade in final goods and intermediate inputs, and it shifted from exporting basic manufacturing products to exporting high-tech manufacturing products. Also, the employment of skilled labor increased, especially for the industries which were more skill-intensive, such as the industries of electronic parts and components, financial services, and professional services, while the relative wage of skilled labor did not trend down, which suggests that the relative demand for skilled labor must have increased. To study the relationship between trade patterns and the relative demand for skilled labor, in this paper, we incorporate a global input-output system to calculate factor content of trade. Even though our calculations include the effect of trade in intermediate input and the effect of outsourcing on the relative demand for skilled labor through the flow of physical goods, we still find that trade has a small effect on the relative demand for skilled labor. However, our calculations so far only include between-industry shifts, so it is worthwhile focusing on the channels through which the relative demand for skilled labor would increase within each industry. Since the prevalence in outsourcing increased for almost every industry in the 2000s, and more skilled labor might be needed to coordinate outsourcing activities, this seems to be a plausible channel, and it is worthwhile quantify the effect of this channel for future research.

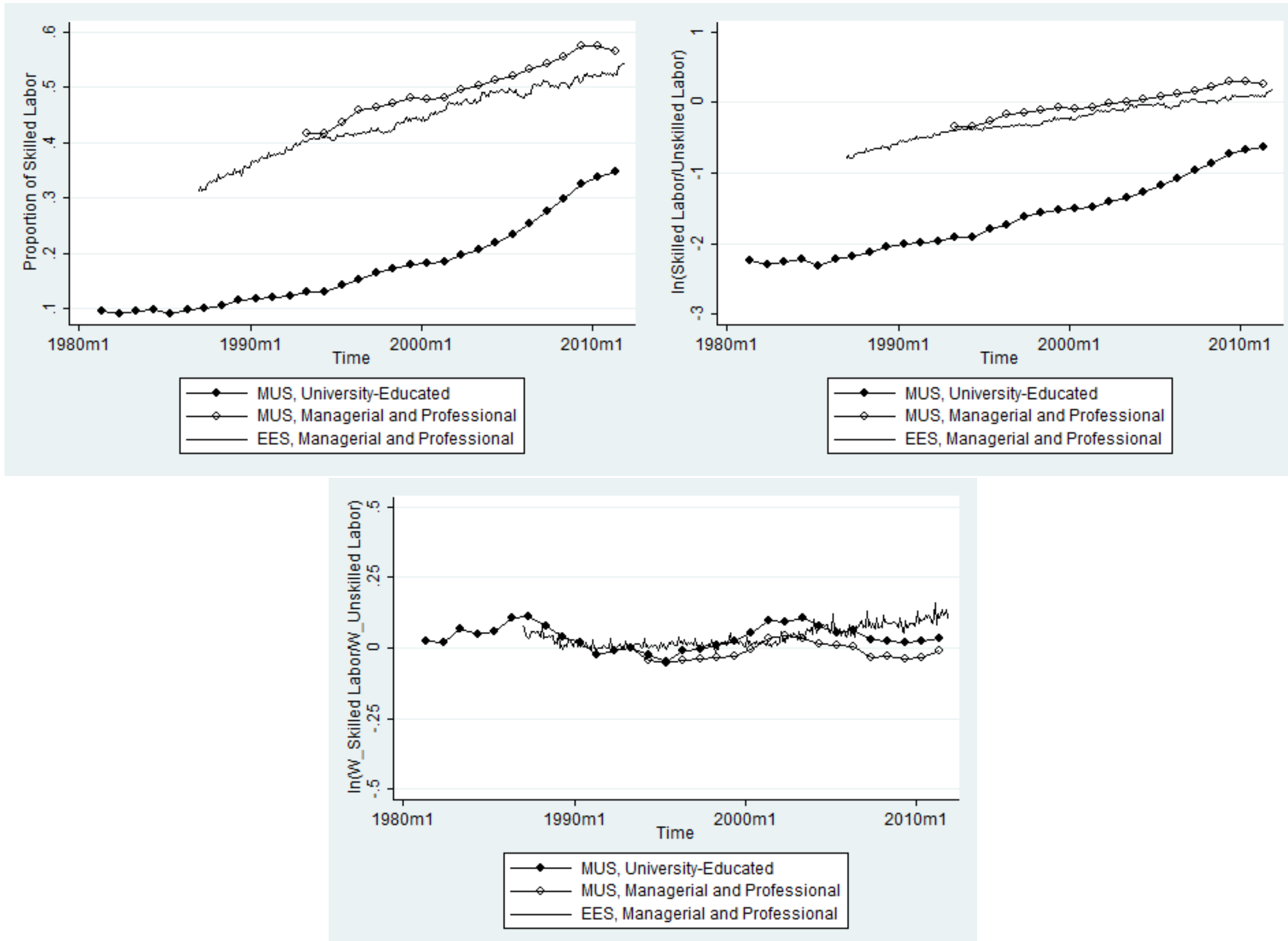


Figure 2.1: Proportion of Skilled Labor (Top-Left), Relative Supply of Skilled Labor (Top-Right), and the Skill Premium (Bottom)

Note: MUS (Manpower Utilization Survey) and EES (Employees' Earnings Survey) are the data used throughout this paper on employment. MUS surveys individuals, while EES surveys firms. Skilled labor is either defined as workers with university education and above, labeled as "University-Educated," or defined as workers with managerial or professional occupations, labeled as "Managerial and Professional." For the MUS, we use total effective weekly working hours to calculate the proportion and the relative supply of skilled labor, and working hours are weighted by workers' demographic characteristics, such as potential experience, educational attainment, and gender. The skill premium using the MUS also controls for workers' demographic characteristics. For the EES, the proportion and the relative supply of skilled labor are based on total effective monthly working hours, which is essentially represented by total monthly wage bill because the EES does not have detailed information on individual workers. Hourly wages in the EES is calculated as total monthly wage bill divided by total monthly working hours, and the skill premium for the EES is calculated from this aforementioned measure. Please refer to Section 2.2.2 for more information about the MUS and the EES, the mapping between educational attainment and occupation, and the generation of relative supply and relative wage measures.

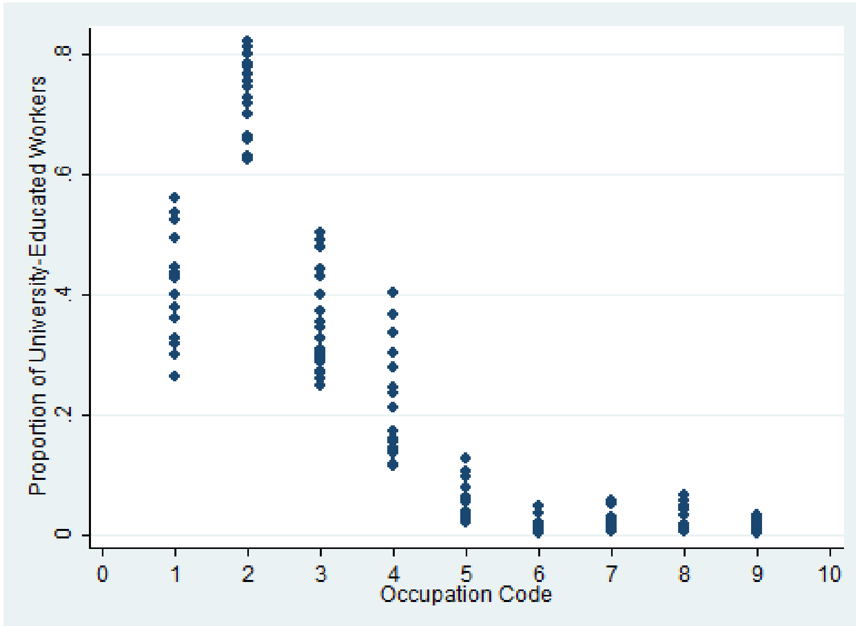


Figure 2.2: Proportion of University-Educated Workers by Occupation Code, 1993-2011

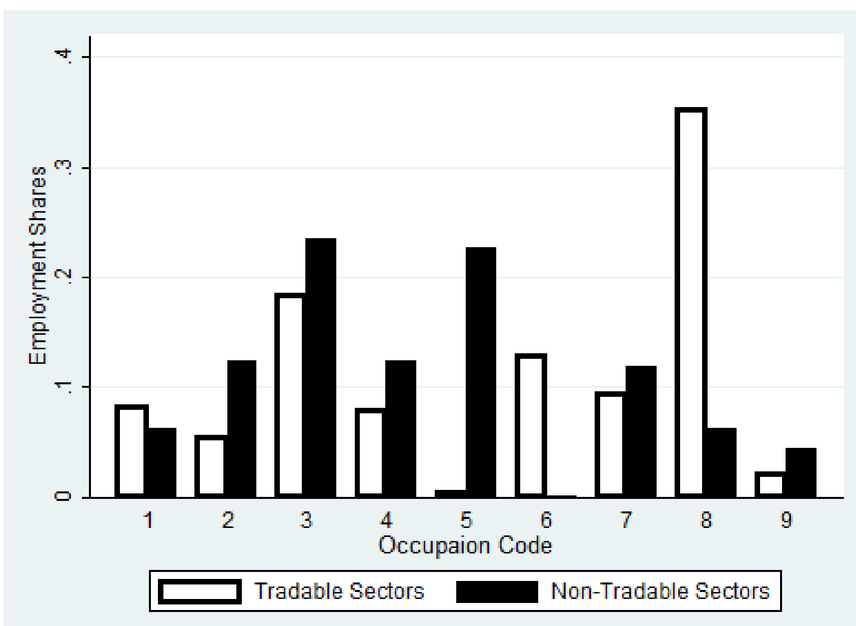


Figure 2.3: Employment Shares of the Tradable and Non-Tradable Sectors by Occupation Code, Averaged Over 1993-2011

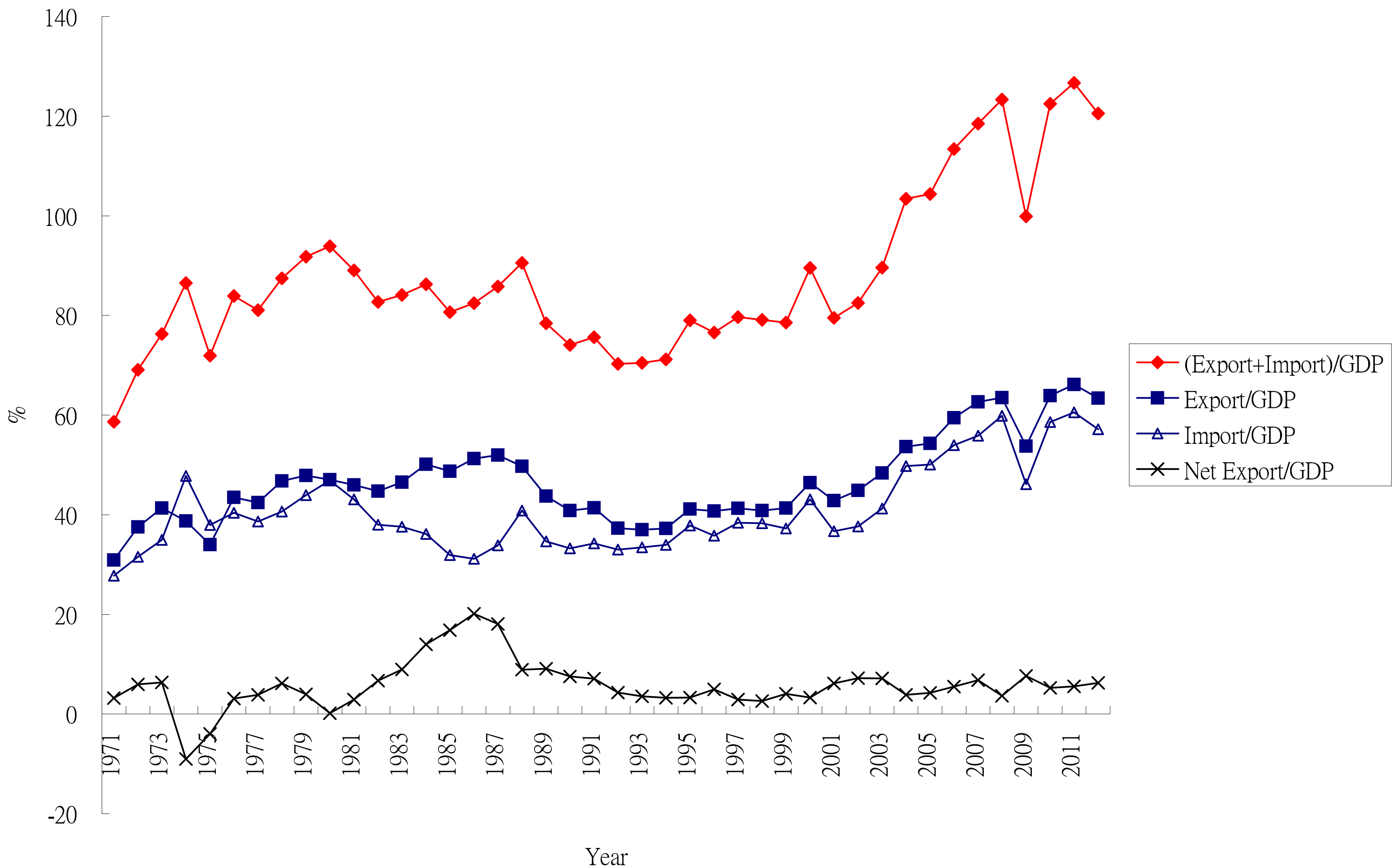


Figure 2.4: Trade as a Share of GDP

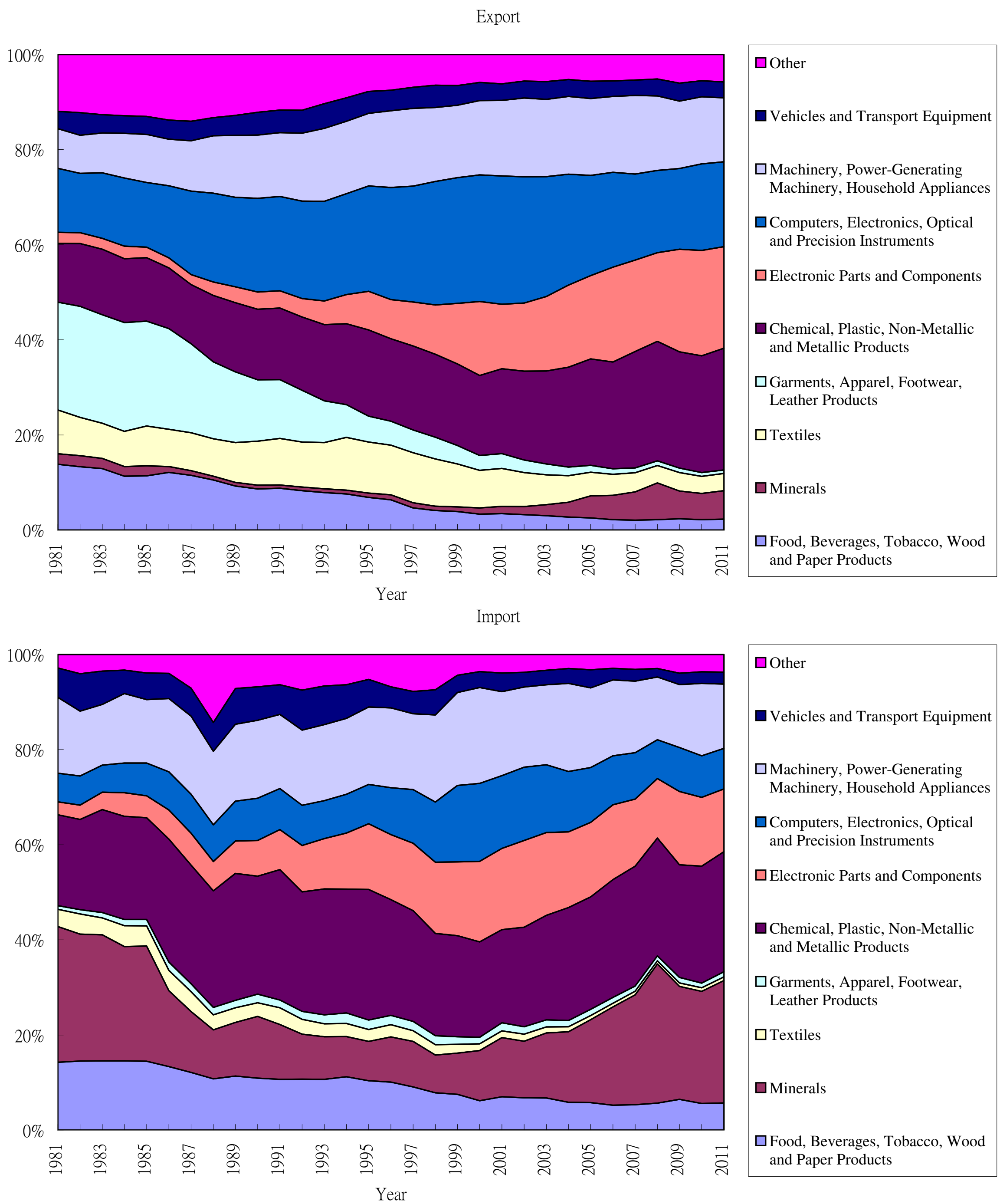


Figure 2.5: Trade Shares by Commodities

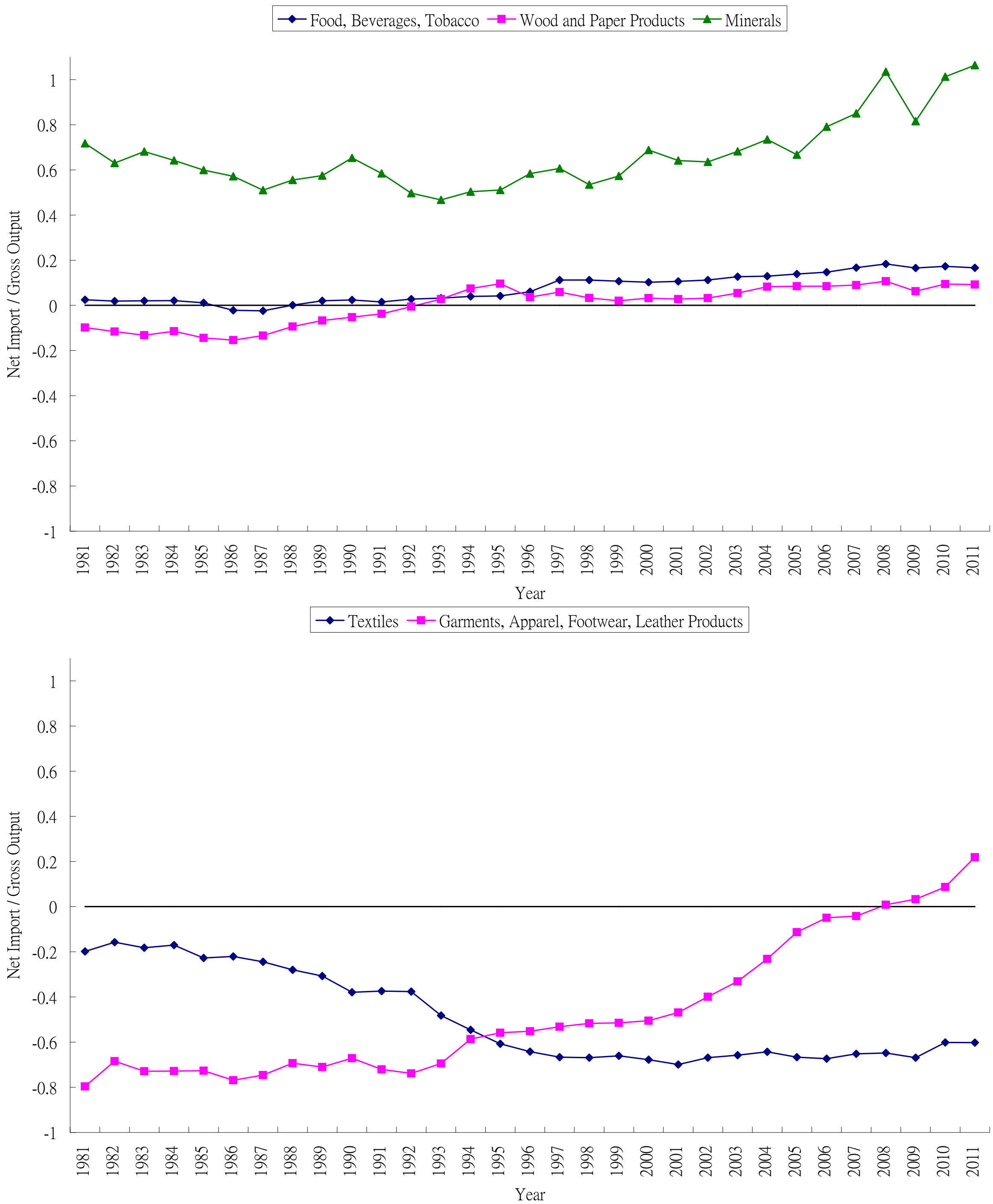


Figure 2.6: Net Import as a Share of Gross Output

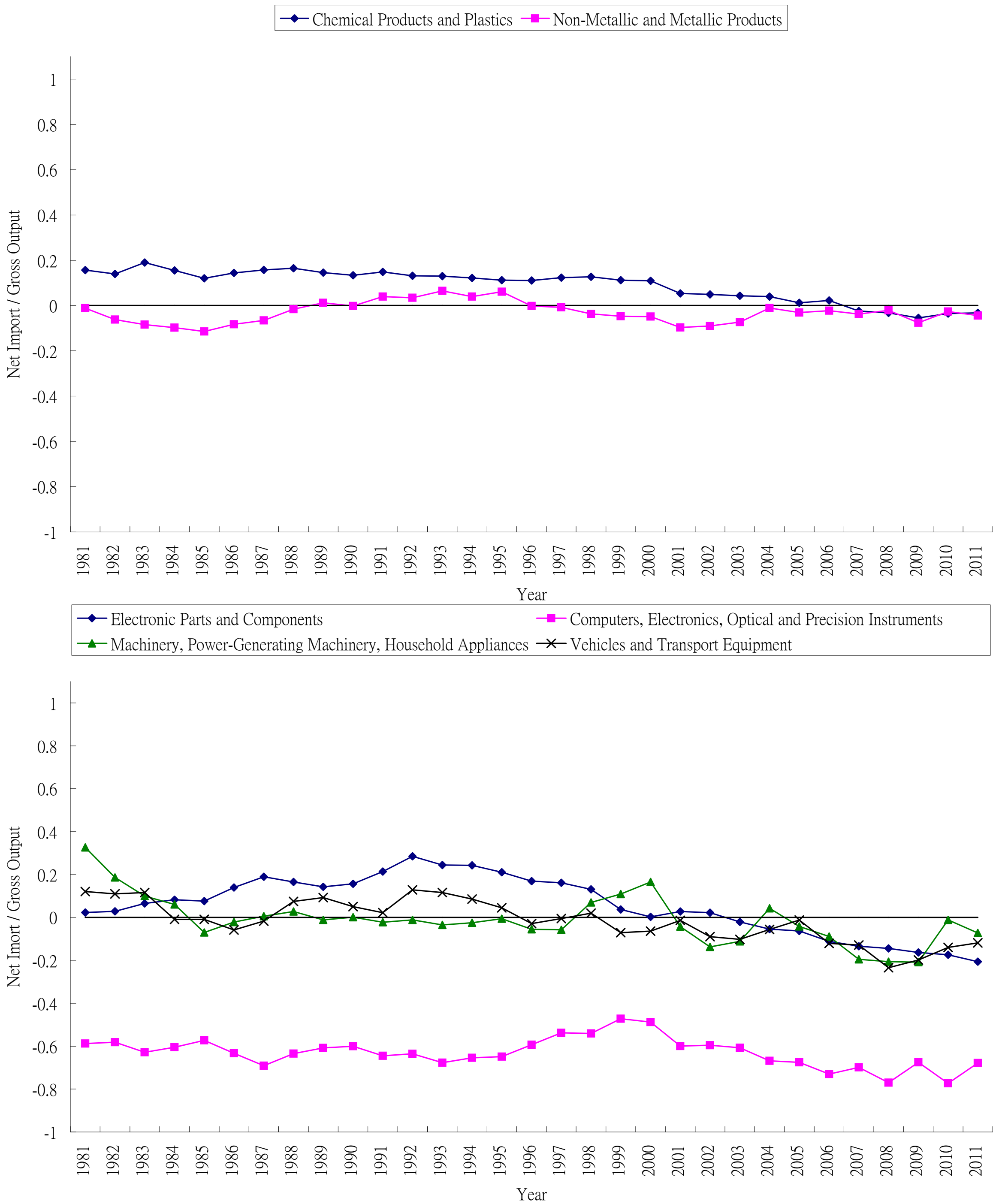


Figure 2.7: Net Import as a Share of Gross Output

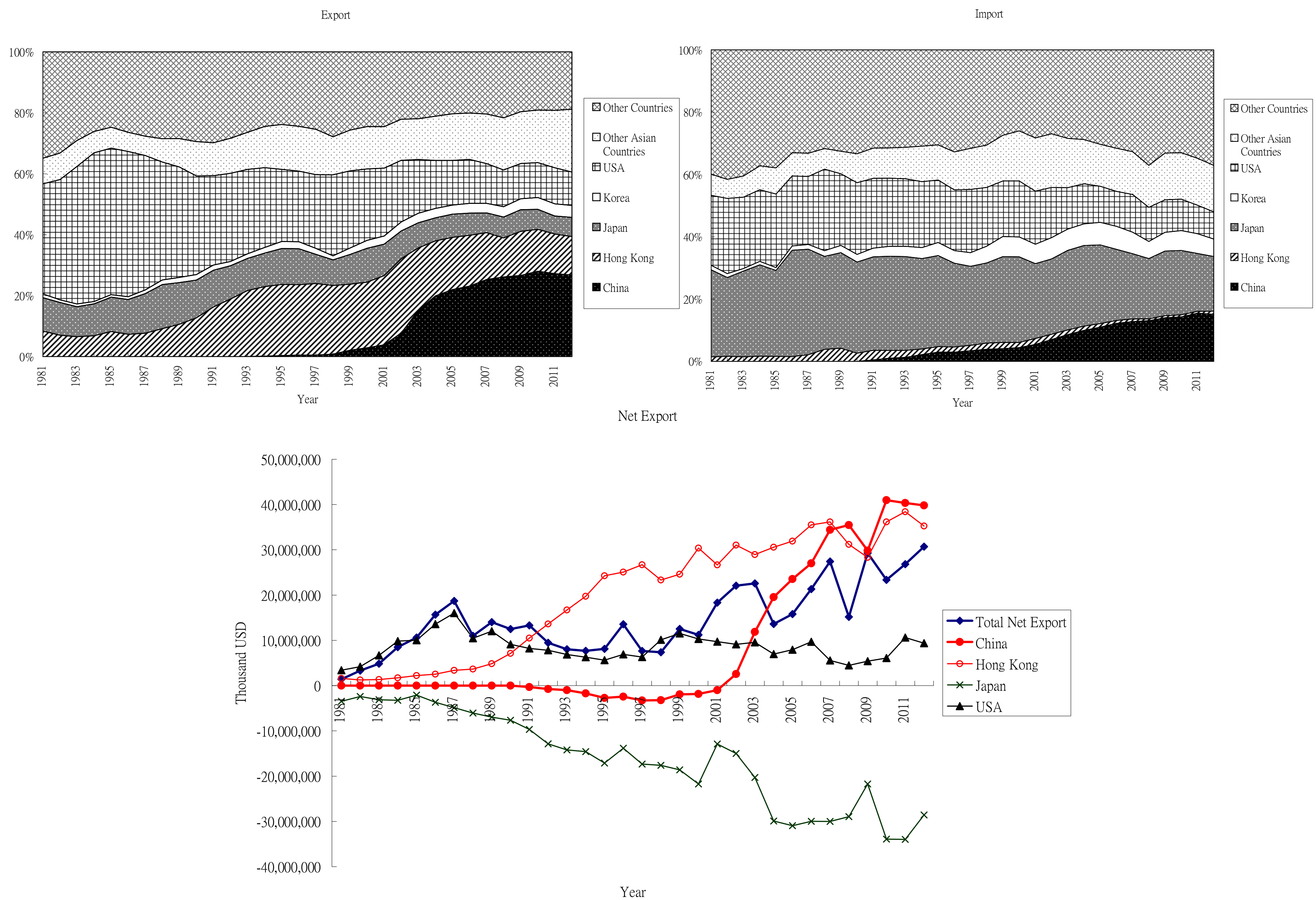


Figure 2.8: Trade Share and Net Export by Trading Partners

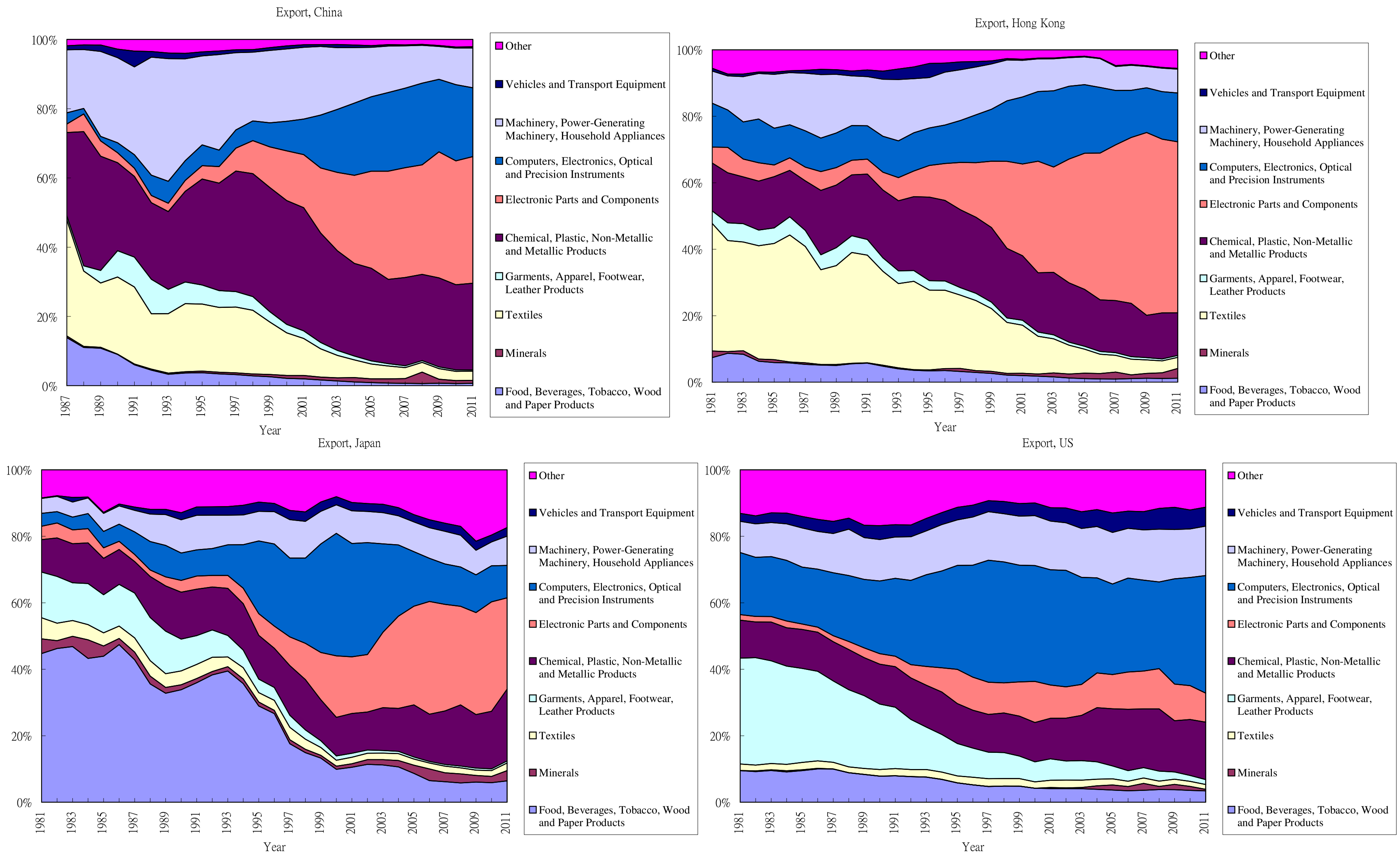


Figure 2.9: Export Shares by Commodities and Trading Partners

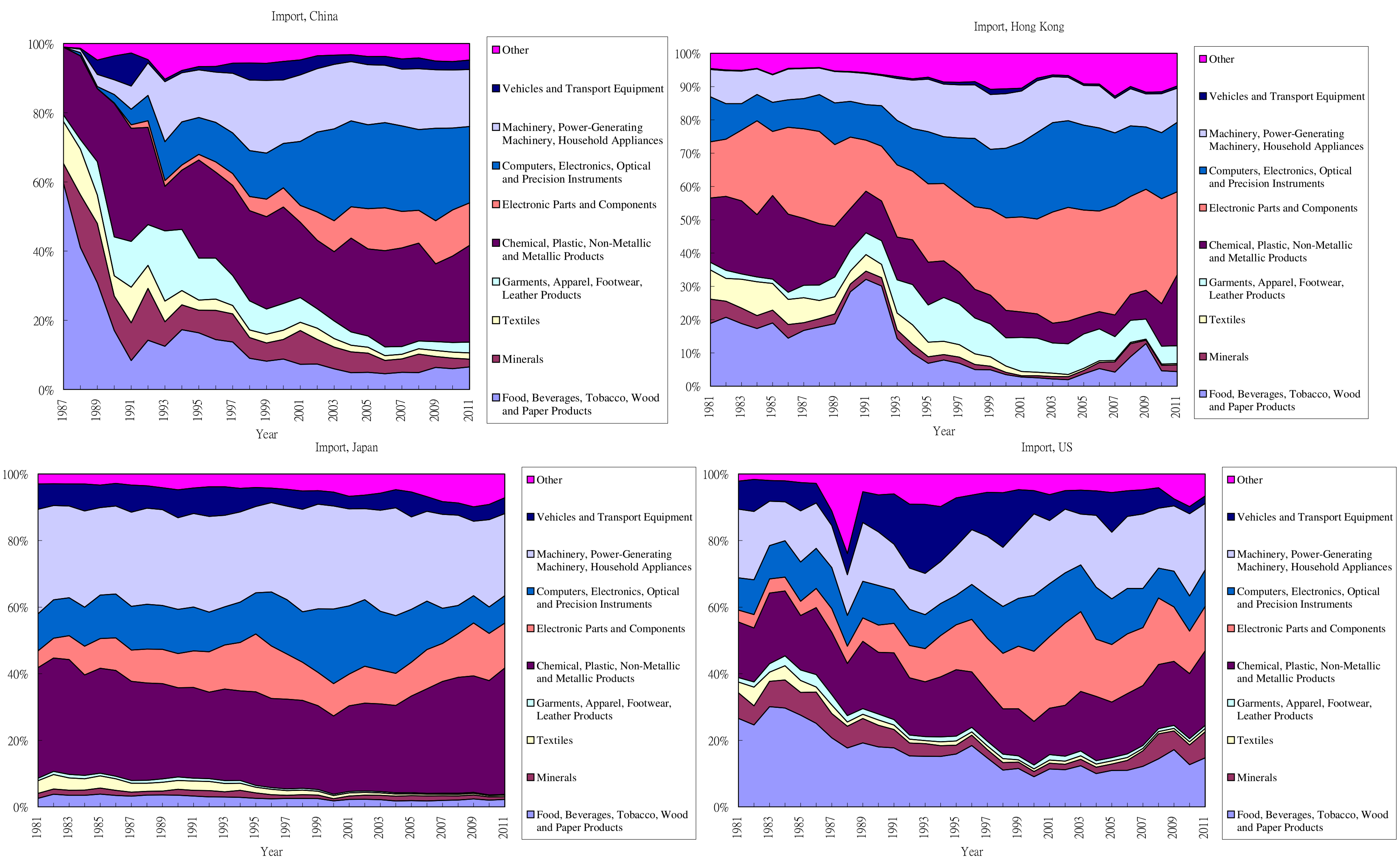


Figure 2.10: Import Shares by Commodities and Trading Partners

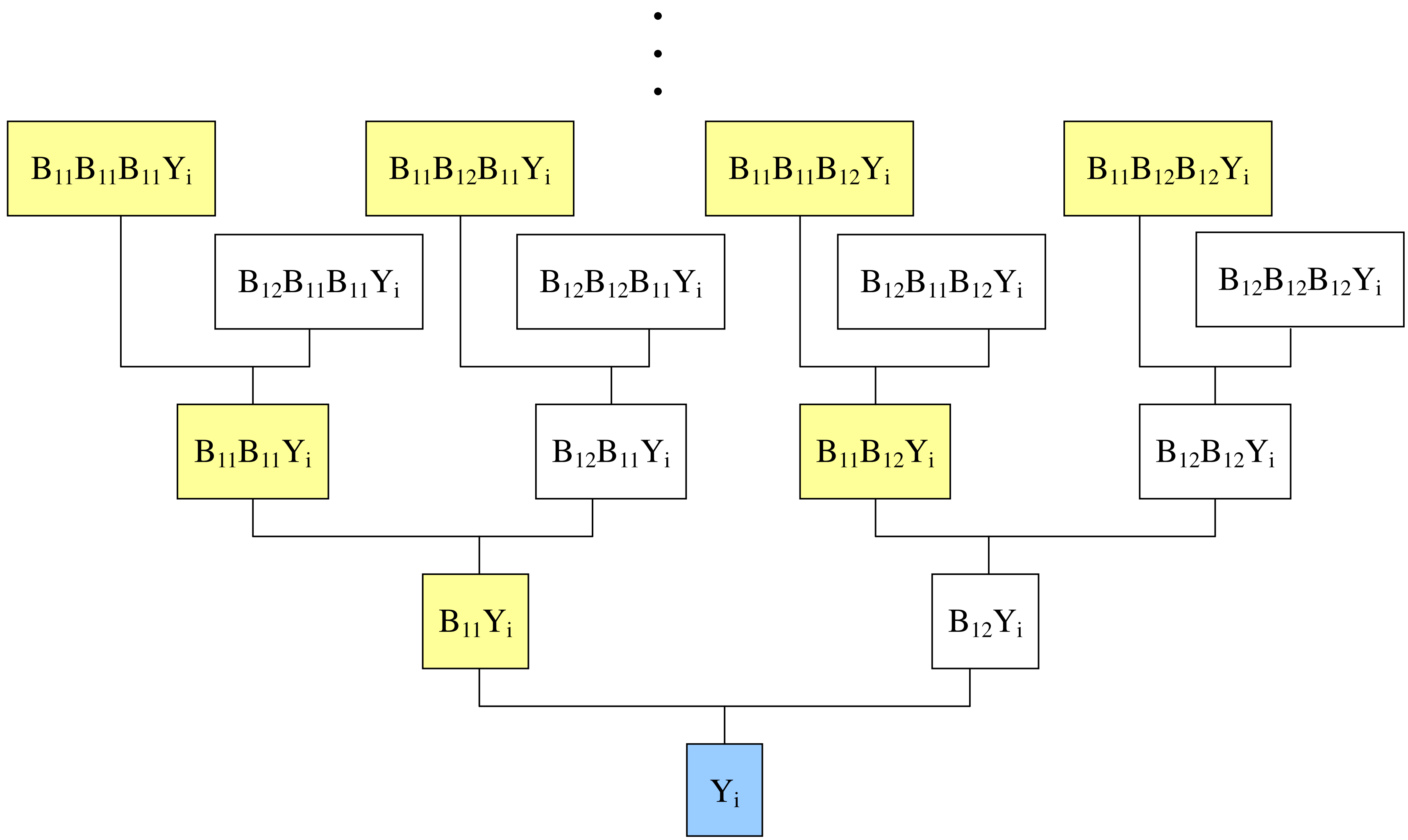


Figure 2.11: Domestic (in Yellow) and Imported (Uncolored) Intermediate Inputs Required to Produce Y_i

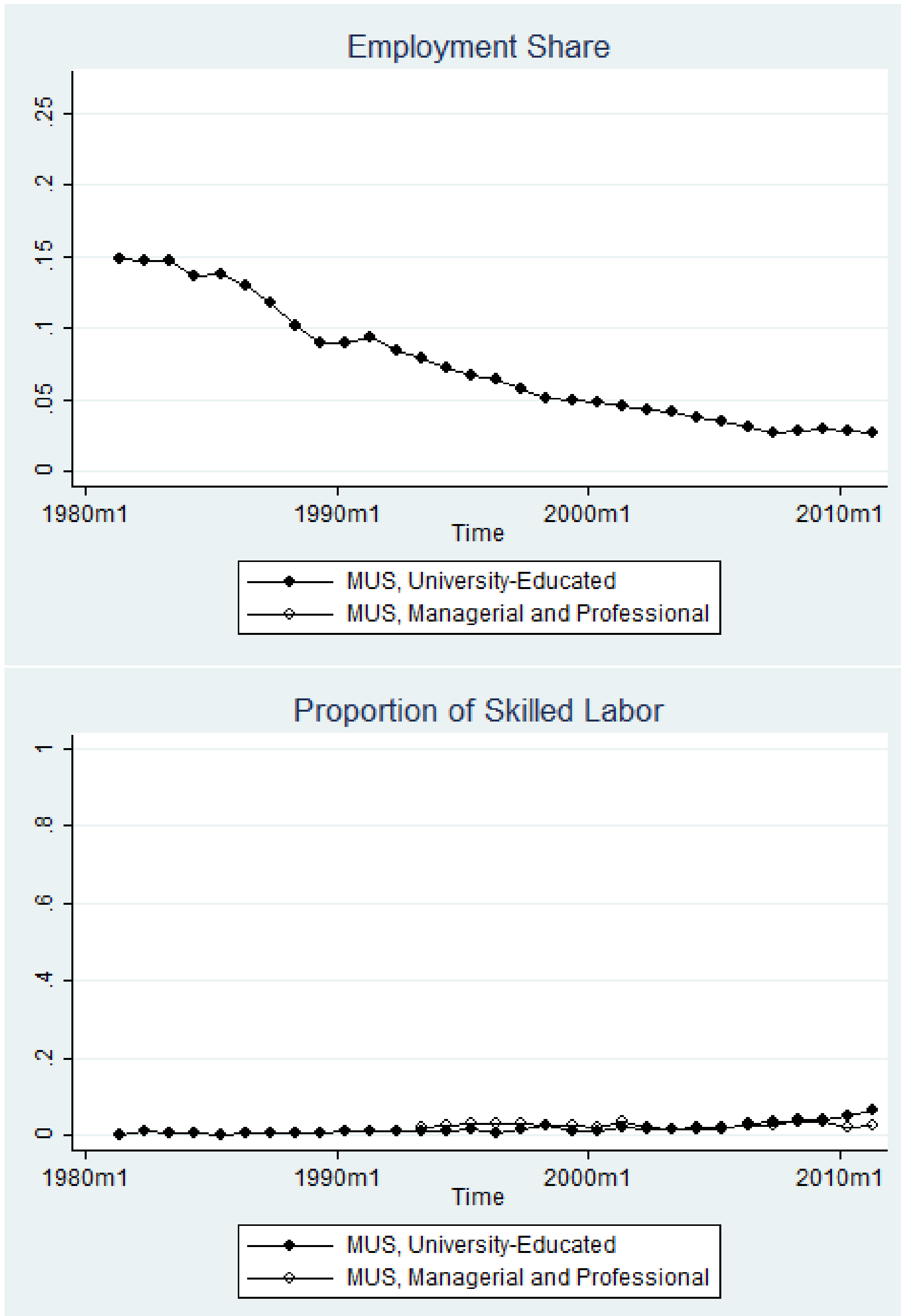


Figure 2.12: Employment Share and the Proportion of Skilled Labor; Agriculture, Forestry, Fishing

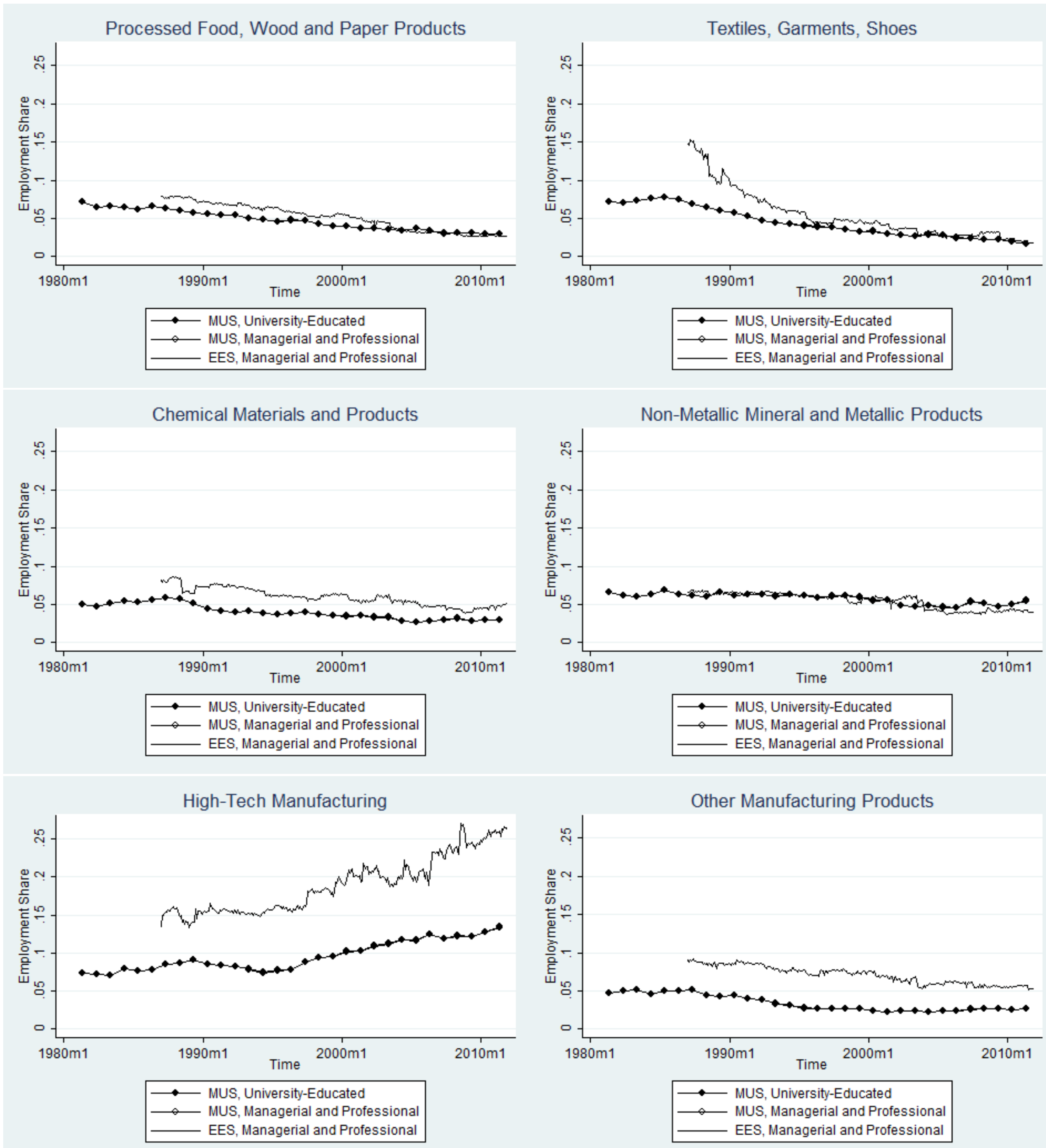


Figure 2.13: Employment Share (to the Whole Non-Agricultural Sector) of the Manufacturing Sector

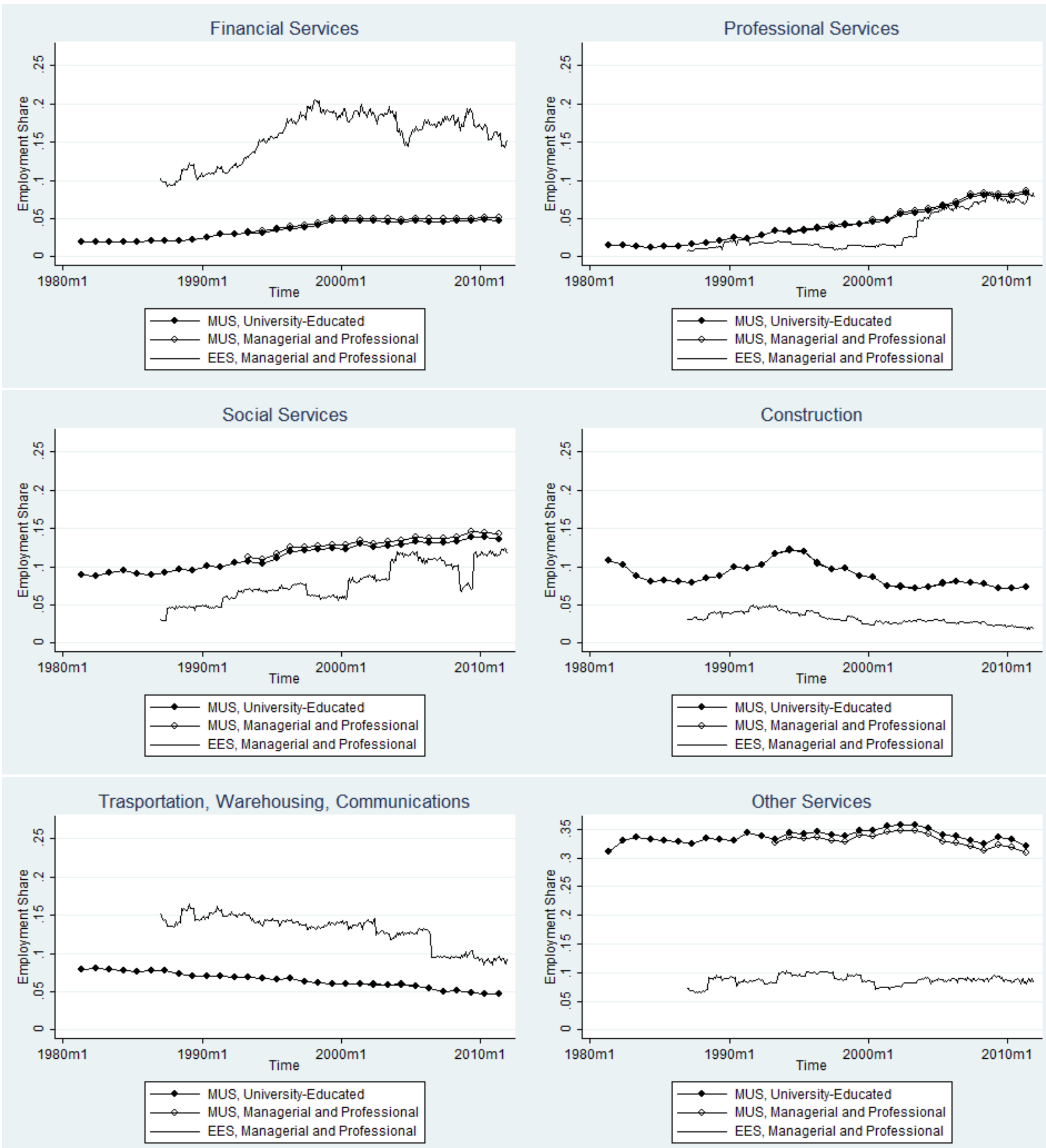


Figure 2.14: Employment Share (to the Whole Non-Agricultural Sector) of the Services Sector

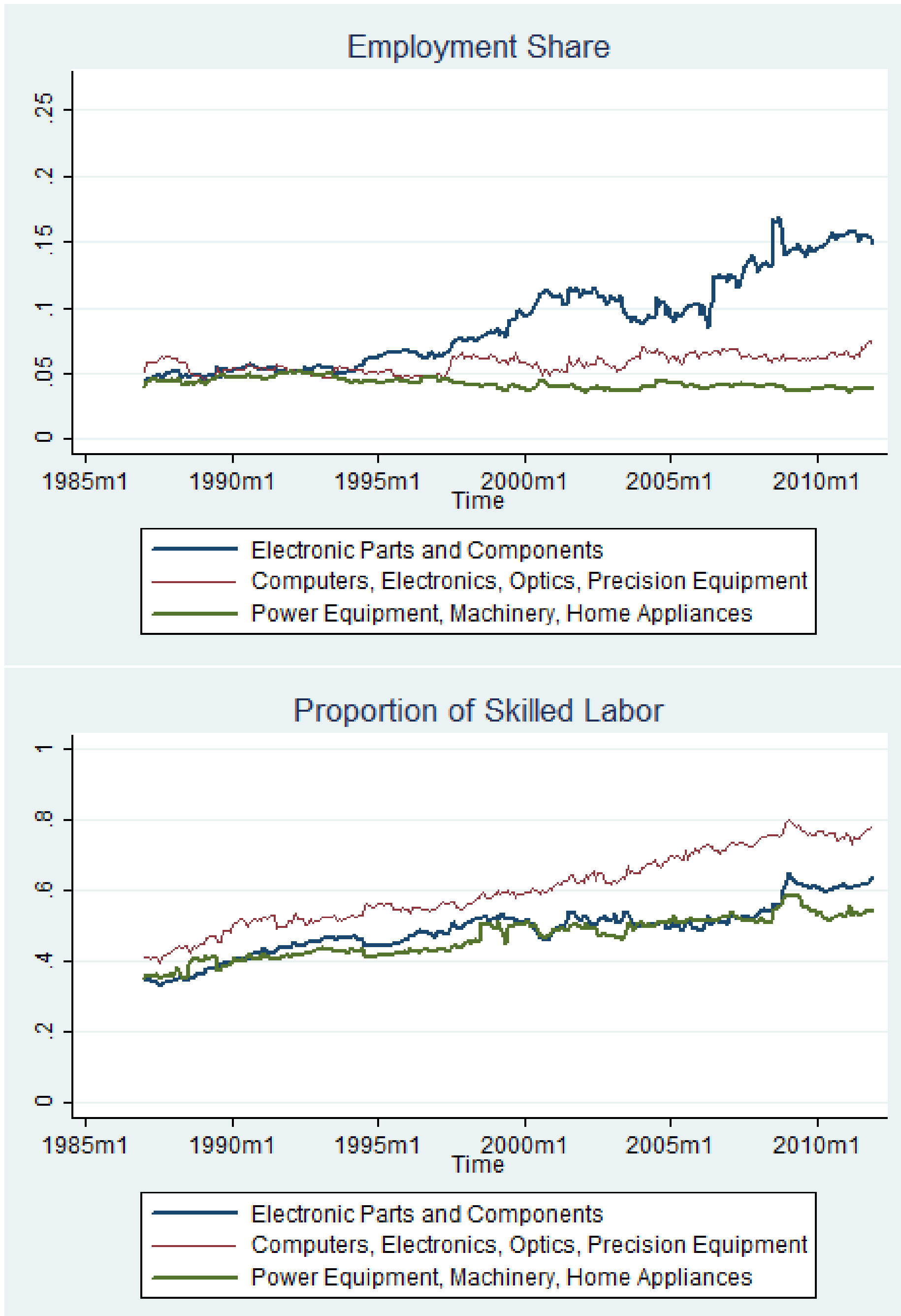


Figure 2.15: Employment Share (to the Whole Non-Agricultural Sector) and the Proportion of Skilled Labor in the High-Tech Sector

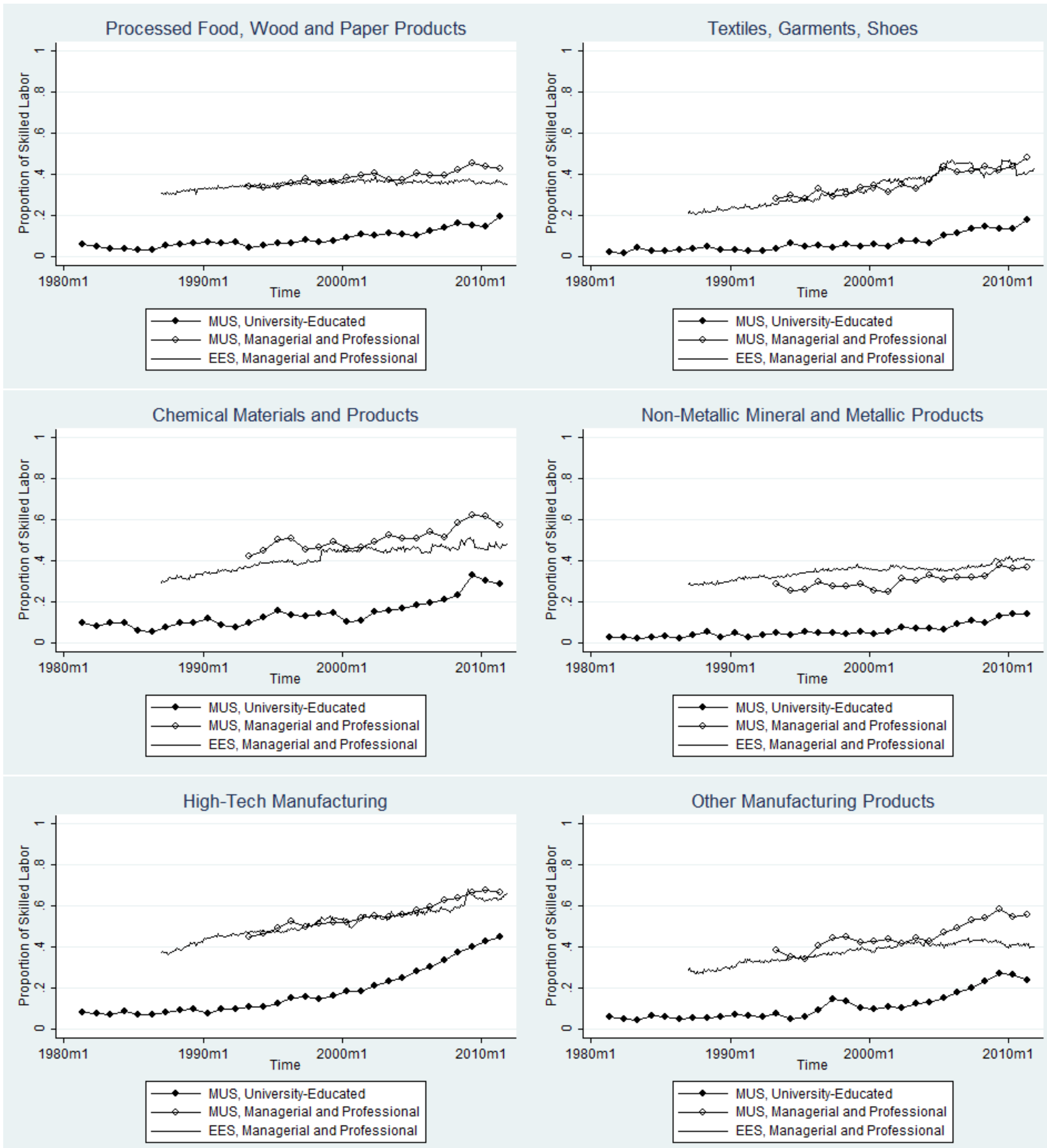


Figure 2.16: Proportion of Skilled Labor in the Manufacturing Sector

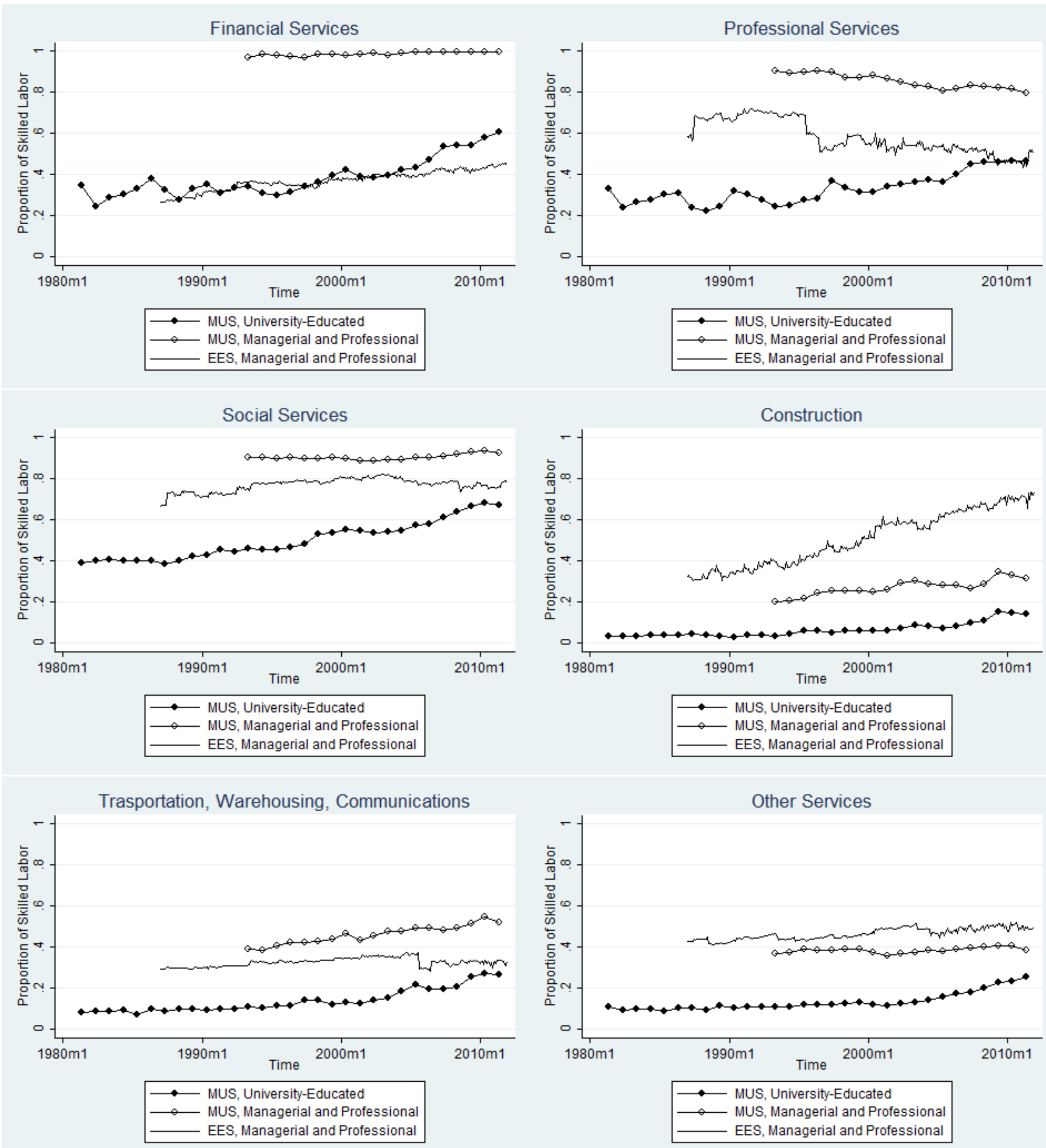


Figure 2.17: Proportion of Skilled Labor in the Services Sector

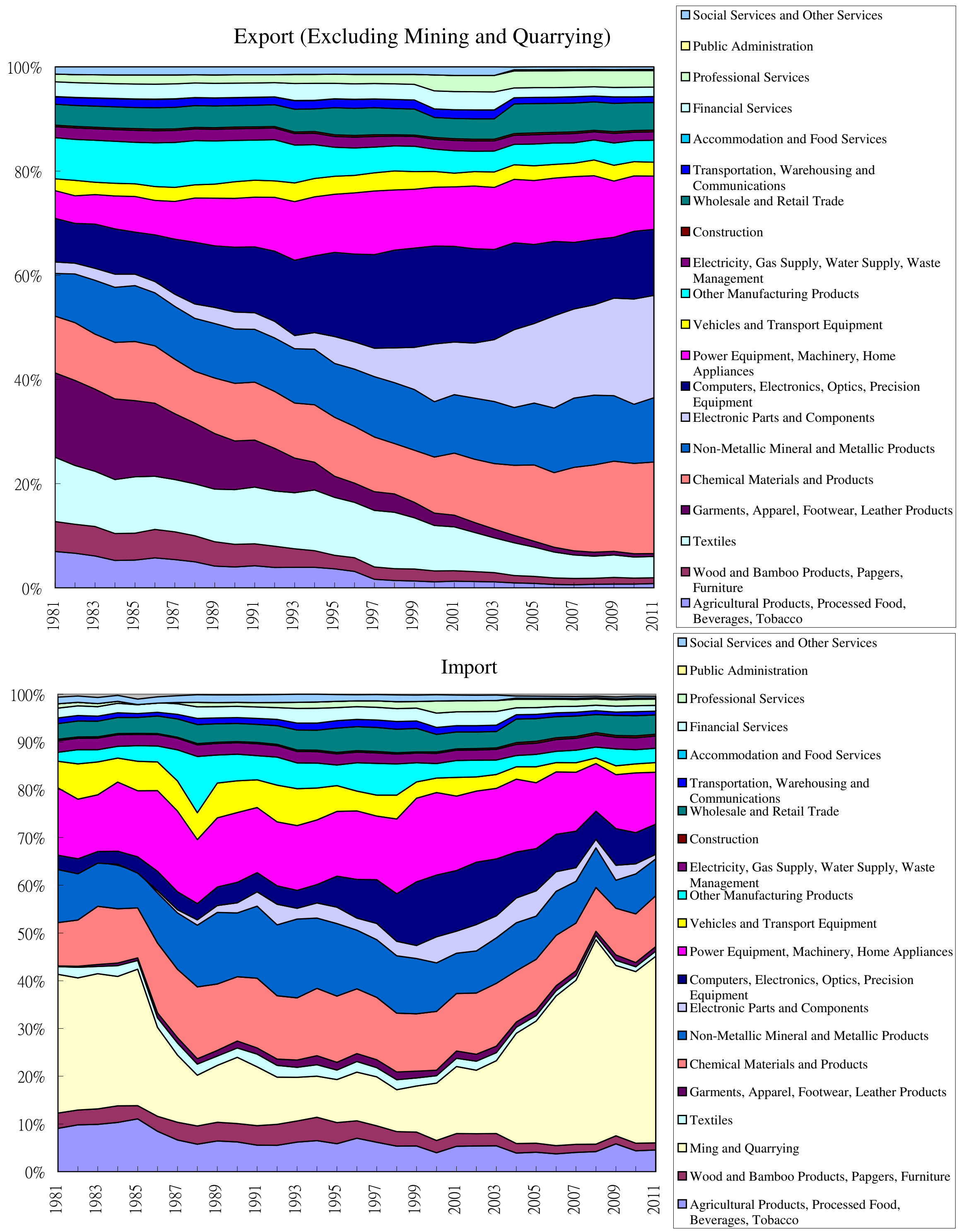


Figure 2.18: Trade Shares by Commodities, Generated from $(I-B)^{-1}G$

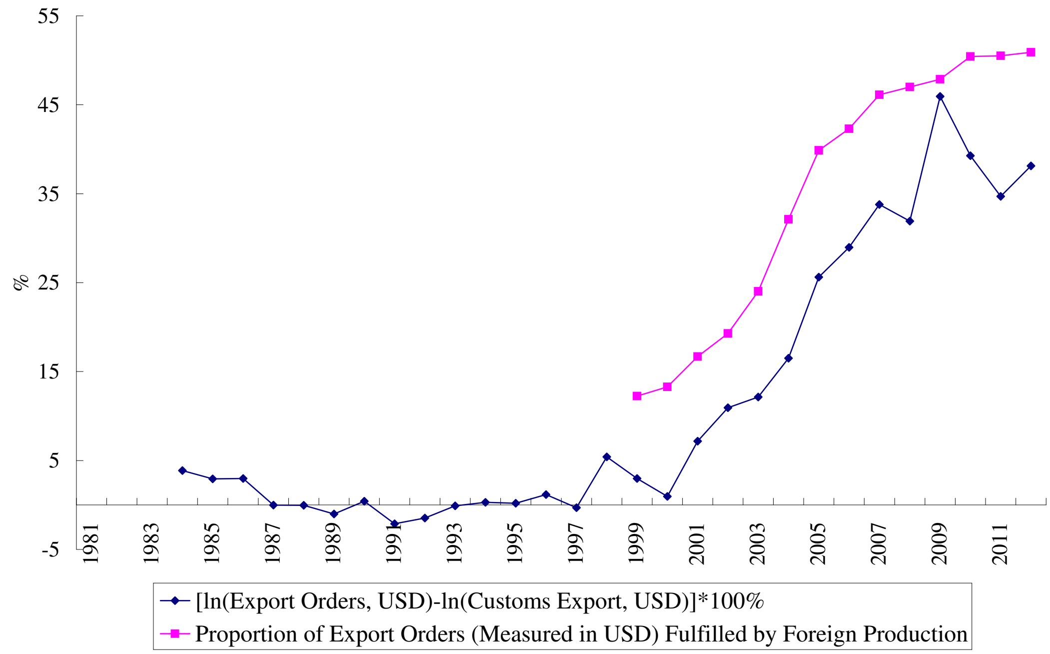


Figure 2.19: Difference between the Amount of Export Orders and Customs Export; Proportion of the Amount of Export Orders Fulfilled by Foreign Production

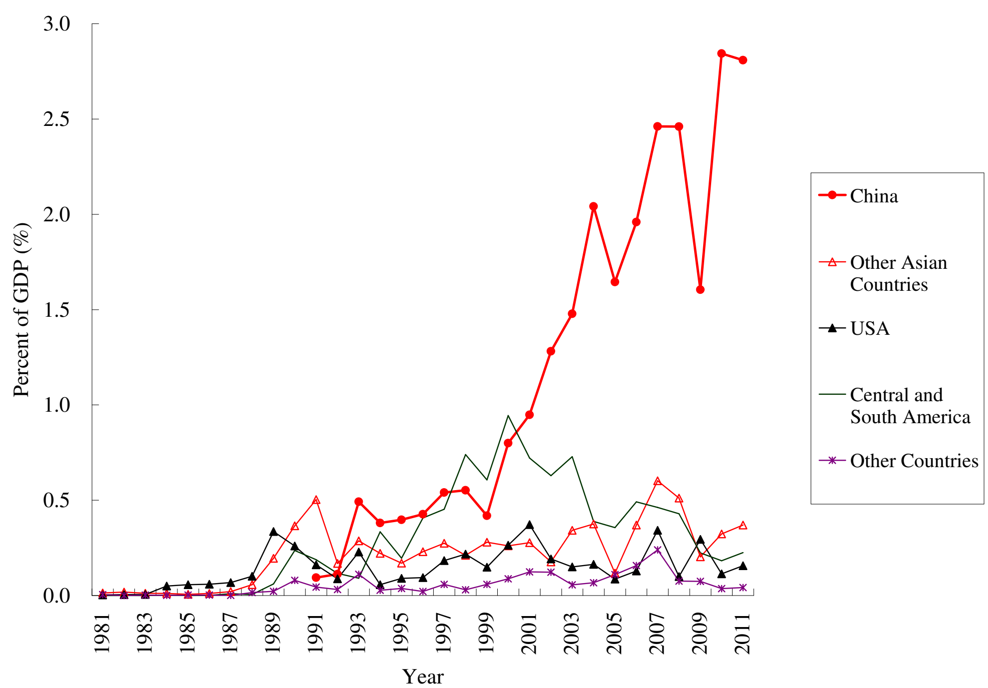


Figure 2.20: Outward FDI from Taiwan to Other Countries

Table 2.1: Proportion of Intermediate Input to Gross Output

Year	All Sectors	Tradable Sector	Non-Tradable Sector
1981	0.6014	0.7160	0.3924
1986	0.5774	0.6902	0.3810
1991	0.5539	0.7021	0.3850
1996	0.5318	0.7129	0.3612
2001	0.5276	0.7378	0.3541
2006	0.5806	0.7922	0.3746

Unit: Intermediate input/gross output.

Table 2.2: Proportion of Imported Intermediate Input to Intermediate Input

Year	All Sectors	Tradable Sector	Non-Tradable Sector
1981	0.2542	0.2843	0.1539
1986	0.2184	0.2399	0.1509
1991	0.2481	0.2869	0.1674
1996	0.2679	0.3217	0.1677
2001	0.2824	0.3523	0.1623
2006	0.3386	0.4120	0.1875

Unit: Imported intermediate input/intermediate input.

Table 2.3: Total Amount of Imported Intermediate Input Required for Producing One Unit of Output in the Industries Listed, Excluding Imported Mining and Quarrying Products Used as Intermediate Input

Year	1981	1986	1991	1996	2001	2006
Tradable Sector						
Agricultural Products, Processed Food, Beverages, Tobacco	0.2617	0.2150	0.2254	0.2630	0.2425	0.3161
Wood and Bamboo Products, Papers, Furniture	0.4366	0.3586	0.4314	0.4350	0.4221	0.5431
Mining and Quarrying	0.1104	0.0683	0.1027	0.0804	0.0849	0.1462
Textiles	0.3760	0.3567	0.4498	0.4801	0.3863	0.5252
Garments, Apparel, Footwear, Leather Products	0.3244	0.3244	0.3840	0.4510	0.4237	0.5771
Chemical Materials	0.3814	0.4413	0.6272	0.6568	0.5223	0.8090
Chemical Products	0.4762	0.4984	0.5787	0.5818	0.5154	0.7103
Rubber Products	0.4506	0.4359	0.4375	0.4785	0.3679	0.6121
Plastic Products	0.3353	0.3322	0.4806	0.5060	0.4604	0.7301
Non-Metallic Mineral Products	0.1570	0.1639	0.1919	0.1931	0.2277	0.2899
Metal Processing	0.5072	0.4750	0.5467	0.5003	0.5133	0.9707
Metallic Products	0.4307	0.3624	0.3998	0.4136	0.3692	0.5995
High-Tech Manufacturing	0.5752	0.5675	0.6601	0.6828	0.7724	0.9297
Electronic Parts and Components			0.6792	0.6893	0.7728	0.9588
Computers, Electronics, Optics, Precision Equipment			0.8675	0.8817	0.9607	0.9876
Power Equipment, Machinery, Home Appliances			0.4880	0.4878	0.5027	0.8307
Vehicles and Transport Equipment	0.4583	0.4283	0.4508	0.4614	0.4406	0.6856
Other Manufacturing Products	0.2925	0.3137	0.4146	0.4567	0.4598	0.5756
Non-Tradable Sector						
Electricity, Gas Supply, Water Supply, Waste Management	0.0828	0.1082	0.1200	0.1090	0.1143	0.1689
Construction	0.2181	0.2024	0.2689	0.2780	0.3062	0.4326
Wholesale and Retail Trade	0.0654	0.0606	0.0674	0.0764	0.0688	0.0833
Transportation, Warehousing and Communications	0.1241	0.1248	0.1521	0.1691	0.1784	0.2784
Accommodation and Food Services	0.0561	0.0686	0.0667	0.0739	0.0643	0.1637
Financial Services	0.0339	0.0966	0.0795	0.0626	0.0693	0.0669
Professional Services	0.0683	0.0686	0.0723	0.0748	0.0884	0.1242
Public Administration	0.2141	0.2042	0.2343	0.1878	0.1198	0.1106
Social Services	0.0987	0.1037	0.1199	0.0984	0.1099	0.1801
Other Services*	0.1737	0.1861	0.1395	0.1564	0.1223	0.1661

* Other Services include maintenance and repair of personal and household items, laundry, hairdressing, beauty treatment, domestic services and other services not elsewhere classified.

Table 2.4: Amount of Imported Intermediate Input Required and Its Proportion to Total Intermediate Input Required for Producing One Unit of High-Tech Manufacturing Products

	Amount of Imported Intermediate Input				Proportion to Total Intermediate Input (%)			
	1991	1996	2001	2006	1991	1996	2001	2006
Electronic Parts and Components	**0.7581**	**0.7584**	**0.8918**	**1.4038**	**38.35**	**41.48**	**42.94**	**50.84**
Mining and Quarrying	0.0790	0.0692	0.1190	0.4451	60.12	62.75	68.78	82.62
Chemical Materials	0.1506	0.1247	0.1003	0.1562	55.73	44.75	40.83	44.89
Metal Processing	0.1115	0.0760	0.0525	0.1101	40.96	43.53	42.55	51.36
Electronic Parts and Components	0.2565	0.3567	0.4334	0.5262	60.80	72.70	65.14	59.88
Computers, Electronics, Optics, Precision Equipment	0.0253	0.0083	0.0078	0.0061	71.97	32.18	55.50	86.26
Power Equipment, Machinery, Home Appliances	0.0328	0.0196	0.0367	0.0331	34.29	38.56	46.33	46.85
Other Industries	0.1026	0.1039	0.1421	0.1270	13.66	14.89	18.31	18.04
Computers, Electronics, Optics, Precision Equipment	**0.9337**	**0.9406**	**1.0671**	**1.4118**	**42.35**	**44.03**	**44.68**	**48.23**
Mining and Quarrying	0.0662	0.0590	0.1063	0.4242	59.89	61.91	68.06	82.35
Chemical Materials	0.0925	0.0879	0.0828	0.1275	48.18	43.57	39.54	42.22
Metal Processing	0.0787	0.0627	0.0471	0.1011	38.47	39.54	38.64	47.07
Electronic Parts and Components	0.3355	0.5511	0.5829	0.5270	63.70	76.34	66.65	60.17
Computers, Electronics, Optics, Precision Equipment	0.2151	0.0483	0.0700	0.0499	80.80	41.39	68.32	74.03
Power Equipment, Machinery, Home Appliances	0.0452	0.0335	0.0534	0.0391	40.53	41.23	52.48	46.38
Other Industries	0.1005	0.0981	0.1245	0.1431	12.67	12.90	15.15	16.49
Power Equipment, Machinery, Home Appliances	**0.5755**	**0.5610**	**0.6320**	**1.3691**	**28.86**	**29.82**	**31.02**	**44.62**
Mining and Quarrying	0.0876	0.0731	0.1294	0.5384	57.43	58.30	64.22	80.93
Chemical Materials	0.0549	0.0528	0.0437	0.0617	41.95	41.28	33.28	40.17
Metal Processing	0.2209	0.2007	0.1750	0.4054	36.69	37.07	35.76	45.59
Electronic Parts and Components	0.0181	0.0423	0.0457	0.0469	53.28	66.01	63.54	60.77
Computers, Electronics, Optics, Precision Equipment	0.0139	0.0084	0.0145	0.0219	56.24	33.21	53.79	87.19
Power Equipment, Machinery, Home Appliances	0.1075	0.1099	0.1417	0.1949	37.74	46.41	49.09	51.20
Other Industries	0.0727	0.0736	0.0821	0.1000	9.50	9.69	9.91	11.40

Note: For example, producing one unit of Electronic Parts and Components in 1991 requires 0.7581 units of imported intermediate input, which includes 0.0790 units of imported Mining and Quarrying products. Imported intermediate input consists of 38.35% of the total amount of intermediate input, and imported Mining and Quarrying products consist of 60.12% of all the Mining and Quarrying products used as intermediate input to produce one unit of Electronic Parts and Components. Please refer to the text for a more detailed description of this table.

Table 2.5: Amount of Imported Intermediate Input Required and Its Proportion to Total Intermediate Input Required for Producing One Unit of Textiles or Garments Products

	Amount of Imported Intermediate Input						Proportion to Total Intermediate Input (%)					
	1981	1986	1991	1996	2001	2006	1981	1986	1991	1996	2001	2006
Textiles	**0.8882**	**0.4820**	**0.5547**	**0.5852**	**0.6186**	**1.4722**	**37.51**	**24.47**	**27.88**	**30.30**	**29.57**	**48.58**
Agricultural Products, Processed Food, Beverages, Tobacco	0.1468	0.0948	0.0980	0.0705	0.0554	0.0511	57.32	57.30	60.83	58.21	61.67	62.81
Mining and Quarrying	0.5122	0.1253	0.1049	0.1051	0.2323	0.9470	71.91	58.84	61.62	63.30	69.92	82.21
Textiles	0.0135	0.0266	0.0624	0.0742	0.0487	0.0418	3.18	6.29	16.11	17.21	10.90	9.27
Garments, Apparel, Footwear, Leather Products	0.0006	0.0006	0.0005	0.0008	0.0010	0.0003	10.26	11.31	12.41	16.08	17.30	15.35
Chemical Materials	0.1123	0.1398	0.1808	0.2134	0.1482	0.2584	16.52	21.41	26.30	29.84	23.12	28.45
Other Industries	0.1027	0.0950	0.1081	0.1211	0.1330	0.1737	16.39	16.08	16.17	17.12	16.64	18.55
Garments, Apparel, Footwear, Leather Products	**0.6789**	**0.4092**	**0.4582**	**0.5181**	**0.5720**	**1.1858**	**28.67**	**20.78**	**23.04**	**26.83**	**27.34**	**39.13**
Agricultural Products, Processed Food, Beverages, Tobacco	0.0956	0.0913	0.0592	0.0735	0.0792	0.1108	52.34	55.21	54.53	51.91	59.18	61.06
Mining and Quarrying	0.3544	0.0848	0.0742	0.0670	0.1483	0.6088	71.84	57.05	60.89	62.38	68.71	81.93
Textiles	0.0474	0.0496	0.0729	0.1035	0.0718	0.0681	7.98	8.66	17.34	21.40	14.35	14.41
Garments, Apparel, Footwear, Leather Products	0.0126	0.0130	0.0279	0.0443	0.0512	0.0722	17.30	12.61	16.01	41.52	51.98	46.01
Chemical Materials	0.0762	0.0865	0.1253	0.1160	0.0926	0.1542	17.71	22.54	29.06	31.93	26.21	31.32
Other Industries	0.0927	0.0840	0.0986	0.1137	0.1289	0.1718	15.57	14.11	13.46	15.61	16.31	17.45

Note: Please refer to the note of Table 2.4 and the text for a more detailed description of this table.

Table 2.6: Decomposition of Growth in the Employment of Managerial and Professional Workers

	Between-Industry				Within-Industry			
Unit=100%	1987-1995	1995-2003	2003-2011	1987-2011	1987-1995	1995-2003	2003-2011	1987-2011
Tradable Sector								
Processed Food, Beverages, Tobacco	0.0008	0.0805	0.1682	0.1592	0.0332	-0.0122	-0.0314	-0.0262
Wood and Bamboo Products, Papers, Furniture	0.0760	0.0814	0.0566	0.2460	0.2372	0.1311	0.0005	0.3316
Mining and Quarrying	0.0154	0.0107	-0.0223	0.0733	0.2386	0.0690	-0.0875	0.1981
Textiles	0.3564	0.2705	0.1242	0.7559	0.2843	0.2051	0.0383	0.5773
Garments, Apparel, Footwear, Leather Products	0.6292	0.0163	-0.0137	0.2121	0.4582	0.2326	0.0888	1.4800
Chemical Materials	0.0022	-0.0005	0.0204	0.0373	0.2645	0.1640	-0.1426	0.2823
Chemical Products	0.0035	0.0051	-0.0288	-0.0205	0.0812	0.0221	0.0053	0.0881
Medicine	0.0020	0.0118	0.0219	0.0413	0.0311	0.0089	0.0591	0.1040
Rubber Products	0.0098	0.0270	0.0426	0.0882	0.0699	0.0280	-0.0249	0.0444
Plastic Products	0.0761	0.0011	0.0817	0.1361	0.1501	0.0400	0.1232	0.3409
Non-Metallic Mineral Products	0.0459	0.0635	0.0262	0.1479	0.0672	0.0429	-0.0071	0.0943
Metal Processing	-0.0037	-0.0118	0.0961	0.0170	0.1062	0.0284	0.2344	0.3190
Metallic Products	0.0277	-0.0159	0.0135	0.0423	0.1718	0.0232	0.0528	0.2603
Electronic Parts and Components	0.0543	0.1332	0.3742	0.6396	0.5878	0.6124	1.2171	2.7799
Computers, Electronics, Optics, Precision Equipment	-0.0824	0.0237	0.1864	0.0741	0.8565	0.3821	0.6391	2.0507
Power Equipment, Machinery, Home Appliances	-0.0056	0.0045	-0.0001	-0.0224	0.2478	0.1769	0.3014	0.7586
Vehicles and Transport Equipment	-0.0147	0.0123	0.0950	0.0626	0.1668	0.4091	-0.0721	0.4173
Other Manufacturing Products	0.0911	0.0348	0.0078	0.0523	0.1136	0.0564	0.1227	0.4073
Non-Tradable Sector								
Electricity, Gas Supply, Water Supply, Waste Management	0.1612	-0.0322	-0.0459	0.0223	0.0680	0.1537	0.0534	0.2408
Construction	-0.0030	-0.0385	-0.1380	-0.1043	0.2980	0.6083	0.2848	0.9880
Wholesale and Retail Trade	-0.0185	0.0235	-0.0059	-0.0242	-0.0137	0.3774	-0.0652	0.2231
Transportation, Warehousing, Communications	0.0099	0.1776	0.4457	0.5030	0.4606	0.4084	-0.2288	0.5056
Accommodation and Food Services	-0.0091	0.0457	-0.0192	0.0230	0.0402	0.0312	-0.0421	0.0180
Financial Services	-0.2934	-0.1990	0.2187	-0.3821	1.2030	0.7793	0.7303	2.3356
Professional Services	0.2241	0.1915	-0.0388	0.5209	0.1521	-0.3211	-0.4946	-0.4726
Arts, Entertainment, Leisure	0.0426	-0.0113	0.0608	0.0657	0.2124	-0.0096	-0.2327	0.0407
Medical Services	1.5844	0.5567	0.8229	2.8539	0.1240	0.2668	-0.3302	0.2020
Other Services*	0.0041	0.0115	-0.0049	0.0142	-0.0003	0.0227	-0.0199	0.0006
All Industries	**2.9863**	**1.4737**	**2.5453**	**6.2348**	**6.7103**	**4.9371**	**2.1721**	**14.5896**

* Other Services include maintenance and repair of personal and household items, laundry, hairdressing, beauty treatment, domestic service, and other services not elsewhere classified.

Table 2.7: Decomposition of Growth in the Employment of Skilled Labor, 1993-2011

(a) MUS

Type of Skilled Workers:	University-Educated		Managerial and Professional	
Unit=100%	Between-Industry	Within-Industry	Between-Industry	Within-Industry
Tradable Sector				
Agriculture, Forestry, Fishing	1.0416	0.2753	2.4040	0.0128
Processed Food, Beverages, Tobacco	0.0082	0.2417	0.0049	0.0225
Wood and Bamboo Products, Papers, Furniture	0.2391	0.2764	0.2327	0.2437
Mining and Quarrying	0.0061	0.0272	-0.0539	0.0619
Textiles	0.1315	0.1650	0.0812	0.1867
Garments, Apparel, Footwear, Leather Products	0.1891	0.2327	0.1830	0.3771
Chemical Materials	0.0007	0.1464	0.0058	0.1132
Chemical Products	0.0019	0.1383	0.0060	0.0466
Rubber Products	0.0529	0.0351	0.0506	0.0417
Plastic Products	0.0864	0.1996	0.0706	0.1748
Non-Metallic Mineral Products	0.0466	0.0406	0.0275	0.0709
Metal Processing	-0.0101	0.1073	-0.0031	0.0724
Metal Products	-0.0175	0.3823	-0.0007	0.3280
High-Tech Manufacturing	0.2256	3.4596	0.3984	2.2122
Vehicles and Transport Equipment	-0.0177	0.2773	-0.0094	0.2686
Other Manufacturing Products	0.0445	0.1584	0.0280	0.1986
Non-Tradable Sector				
Electricity, Gas Supply, Water Supply, Waste Management	-0.0013	0.2079	0.0029	0.0706
Construction	0.5419	0.9393	0.8653	1.0184
Wholesale and Retail Trade	0.0627	2.5287	0.1216	0.3970
Transportation, Warehousing and Communications	0.0946	0.8435	0.0678	0.7015
Accommodation and Food Services	-0.2843	0.5346	-0.5264	-0.1045
Financial Services	0.4171	0.9980	0.9496	0.1166
Professional Services	0.5830	1.2527	1.8443	-0.6053
Public Administration	0.0492	0.9232	0.0693	0.1818
Social Services	1.1085	2.4721	1.4994	0.2577
Other Services*	0.0719	0.3017	0.1848	0.0788
All Industries	**4.6722**	**17.1647**	**8.5042**	**6.5441**

(b) EES

Type of Skilled Workers:	Managerial and Professional	
Unit=100%	Between-Industry	Within-Industry
Tradable Sector		
Processed Food, Beverages, Tobacco	0.2522	-0.0263
Wood and Bamboo Products, Papers, Furniture	0.1833	0.1356
Mining and Quarrying	0.0135	-0.0343
Textiles	0.4201	0.2826
Garments, Apparel, Footwear, Leather Products	0.0790	0.4163
Chemical Materials	0.0316	0.0666
Chemical Products	-0.0179	0.0480
Medicine	0.0429	0.0651
Rubber Products	0.0801	-0.0061
Plastic Products	0.1161	0.2234
Non-Metallic Mineral Products	0.1092	0.0512
Metal Processing	0.0851	0.3395
Metallic Products	0.0140	0.1012
Electronic Parts and Components	0.7771	1.5713
Computers, Electronics, Optics, Precision Equipment	0.2874	1.2227
Power Equipment, Machinery, Home Appliances	-0.0247	0.4774
Vehicles and Transport Equipment	0.1318	0.3884
Other Manufacturing Products	0.0259	0.2120
Non-Tradable Sector		
Electricity, Gas Supply, Water Supply, Waste Management	-0.0842	0.1314
Construction	-0.2507	1.0618
Wholesale and Retail Trade	-0.0398	0.1582
Transportation, Warehousing, Communications	0.7438	0.2665
Accommodation and Food Services	0.0606	0.0007
Financial Services	-0.1671	1.1836
Professional Services	0.5558	-1.1566
Arts, Entertainment, Leisure	0.0187	-0.1408
Medical Services	1.4618	0.0647
Other Services*	0.0175	-0.0076
All Industries	**4.9232**	**7.0965**

* Other Services include maintenance and repair of personal and household items, laundry, hairdressing, beauty treatment, domestic service, and other services not elsewhere classified.

Table 2.8: OLS Regression of Skill Premium

(a) MUS

1981-2011, Skilled Labor=University-Educated				
Dependent Variable: $\ln(W_t^C/W_t^N)$	(1)	(2)	(3)	(4)
$\ln(C_t/N_t)$	0.0004	-0.01	-0.52	-0.50
	(0.01)	(0.0)	(0.14)	(0.14)
$t/10$		0.01	0.04	-0.06
		(0.04)	(0.04)	(0.09)
$(t/10)^2$			0.08	0.15
			(0.02)	(0.05)
$(t/10)^3$				-0.01
				(0.01)
Observations	31	31	31	31
Adjusted R^2	-0.03	-0.07	0.24	0.26

1993-2011, Skilled Labor=Managerial and Professional				
Dependent Variable: $\ln(W_t^C/W_t^N)$	(5)	(6)	(7)	(8)
$\ln(C_t/N_t)$	0.01	-0.49	-0.52	-0.49
	(0.03)	(0.18)	(0.11)	(0.11)
$t/10$		0.18	0.31	0.23
		(0.06)	(0.05)	(0.14)
$(t/10)^2$			-0.06	0.02
			(0.02)	(0.13)
$(t/10)^3$				-0.03
				(0.04)
Observations	19	19	19	19
Adjusted R^2	-0.05	0.24	0.54	0.53

(b) EES

1987-2011, May, Skilled Labor=Managerial and Professional				
Dependent Variable: $\ln(W_t^C/W_t^N)$	(9)	(10)	(11)	(12)
$\ln(C_t/N_t)$	0.11	-0.34	0.02	0.11
	(0.03)	(0.09)	(0.09)	(0.08)
$t/10$		0.15	-0.08	-0.22
		(0.03)	(0.04)	(0.07)
$(t/10)^2$			0.04	0.14
			(0.01)	(0.04)
$(t/10)^3$				-0.02
				(0.01)
Observations	25	25	25	25
Adjusted R^2	0.49	0.74	0.89	0.92

1987-2011, Monthly, Skilled Labor=Managerial and Professional				
Dependent Variable: $\ln(W_t^C/W_t^N)$	(13)	(14)	(15)	(16)
$\ln(C_t/N_t)$	0.10	-0.31	0.02	0.10
	(0.01)	(0.03)	(0.03)	(0.03)
	[0.03]	[0.09]	[0.07]	[0.05]
$t/10$		0.14	-0.08	-0.22
		(0.01)	(0.01)	(0.02)
		[0.03]	[0.03]	[0.04]
$(t/10)^2$			0.04	0.14
			(0.002)	(0.01)
			[0.004]	[0.03]
$(t/10)^3$				-0.02
				(0.003)
				[0.006]
Month Dummies	Yes	Yes	Yes	Yes
Observations	300	300	300	300
Adjusted R^2	0.48	0.68	0.86	0.89

t is year index, re-scaled so that $t = 1, 2, 3, ...$ Heteroskedastically-robust standard errors are in parentheses. Clustered standard errors by year are in brackets.

Table 2.9: Shifts in the Relative Demand for Skilled Labor, $\ln(D_t) - \ln(D_{t_0})$, and the Shifts Explained by Trade, $\ln(T_t) - \ln(T_{t_0})$

Unit: 100%, $1/\sigma = 0.5$

*MUS, University-Educated	1981-2011	1981-1986	1986-1991	1991-1996	1996-2001	2001-2006	2006-2011
$\ln(D_t) - \ln(D_{t_0})$	81.79	9.37	-1.25	14.44	22.92	17.00	19.31
$\ln(T_t) - \ln(T_{t_0})$	-0.22	-1.43	0.99	0.84	0.00	0.09	-0.71
*MUS, Managerial and Professional	1993-2011			1993-1996	1996-2001	2001-2006	2006-2011
$\ln(D_t) - \ln(D_{t_0})$	29.24			4.66	11.77	7.41	5.40
$\ln(T_t) - \ln(T_{t_0})$	0.03			0.02	0.03	0.13	-0.15
*EES, Managerial and Professional	1987-2011		1987-1991	1991-1996	1996-2001	2001-2006	2006-2011
$\ln(D_t) - \ln(D_{t_0})$	50.53		9.36	10.64	7.85	10.33	12.35
$\ln(T_t) - \ln(T_{t_0})$	0.42		0.18	0.08	-0.08	0.79	-0.55
**EES, Managerial and Professional, Trade Data from Transaction Tables	1991-2006			1991-1996	1996-2001	2001-2006	
$\ln(D_t) - \ln(D_{t_0})$	28.82			10.64	7.85	10.33	
$\ln(T_t) - \ln(T_{t_0})$	1.33			0.43	-0.01	0.91	

* "MUS, University-Educated" and "MUS, Managerial and Professional" include 25 industries (15 in the tradable sector and 10 in the non-tradable sector), while "EES, Managerial and Professional" uses the EES data in May and includes 28 industries (18 in the tradable sector and 10 in the non-tradable sector). The trade data for these rows are from the *Monthly Statistics of Exports and Imports*, Comtrade, and the NBER-United Nations Trade Data. We calculate the change between two adjacent years, and a_i^C is the employment share of skilled labor in industry i, averaged between the two adjacent years. We then sum up all the changes according to the periods specified in the table.

** "EES, Managerial and Professional, Trade Data from Transaction Tables" uses the EES data in May and includes 91 industries (68 in the tradable sector and 23 in the non-tradable sector), and the trade data for this row comes from transaction tables, Since we only use the transaction tables of years 1991, 1996, 2001, and 2006, we calculate directly the changes between 1991 and 1996, between 1996 and 2001, and between 2001 and 2006, and a_i^C is the employment share of skilled labor in industry i, averaged over the whole five-year periods as specified in the table.

Table 2.10: Shifts in the Relative Demand for Skilled Labor Explained by Trade, $\ln(T_t) - \ln(T_{t_0})$, including Trade in Final and Intermediate Goods

Unit: 100%, $1/\sigma = 0.5$

*MUS, University-Educated	1981-2011	1981-1986	1986-1991	1991-1996	1996-2001	2001-2006	2006-2011
	-3.20	-3.99	2.81	1.06	-0.39	-0.59	-2.10
*MUS, Managerial and Professional	1993-2011			1993-1996	1996-2001	2001-2006	2006-2011
	-0.56			-0.30	0.03	0.00	-0.29
*EES, Managerial and Professional	1987-2011		1987-1991	1991-1996	1996-2001	2001-2006	2006-2011
	-1.02		-0.57	-0.29	-0.92	1.15	-0.39
**EES, Managerial and Professional, Trade Data from Transaction Tables	1991-2006			1991-1996	1996-2001	2001-2006	
	0.48			0.24	-0.64	0.88	

* "MUS, University-Educated" and "MUS, Managerial and Professional" include 25 industries (15 in the tradable sector and 10 in the non-tradable sector), while "EES, Managerial and Professional" uses the EES data in May and includes 28 industries (18 in the tradable sector and 10 in the non-tradable sector). The trade data for these rows are from the *Monthly Statistics of Exports and Imports*, Comtrade, and the NBER-United Nations Trade Data. We calculate the change between two adjacent years, and a_i^C is the employment share of skilled labor in industry i, averaged between the two adjacent years. We then sum up all the changes according to the periods specified in the table.
** "EES, Managerial and Professional, Trade Data from Transaction Tables" uses the EES data in May and includes 91 industries (68 in the tradable sector and 23 in the non-tradable sector), and the trade data for this row comes from transaction tables, Since we only use the transaction tables of years 1991, 1996, 2001, and 2006, we calculate directly the changes between 1991 and 1996, between 1996 and 2001, and between 2001 and 2006, and a_i^C is the employment share of skilled labor in industry i, averaged over the whole five-year periods as specified in the table.

Table 2.11: Triangular Trade in Manufacturing, Wholesale/Retail, and Selected Manufacturing Industries, 2006 and 2011

Industry	2006 Number of Firms	2006 Proportion Performing Triangular Trade,%	2006 Profit Margin, %*	2011 Number of Firms	2011 Proportion Performing Triangular Trade,%	2011 Profit Margin, %*
Manufacturing	148,017	1.30	7.40	157,228	1.71	4.37
Textiles	6,158	1.10	11.35	5,862	1.21	12.03
Garments and Apparel	3,975	1.81	16.76	3,764	1.94	13.41
Footwear and Leather Products	1,819	1.48	4.23	1,766	1.81	13.51
Electronic Parts and Components	5,680	6.88	9.11	5,990	8.35	2.53
Computers, Electronics, Optics, Precision Equipment	3,445	9.32	6.65	3,566	10.21	3.94
Power Equipment, Electrical Equipment, and Home Appliances	5,910	3.16	6.65	6,243	3.62	10.99
Machinery	18,003	0.96	17.79	19,094	1.71	21.10
Wholesale/Retail	490,017	0.92	5.50	495,880	1.05	5.62

* Profit margin=(Sales revenue-Cost of purchasing from abroad)/Sales Revenue×100%

CHAPTER III

Family Socio-Economic Status and Educational Attainment in Taiwan

3.1 Introduction

One might wonder if the inequality in post-secondary education attainment can be alleviated by expanding post-secondary education. Taking advantage of the post-secondary education expansion in Taiwan during the 1990-2000 period, in this paper, we study how expansion in post-secondary education may affect the effect of family socio-economic status (SES) on post-secondary education attainment.

To study how SES affects educational attainment, Luoh (2004) formulated a model to illustrate how changes in admission quotas might change differently the probability of educational progression between those with higher and lower SES, and this difference depends on the enrollment rate before the change in admission quotas. He then ran probit regressions for birth cohorts 1956-1982 in Taiwan and found that the marginal effect of SES on advancing to university increased over time because the rate of enrollment into university in the beginning was very small. Instead of focusing on marginal effects, Tsai and Shavit (2007) focused on coefficients, used logistic regressions for birth cohorts 1946-1979 in Taiwan, and concluded that the effect of SES on advancing to junior college and above decreased over time, although the effect of SES on advancing to university in contrast to junior college increased over time. Their framework was based on Mare (1981), which distinguished two concepts of educational stratification: the *distribution* of educational attainment in the population, and the *allocation* of educational attainment among people with different levels of SES. Mare (1981) also compared a linear probability model and a logistic response model of educational progression and showed that the coefficient of SES in the logistic response model represents the allocation effect, holding fixed the distribution of educational attainment in the population, while the coefficient of SES in the linear probability model reflects a mixture of distribution and allocation effects.

In the context of the expansion in post-secondary education during the 1990-2000 period in Taiwan, distribution is determined by the sheer increase in admission quotas, while allocation might be affected by the nature of the expansionary policy or other factors. Therefore, we formulate a model which explicitly distinguishes between distribution and allocation, takings into account selection into university, and this model can be estimated by running probit regressions of post-secondary education attainment on SES and other control variables. If expansion in post-secondary education is only about increasing admission quotas, or changing the distribution of educational attainment, the marginal effect of SES will change, but the coefficient of SES should not change. If the coefficient of SES changes, it suggests that factors other than the increase in admission quotas may have changed at the same time to affect the allocation of post-secondary education among those with different levels of SES.

With regard to our results, when we run a probit regression of attainment in post-secondary education on SES and other controls, the coefficient of SES seems to increase with admission quotas, especially with the admission quotas to academic post-secondary education, although the increase is statistically insignificant. We also find that vocational post-secondary institutions tend to enroll students coming from a lower SES background.

The rest of the paper is organized as follows: Section 3.2 briefly summarizes the Taiwanese education system; Section 3.3 formulates a model on how admission quotas and SES may affect the distribution and allocation of education; Section 3.4 describes the dataset used in the paper; Section 3.5 reports empirical results; and Section 3.6 concludes.

3.2 Summary of the Taiwanese Education System

Figure 3.1 illustrates the current education system in Taiwan. The compulsory education in Taiwan takes nine years, with six years of education in elementary school and three years in junior high school. Beyond junior high school, secondary education (10-12 years of schooling) and post-secondary education (13 and more years of schooling) are separated into academic and vocational tracks, and students' placement depends on their entrance examination scores and preferences.

The Taiwanese government increased admissions in post-secondary education in around 1990-2000. In addition to allowing existing schools to increase admission quotas, the increase in admission was mainly accounted for by the creation and the expansion of post-secondary institutions in the vocational track, which were almost non-existent before 1990. Since switching tracks during secondary education was rare, the opportunity of advancing to post-secondary education for students placed in the vocational track at the level of secondary education before 1990 was limited. Therefore, the expansion in the post-secondary educaiton during the 1990-2000 period greatly increased the accessibility to post-secondary education, especially for students placed in the vocational track during the stage of secondary education. More detailed description on the education system as well as the expansion in post-secondary education in Taiwan can be found in Chapter 1.

Since those who came from a lower SES background in the past were more likely to be placed in the vocational track at the stage of secondary education, and the expansion in post-secondary education in Taiwan during the 1990-2000 period was achieved not only by increasing admissions in sheer numbers but also by creating a new type of post-secondary institution, the expansionary policy might affect both the distribution of educational attainment in the population and the allocation of education resources among people with different levels of SES. Therefore, in the following section, we will present a model which separates the effect of distribution and allocation, taking into account the characteristics of the Taiwanese education system.

3.3 A Model on Progression of Education

Consider the following model:

$$X = \beta B + \varepsilon$$

$$\varepsilon \sim N(0, \sigma_\varepsilon^2)$$

$$B \sim N(\mu_B, \sigma_B^2)$$

X can be viewed as "test score" or "academic preparedness," and those with higher X progress to post-secondary education before those with lower X until the admission quota is met. We assume that X is determined by B, a measure of SES, and ε, an error term capturing all the factors independent from SES, such as preference and the part of innate ability independent from SES. β measures the extent to which higher SES translates to higher educational attainment and may be determined by the optimization behavior of individuals. For example, Solon (2004) extended the Becker and Tomes (1979) model and provided comparative statics analysis in parents' decision on investing in children's human capital. If this investment is achieved through supporting children's formal education, β will be related to parents' investment decisions.

Since what matters to admission is the value of X compared with other students, not the exact value of X itself, if we assume B and ε follow a bivariate normal distribution, we can standardize X and denote the standardized version of X as Z:

$$Z = \frac{X - E(X)}{\nu} = \frac{1}{\nu}\varepsilon + \frac{\beta}{\nu}(B - \mu_B),$$

where ν equals $\sqrt{\sigma_\varepsilon^2 + \beta^2 Var(B)}$, so Z follows a standard normal distribution. Figure 3.2 illustrates the distribution of Z conditional on the value of B. For the purpose of illustration, we only draw two conditional distributions, and $B_{\text{High}} > B_{\text{Low}}$. As can be seen, if β increases, β/ν will also increase, so the distance between $Z_{\text{High SES}}$ and $Z_{\text{Low SES}}$ will increase (the mean of $Z_{\text{High SES}}$ will be further away from the mean of $Z_{\text{Low SES}}$).

Now, suppose students are admitted into universities if $Z > c$, where c represents admission thresholds, and Y is a categorical variable which equals 0 when $Z \leq c$ and 1 when $Z > c$. Then, the probability of entering university is

$$\begin{aligned}
&Prob(Y = 1|B, c) = Prob(Z > c|B, c) \\
=&Prob(\frac{1}{\nu}\varepsilon + \frac{\beta}{\nu}(B - \mu_B) > c|B, c) \\
=&Prob(\frac{\varepsilon}{\sigma_\varepsilon} > \frac{\nu c}{\sigma_\varepsilon} - \frac{\beta}{\sigma_\varepsilon}(B - \mu_B)|B, c) \\
=&1 - \Phi(\frac{\nu c}{\sigma_\varepsilon} - \frac{\beta}{\sigma_\varepsilon}(B - \mu_B)) \\
=&\Phi(-\frac{\nu c}{\sigma_\varepsilon} - \frac{\beta}{\sigma_\varepsilon}\mu_B + \frac{\beta}{\sigma_\varepsilon}B). \qquad (3.1)
\end{aligned}$$

If we would like to understand how β (or β/σ_ε) changes over time, Equation (3.1) suggests that we can run a probit regression of Y on B and c and then compare the coefficient of B across cohorts. B is available from data, while there are two ways to include c in the regression. Since assuming ε and B to follow a bivariate normal distribution makes the distribution of Z, and thus the value of c, fully tractable, the first way is to construct $c = \Phi^{-1}(1 - p)$, where p is the proportion of university graduates. However, from the derivation in Equation (3.1), we can see that we only need the conditional distribution of ε, not the joint distribution of ε and B, to estimate Equation (3.1). Therefore, the second way is to construct c in a less parametric way, such as using time trend or birth cohort dummies to represent c.

It is worth noting that the existence of c in the model implies that we should take into account the change in admission quotas by birth cohort within each regression, or we would encounter the issue of neglected heterogeneity as described by Wooldridge (2002, Chapter 15.7). Ideally, if we could run separate regressions for every single year of birth cohort, the constant term would capture the admission quota in each year. However, because most data on SES and educational attainment has a small sample size, most studies in the existing literature usually group more than one, usually ten years of birth cohorts, together, and then compare the effect of SES on educational attainment across decade-cohorts. If the admission quota does not change much for older decade-cohorts, but it increases dramatically for younger decade-cohorts, without controlling for the change in the admission quota within each decade-cohort, the coefficient of B will be underestimated more severely for younger decade-cohorts, which affects the comparison between decade-cohorts.

Figure 3.2 suggests how we can interpret our regression results. As can be seen, the distance between $Z_{\text{High SES}}$ and $Z_{\text{Low SES}}$ is determined by β and unrelated to the value of c because c depends on the *unconditional* distribution of Z, which is standard-normal. If the admission quota changes and β is fixed, the coefficient of B will not change, while the marginal effect of B will depend on the location of c and will either increase or decrease, and the model degenerates to the model in Luoh (2004). In contrast, if the admission quota is fixed and β increases, the coefficient of B will increase, while the marginal effect of B will either increase or decrease. Therefore, if the expansionary policy in post-secondary education merely raises the number of admissions, and if the optimization behavior of individuals is not altered by this policy, we should expect to see that the coefficient of B stays fixed over time.[1]

3.4 Data

We use the Panel Study of Family Dynamics (PSFD), administered by the Academia Sinica. PSFD is composed of longitudinal surveys tracking individuals and their offspring born after 1934, and its design is similar to the PSID in the U.S. Figure 3.3 illustrates the structure of the surveys used in this paper, and the birth cohorts included in the same cell are interviewed with the same survey. The surveys of the PSFD can be classified into three categories: R surveys, or the surveys for the main respondents (aged 25 and above); C surveys, or the surveys for the main respondents' children aged 16-24; and RCI surveys, or the surveys for the main respondents' children who reach age 25 and thus will become main respondents later. The nomenclature of the surveys is as follows: R surveys start with "RR-" or "R#-," where # stands for Roman numerals, followed by survey year; RCI surveys start with "RCI-," followed by survey year; and C surveys start with "C#-," followed by survey year.[2]

All the surveys, except survey "RIV-2003, RV-2003," collect information on current labor market outcomes, whereas detailed demographic information, such as age, sex, educational attainment, and names of schools attended, are collected in RI-1999, RI-2000, RI-2003, all RCI surveys, and all C surveys. Therefore, we combine information across survey waves to gather relevant information.

[1] This property is similar to the property of logistic regression models, in which the distribution of the dependent variable alone does not affect the coefficient of independent variables. The property of logistic regression models is also indicated in Mare (1981).

[2] When the PSFD was launched and gradually expanded its scale between 1999 and 2003, since main respondents were recruited in different years and were given different surveys according to their birth year, the nomenclature of the surveys used the Roman numerals to indicate the number of waves from time of recruitment. For example, as can be seen Figure A.1, in 2003, the main respondents who were born in 1935-1954 or 1953-1964 answered one and the same survey, while the main respondents born in 1964-1976 responded to a different survey; in 2004, the main respondents who were born in 1935-1954, 1953-1964, and 1964-1976 all responded to one and the same survey. Since 2005, all the main respondents have been interviewed with the same survey, so the Roman numerals are suppressed.

3.5 Results

3.5.1 The Effect of SES on Receiving Post-Secondary Education

As described in Section 3.3, the effect of SES on receiving post-secondary education can be obtained from running a probit regression based on Equation (3.1). Since PSFD collects information on the name of post-secondary institutions respondents graduated from, attended, or were attending, we can identify whether respondents graduated from, attended, or were attending an academic or vocational post-secondary institution (namely, university/college versus institute/university of technology in Figure 3.1). Therefore, we run two sets of regressions, the dependent variable of the first set is an indicator equaling 1 if respondents graduated from, attended, or were attending any post-secondary institutions, while the dependent variable in the second set of regressions equals 1 if respondents graduated from, attended, or were attending academic post-secondary institutions. We only include the respondents who were aged 20 and above in the most recent survey that they answered so that we have the most updated information on their educational attainment, especially for respondents in C surveys. Given that more senior students in junior colleges have the same years of education as freshmen or sophomores in universities, restricting respondents to be aged 20 and above also avoids the complication of whether we should classify junior college students as with or without university education.

We need information on SES and admission thresholds to estimate Equation (3.1). Figures 3.4 and 3.5 respectively illustrate the proportion of university graduates and university graduates from the academic track by birth cohort, where "Administrative Data" indicates that the proportions are calculated from the official statistics of birth, infant mortality, and university graduates, while "PSFD" indicates that the proportions are calculated from the PSFD dataset.[3] Although university graduates

[3]We do not distinguish graduates, drop-outs and current students in our calculations using PSFD. Given that the graduation rate in Taiwan is high, we expect most of those who were university

from the academic track are over-represented in PSFD, the proportions calculated from administrative data are still close to the proportions calculated from PSFD, so we use the proportions from administrative data to calculate the admission thresholds to any university, c, and to university in the academic track, c_{acad}, which are plotted in Figure 3.6. As can be seen, the rate of decrease in c is the largest for birth cohorts 1976-1986, reflecting the expansion in post-secondary education, and the rate of decrease in c is larger than the rage of decrease in c_{acad}.

With regard to the information on SES, the variables reflecting SES include parents' occupation, employment status, education, and ethnicity, and we combine these variables into a single SES index to represent B. To combine these SES variables, we use a regression-based approach to determine the weight of each variable. Specifically, we regress log of parental income (sum of father's and mother's income) on SES variables, parents' age and age squared, and other control variables which will be included in the subsequent probit regression. Only children (respondents in C surveys and RCI surveys) aged 20 and above are included in the regression because we can find information on their parents' income in R surveys. We average parents' income and use the median of parents' other characteristics across survey waves, and each child appears only once in the regression. After running the regression, the coefficients of SES variables are then used to construct the SES index for all observations. The essence of this approach is similar to the MIMIC (Multiple Indicators and MultIple Causes) model as described in Joreskog and Goldberger (1975): We can imagine SES as a latent variable that determines how observed indicators – parents' employment, education, and ethnicity – behave, but our second-stage regression is non-linear. This approach is also similar to the two-stage least square estimation in the context of instrumental variable regressions, but not all observations are used in our first-stage regression.

students when being surveyed would graduate.

Since the SES index is a generated regressor, we bootstrap the whole two-stage estimation procedure 1000 times and calculate bootstrap standard errors. Because PSFD surveys households, we resample household clusters with replacement, so each bootstrap resample has the same number of clusters as the observed dataset. Our bootstrap standard errors tend to be larger than the standard errors of a typical probit regression.

Tables 3.1 and 3.2 report the estimation of Equation (3.1). Table 3.1 includes everyone, while Table 3.2 includes only those who had advanced to secondary education. Birth cohorts are grouped in a way based on the pattern of c and data availability, and birth cohorts 1979-1988 are the cohorts who are the most directly affected by the expansion in post-secondary education. We use a quadratic trend to represent c and c_{acad}, and the results of using linear time trend and birth year dummies are similar and thus not reported. As can be seen, the coefficients of SES for birth cohorts 1959-1968 are higher than those born in and after 1969, and this might be attributable to a stronger law enforcement in the enrollment of compulsory education since 1982, especially at the level of junior high school.[4]

Since the coefficients of SES for cohorts born in and after 1969 do not show a clear pattern in Tables 3.1 and 3.2, and we would like to know whether the effect of SES on advancing to post-secondary education changed during the expansion in post-secondary education, we run a pooled regression for birth cohorts 1969-1988, including admission thresholds (c and c_{acad}) and the interaction between SES and admission thresholds as additional regressors. As explained in Section 3.3, if the expansion in post-secondary education only affects admission thresholds, β will not change, suggesting that the coefficient of the interaction term should be zero. The results are reported in Table 3.3, and as can be seen, in terms of the point estimates, the coefficients of the interaction term are negative, indicating that the effect of SES

[4] 1982-12=1970, so most of those who were subject to the stronger law enforcement in the enrollment of junior high school would be those who were born in September 1969 or later.

increased when the admission threshold decreased during the expansion. However, these coefficients are insignificantly different from zero because the standard errors are very large.

We can interpret the coefficient of the interaction term as follows. According to Figure 3.6, comparing those who were born in 1969 and 1988, c decreased from around 1 to -0.5, and c_{acad} decreased from around 1 to 0.5. Therefore, the point estimates in Table 3.3 suggest that the effect of SES for everyone on advancing to any university increased by about 12% ($(-1.5) \times (-0.083) \div 1.003 = 0.1241$), and the effect of SES for everyone on advancing to academic post-secondary institutions increased by about 10% ($(-0.5) \times (-0.219) \div 1.079 = 0.1015$). However, due to large standard errors, these percentages are very imprecisely estimated.

3.5.2 SES and Track Placement in Post-Secondary Education

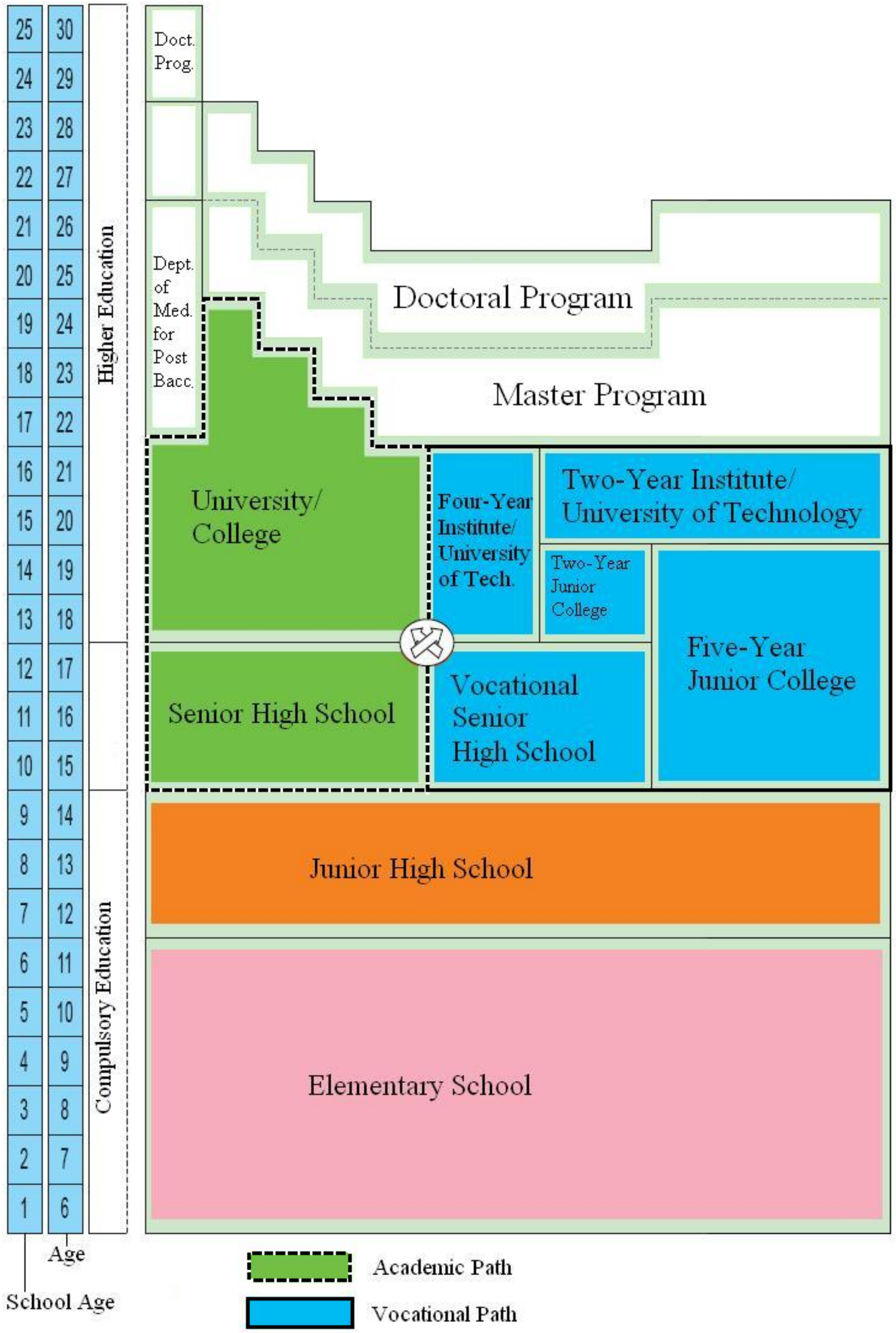
We now investigate further the student body of academic and vocational post-secondary institutions. Table 3.4 compares the components of the SES index by educational attainment and track of post-secondary education. As can be seen, those placed in academic post-secondary institutions tend to have a higher level of SES: Their parents are more likely to work in managerial and professional occupations, work as employees in government or non-profit organizations or employers, have more years of education, and be mainlanders in ethnicity (those and descendants of those who immigrated to Taiwan from China during the late 1940s, especially those who arrived with Chiang Kai-Shek's regime). To compare the mean of the SES index by track of post-secondary education, Table 3.5 reports the results of regressing the SES index on dummies of post-secondary education and other controls, and the results further confirm that those placed in academic post-secondary institutions tend to come from a higher SES background.

By construction, the creation of vocational post-secondary institutions would increase the access to post-secondary education for students in the vocational track, who were more likely to come from a lower SES background, so this mechanism alone would be consistent with a decrease in β, or a *positive* coefficient of the interaction term in the upper panel of Table 3.3, but our point estimates are negative. However, since the standard error of these coefficients are large, it is hard to draw conclusion on their signs.

3.6 Conclusion

In this paper, we have formulated a model to study how expansion in post-secondary education may affect the effect of SES on receiving post-secondary education. Our model distinguishes the distribution of educational attainment, which is determined by the number of admissions, from the allocation of education among people with different levels of SES, which holds fixed admission quotas and is determined by other factors, such as the admissions process and the optimization behavior of individuals. Our model can be estimated by running a probit regression of educational attainment on SES and other controls, and the coefficient of SES represents the allocation effect, while the marginal effect of SES represents a combination of distribution and allocation effects.

In the context of the expansion in post-secondary education during the 1990-2000 period in Taiwan, when we run a probit regression of receiving post-secondary education on SES and other controls, the coefficient of SES seems to increase with admission quotas, especially with the admission quotas of academic post-secondary education, although the increase is statistically insignificant. We also find that vocational post-secondary institutions tend to enroll students coming from a lower SES background.



Source: Adapted from Ministry of Education, Taiwan.

Figure 3.1: The Current Education System in Taiwan

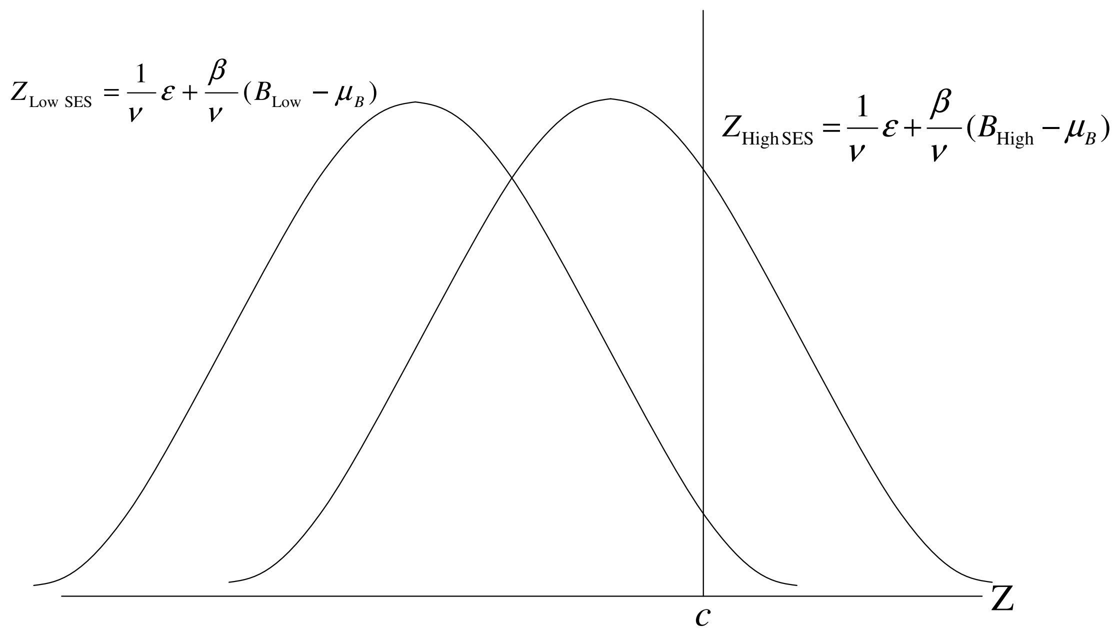


Figure 3.2: Conditional Distributions of Z

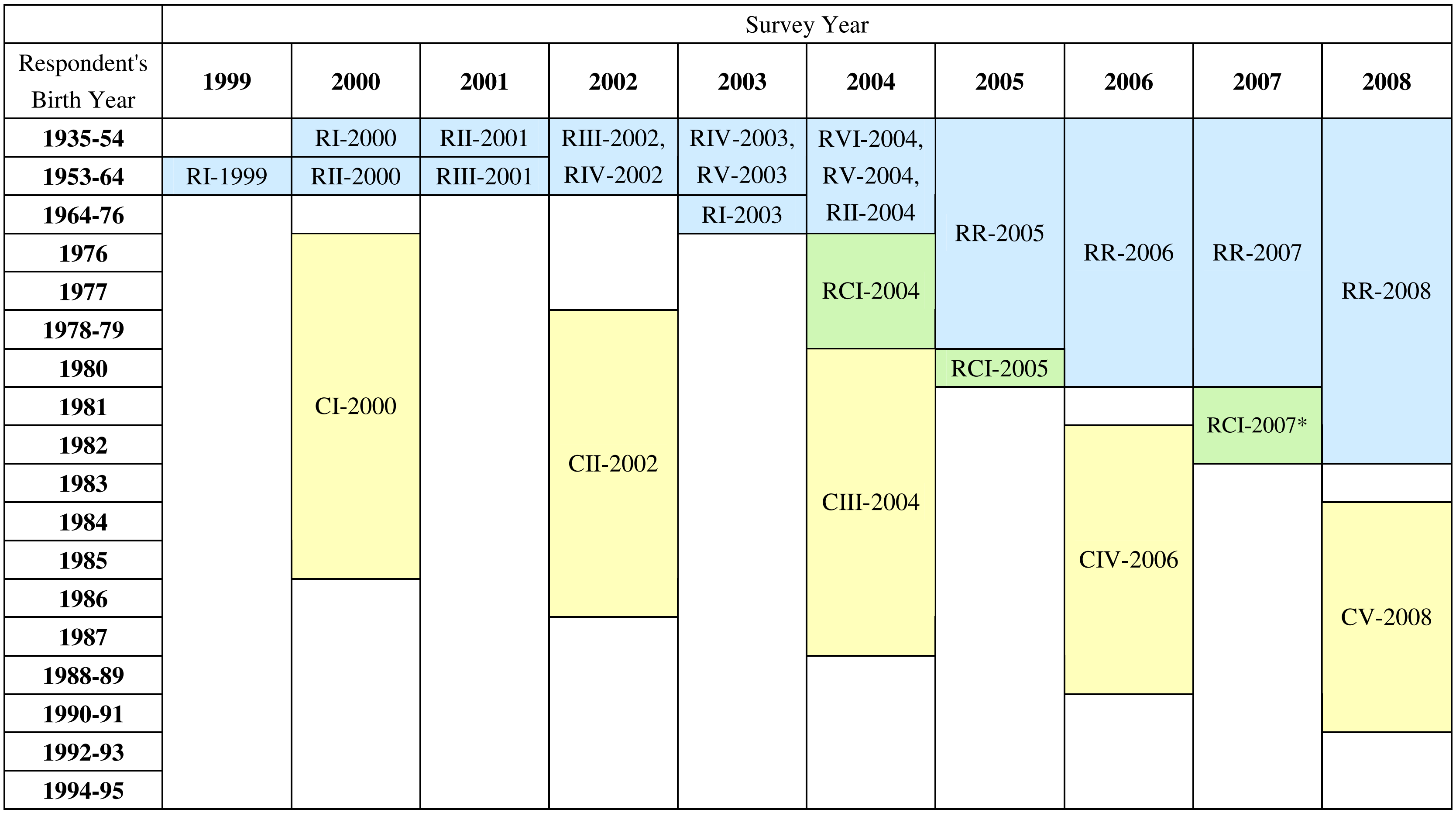


Figure 3.3: PSFD Survey Structure

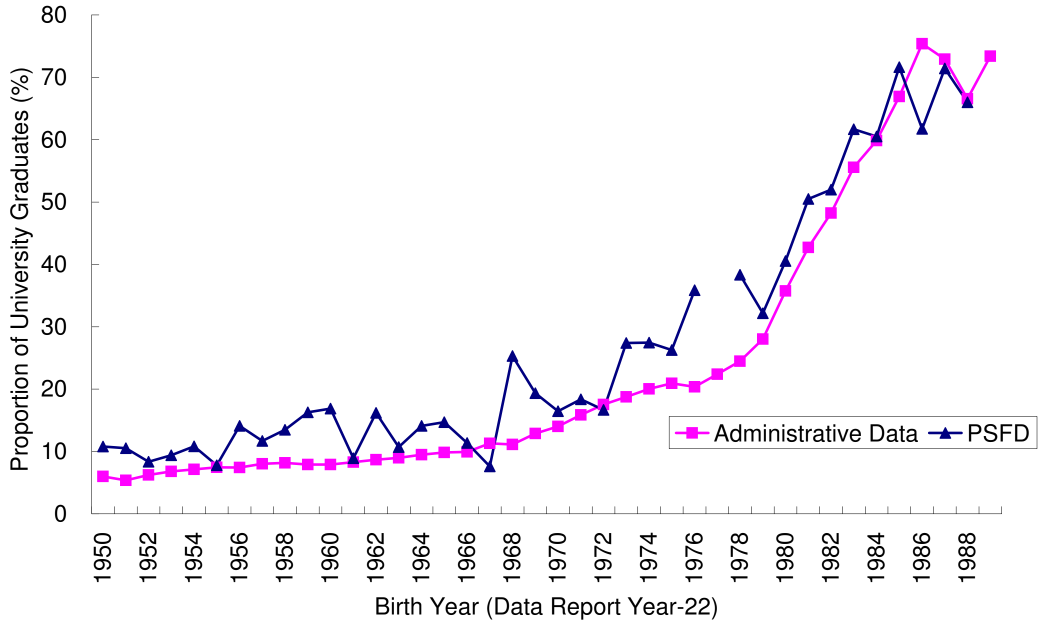


Figure 3.4: Proportion of University Graduates by Birth Cohort

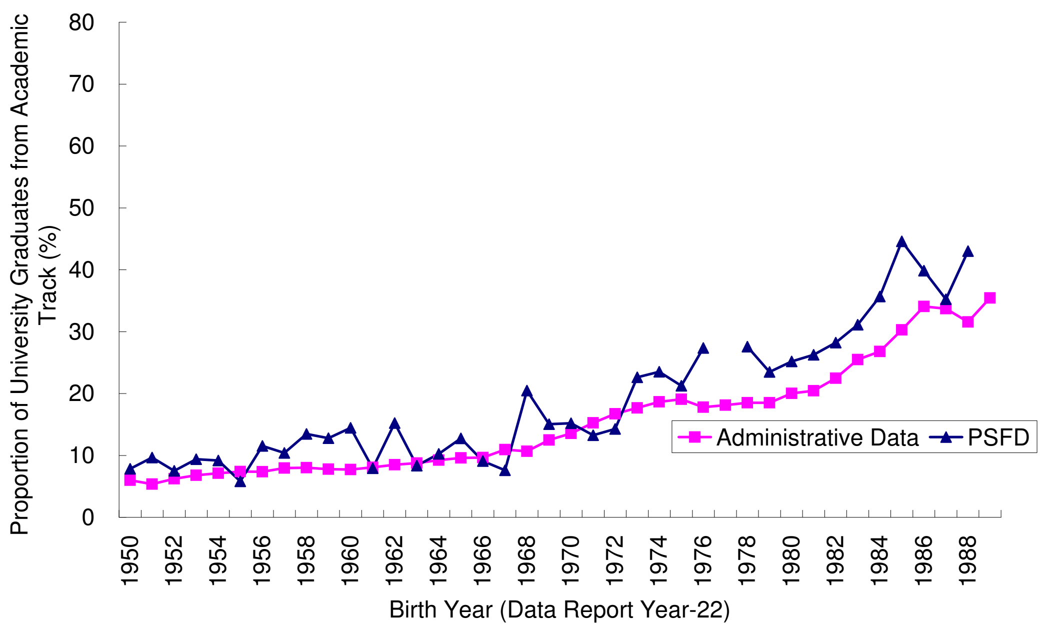


Figure 3.5: Proportion of University Graduates from an Academic Post-Secondary Institution by Birth Cohort

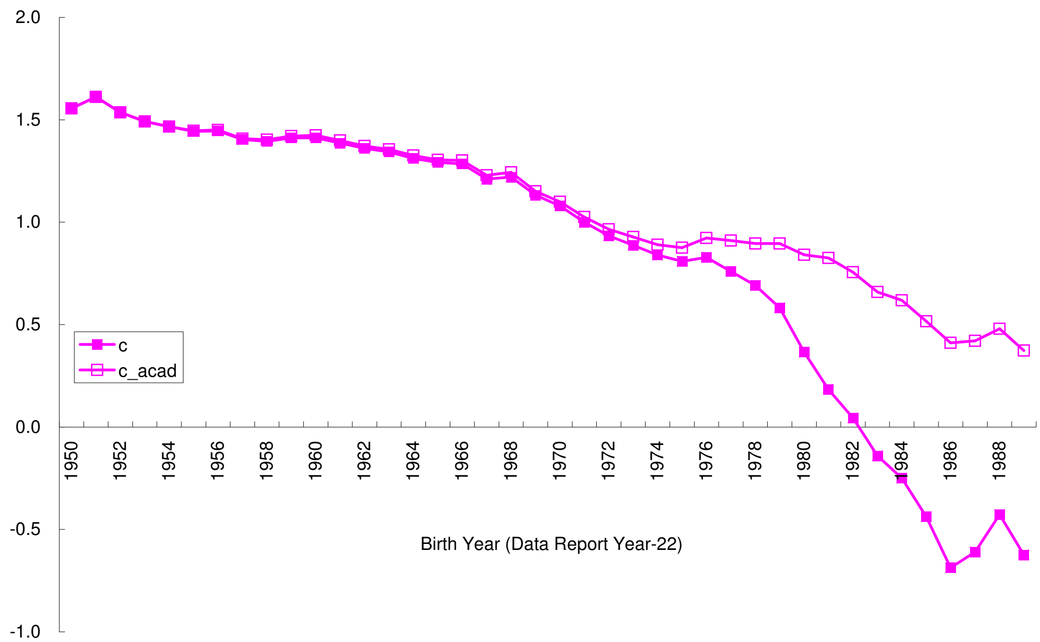


Figure 3.6: Value of c and c_{acad} by Birth Cohort

Table 3.1: Probit Regression of Post-Secondary Education Attainment on SES

Dependent Variable: 1=Any Post-Secondary Institutions

Birth Year:	1959-68	1969-78	1979-88	1959-63	1964-68	1969-73	1974-78	1979-83	1984-88
SES	1.283	0.935	0.996	1.217	1.389	0.764	1.135	0.992	1.022
	(0.171)	(0.149)	(0.117)	(0.219)	(0.255)	(0.211)	(0.211)	(0.133)	(0.200)
Hometown (Urban=1)	0.114	0.190	0.200	0.051	0.233	0.162	0.212	0.243	0.070
	(0.134)	(0.118)	(0.095)	(0.189)	(0.195)	(0.184)	(0.154)	(0.111)	(0.166)
Gender (Male=1)	0.087	-0.047	-0.130	0.220	-0.043	0.083	-0.142	-0.104	-0.182
	(0.122)	(0.098)	(0.085)	(0.175)	(0.188)	(0.151)	(0.138)	(0.105)	(0.137)
Number of siblings	-0.043	-0.065	-0.079	-0.021	-0.065	-0.038	-0.091	-0.071	-0.095
	(0.039)	(0.046)	(0.053)	(0.050)	(0.064)	(0.063)	(0.070)	(0.062)	(0.091)
Observations	805	831	1,168	402	403	402	429	767	401

Dependent Variable: 1=Academic Post-Secondary Institutions

Birth Year:	1959-68	1969-78	1979-88	1959-63	1964-68	1969-73	1974-78	1979-83	1984-88
SES	1.230	0.740	0.995	1.208	1.278	0.665	0.834	1.052	0.902
	(0.172)	(0.144)	(0.116)	(0.231)	(0.250)	(0.205)	(0.202)	(0.134)	(0.188)
Hometown (Urban=1)	-0.048	0.169	0.071	-0.236	0.168	0.168	0.171	0.101	0.020
	(0.144)	(0.120)	(0.096)	(0.217)	(0.205)	(0.190)	(0.156)	(0.119)	(0.150)
Gender (Male=1)	0.137	-0.061	-0.185	0.256	0.019	0.014	-0.103	-0.255	-0.089
	(0.128)	(0.106)	(0.085)	(0.186)	(0.196)	(0.157)	(0.146)	(0.109)	(0.140)
Number of siblings	-0.041	-0.087	-0.093	-0.042	-0.036	-0.047	-0.131	-0.116	-0.072
	(0.040)	(0.048)	(0.057)	(0.053)	(0.065)	(0.064)	(0.079)	(0.072)	(0.092)
Observations	805	831	1,168	402	403	402	429	767	401

Constant, birth year and birth year squared (re-scaled so that t =Birth year-1958) are included in the regressions. Coefficients are reported; bootstrap standard errors are in parentheses.

Table 3.2: Probit Regression of Post-Secondary Education Attainment on SES, Including Only Those Who Had Advanced to Secondary Education

Dependent Variable: 1=Any Post-Secondary Institutions

Birth Year:	1959-68	1969-78	1979-88	1959-63	1964-68	1969-73	1974-78	1979-83	1984-88
SES	1.127	0.863	1.012	0.982	1.265	0.703	1.057	1.034	0.981
	(0.176)	(0.149)	(0.123)	(0.235)	(0.258)	(0.214)	(0.211)	(0.140)	(0.223)
Hometown (Urban=1)	0.050	0.177	0.230	-0.059	0.204	0.150	0.197	0.243	0.164
	(0.136)	(0.120)	(0.103)	(0.194)	(0.198)	(0.188)	(0.157)	(0.120)	(0.180)
Gender (Male=1)	0.114	0.022	-0.074	0.211	0.026	0.168	-0.082	-0.090	-0.031
	(0.129)	(0.100)	(0.091)	(0.190)	(0.191)	(0.158)	(0.139)	(0.110)	(0.150)
Number of siblings	-0.039	-0.057	-0.087	-0.017	-0.058	-0.024	-0.088	-0.065	-0.140
	(0.041)	(0.046)	(0.057)	(0.058)	(0.063)	(0.065)	(0.071)	(0.066)	(0.106)
Observations	591	746	1,010	265	326	345	401	685	325

Dependent Variable: 1=Academic Post-Secondary Institutions

Birth Year:	1959-68	1969-78	1979-88	1959-63	1964-68	1969-73	1974-78	1979-83	1984-88
SES	1.052	0.672	1.048	0.941	1.157	0.602	0.763	1.148	0.871
	(0.176)	(0.144)	(0.122)	(0.244)	(0.253)	(0.208)	(0.203)	(0.139)	(0.206)
Hometown (Urban=1)	-0.089	0.157	0.116	-0.305	0.136	0.158	0.157	0.170	0.044
	(0.145)	(0.122)	(0.105)	(0.217)	(0.206)	(0.193)	(0.159)	(0.127)	(0.174)
Gender (Male=1)	0.183	-0.001	-0.168	0.285	0.083	0.084	-0.051	-0.203	-0.103
	(0.135)	(0.107)	(0.094)	(0.200)	(0.199)	(0.164)	(0.148)	(0.117)	(0.162)
Number of siblings	-0.032	-0.081	-0.129	-0.032	-0.029	-0.034	-0.129	-0.106	-0.163
	(0.042)	(0.048)	(0.062)	(0.060)	(0.064)	(0.066)	(0.081)	(0.079)	(0.099)
Observations	591	746	1,010	265	326	345	401	685	325

Constant, birth year and birth year squared (re-scaled so that t =Birth year-1958) are included in the regressions. Coefficients are reported; bootstrap standard errors are in parentheses.

Table 3.3: Probit Regression of Post-Secondary Education Attainment on SES, Birth Cohorts 1969-1988

Dependent Variable: 1=Any Post-Secondary Institutions		
	Everyone	With Secondary Education
SES	1.003	1.021
	(0.112)	(0.119)
SES×c	-0.083	-0.165
	(0.148)	(0.158)
c	-0.589	-0.433
	(0.075)	(0.083)
Hometown (Urban=1)	0.214	0.224
	(0.075)	(0.078)
Gender (Male=1)	-0.096	-0.033
	(0.063)	(0.066)
Number of siblings	-0.077	-0.075
	(0.035)	(0.037)
Constant	0.061	-0.052
	(0.190)	(0.194)
Observations	1999	1756
Dependent Variable: 1=Academic Post-Secondary Institutions		
	Everyone	With Secondary Education
SES	1.079	1.339
	(0.339)	(0.374)
SES×c_{acad}	-0.219	-0.537
	(0.405)	(0.441)
c_{acad}	-0.480	-0.132
	(0.227)	(0.268)
Hometown (Urban=1)	0.112	0.134
	(0.074)	(0.078)
Gender (Male=1)	-0.133	-0.092
	(0.067)	(0.071)
Number of siblings	-0.087	-0.097
	(0.037)	(0.038)
Constant	-0.161	-0.453
	(0.273)	(0.318)
Observations	1999	1756

Coefficients are reported; bootstrap standard errors are in parentheses.

Table 3.4: Summary of SES Variables by Track of Post-Secondary Education, Birth Cohorts 1979-1988

Unit: %, except years of education	Without Post-Secondary Education	Track of Post-Secondary Education	
		Vocational	Academic
Father's Occupation			
Managerial and Professional	9.27	17.12	31.22
Administrative, Clerical, and Sales	18.70	26.71	27.15
Production Workers and Laborers	72.03	56.16	41.63
Mother's Occupation			
Managerial and Professional	1.81	5.72	16.14
Administrative, Clerical, and Sales	22.00	32.66	35.43
Production Workers and Laborers	76.19	61.62	48.43
Father's Employment Status			
Employer	13.45	13.89	16.21
Employee in Government or Non-Profit Organizations	8.91	18.06	24.66
Employee in Private Firms	34.79	37.15	30.14
Self-Employed, Unemployed, Family Worker	42.86	30.90	29.00
Mother's Employment Status			
Employer	2.13	0.67	3.17
Employee in Government or Non-Profit Organizations	3.93	7.41	18.33
Employee in Private Firms	29.79	30.64	27.60
Self-Employed, Unemployed, Family Worker	64.16	61.28	50.90
Father's Ethnicity			
Mainlander	3.78	8.50	11.54
Mother's Ethnicity			
Mainlander	3.95	6.67	11.16
Father's Years of Education			
Mean	8.54	10.04	12.07
Standard Deviation	3.49	3.52	3.42
Mother's Years of Education			
Mean	7.65	9.17	11.22
Standard Deviation	3.57	3.27	3.37

Table 3.5: OLS Regression of SES on Track of Post-Secondary Education

Dependent Variable: SES			
Birth Year:	1979-88	1979-83	1984-88
Track of Post-Secondary Education (Base Group =Without Post-Secondary Education):			
Vocational	0.145	0.116	0.154
	(0.031)	(0.037)	(0.053)
Academic	0.355	0.357	0.310
	(0.034)	(0.044)	(0.051)
Hometown (Urban=1)	0.138	0.121	0.209
	(0.032)	(0.038)	(0.048)
Gender (Male=1)	-0.038	-0.017	-0.078
	(0.024)	(0.030)	(0.041)
Number of siblings	-0.124	-0.116	-0.125
	(0.015)	(0.019)	(0.023)
Constant	0.274	0.228	0.349
	(0.046)	(0.057)	(0.069)
R-squared	0.28	0.26	0.29
Observations	1152	757	395

Clustered standard errors by household are in parentheses.

APPENDICES

APPENDIX A

Appendices for Chapter 1

A.1 Data

A.1.1 Manpower Utilization Survey (MUS)

We use the 1978-2011 MUS as our main dataset for this paper. MUS is conducted by the DGBAS (Directorate General of Budget, Accounting and Statistics) of Taiwan, and it is analogous to the U.S. March Current Population Survey and the March Annual Demographic Supplement combined (CPS plus March Supplement). It surveys about 20,000 households, or about 60,000 respondents aged 15 and above (excluding soldiers and prisoners), and respondents are interviewed by phone or in person. The reference week of the MUS is the week of May 15. MUS has a sample rotation structure similar to the CPS, so half of the sample in our data overlaps with the sample in the following year.

Some people might be concerned about the following data issues, but these issues generally affect our results very little. First, since the MUS did not distinguish baccalaureates from postgraduate degrees before 1988, we aggregate both into one category, "university and above," and view the respondents in this category as university-educated workers. This should not pose a big concern because for the data after 1988, the results are similar no matter whether we separate postgraduate degrees from baccalaureates or not.

Second, although MUS provides information on the educational attainment of each respondent, before 2007, it did not specify whether the respondent had actually completed or simply had attended the indicated schooling without completion. For example, when the educational attainment of a respondent is classified as "senior high school," she might either be a student, a dropout, or a graduate from senior high school. Fortunately, since the surveys of 2007-2011 have information on graduation, and the surveys of 1978-1987 have information on whether respondents are in school, we can calculate the graduation rate and in-school rate in these years to see whether graduates need to be distinguished from non-graduates. Using the survey data in 2007-2011, 80% of the whole sample (aged 15 and above) graduated from the indicated level of schooling, and 13% of the whole sample were still in school. For age 30 and above, 95% graduated from the indicated level of schooling, and the in-school rate was lower than 0.4%. Likewise, using the survey data in 1978-1987, the in-school rate was about 13% for age 15 and above and 0.1% for age 30 and above. Therefore, since the graduation rate is relatively high, and few people have long lags in their schooling trajectory, it should not be a big concern if we cannot distinguish graduates from non-graduates in our data.

Besides, instead of comparing university- and non-university-educated workers of the same age, we compare them by years of potential experience. Conceptually, potential experience means the number of years "potentially" in the labor market, so it equals age subtracted by years not in the labor market. In Taiwan, given that elementary school starts at age six, that people younger than age 15 are generally not allowed to work, and that men,unless they are still at school, have to complete the mandatory military service of about two years by the January of the year when they turn 19, we define years of potential experience for men as

$$\begin{cases} \text{Age} - \text{Years not in the Labor Market} - 2, & \text{if Age} \geq 19 \\ \text{Age} - \text{Years not in the Labor Market}, & \text{if Age} \leq 18 \end{cases}$$

and for women as

$$\text{Age} - \text{Years not in the Labor Market}.$$

"Years not in the Labor Market" equals 15 (=6+9) for individuals whose educational attainment is junior high school and below, 18 (=6+12) for senior high school or vocational senior high school, 20 (=6+14) for junior college, 22 (=6+16) for baccalaureate, and 24 (=6+18) for master's or Ph.D. Those whose years of potential experience are negative are excluded.

A.1.2 Taiwan Integrated Postsecondary Education Database (TIPED)

As mentioned in Section 1.5.1, we use the *Taiwan Integrated Postsecondary Education Database* (TIPED) and the *Panel Study of Family Dynamics* (PSFD) to gather information on the labor market outcomes of vocational and academic graduates. This subsection describes the structure of TIPED.

The TIPED, administered by the Ministry of Education and National Taiwan Normal University, surveys university students, recent graduates and faculty. Since our purpose is to find the wage gap and the difference in the occupational structure between vocational and academic graduates, we use the surveys of recent university graduates. Those who graduated from university in years 2006-2010 were surveyed one year after graduation, while those who graduated in 2005 were surveyed both one year and three years after their graduation. The response rate is about 35-60%, but most of the surveys were intended to be delivered to everyone in the corresponding graduation cohort, so the sample size of each graduation cohort ranges from around 90,000 to 200,000. Samples are weighted to match population characteristics (school, major and gender), which are available from administrative records.

Most of the micro-level data of the TIPED is not yet released, but detailed frequency tables and descriptive statistics, weighted to match population characteristics, are reported.[1] Therefore, we use their reports to gather information on the wage gap and the difference in the occupational structure between vocational and academic graduates.

Since male university graduates have to serve military service for about two years immediately after graduation, those who answer the questions about labor market outcomes might be disproportionately female university graduates. Therefore, in addition to the TIPED, we also use the PSFD, which allows us to include both male and female university graduates, as a comparison. The following subsection will discuss the data structure of the PSFD.

A.1.3 Panel Study of Family Dynamics (PSFD)

The design of the PSFD is similar to the PSID in the U.S. PSFD is administrated by the Academia Sinica. It is composed of longitudinal surveys, and it tracks individuals and their offspring born after 1934. The surveys of the PSFD can be classified into three categories: R surveys, or the surveys for the main respondents (aged 25 and above); C surveys, or the surveys for the main respondents' children aged 16-24; and RCI surveys, or the surveys for the main respondents' children who reach age 25 and thus will become main respondents later. The nomenclature of the surveys is as follows: R surveys start with "RR-" or "R#-," where # stands for Roman numerals, followed by survey year; RCI surveys start with "RCI-," followed by survey year; and C surveys start with "C#-," followed by survey year. Figure A.1 illustrates the

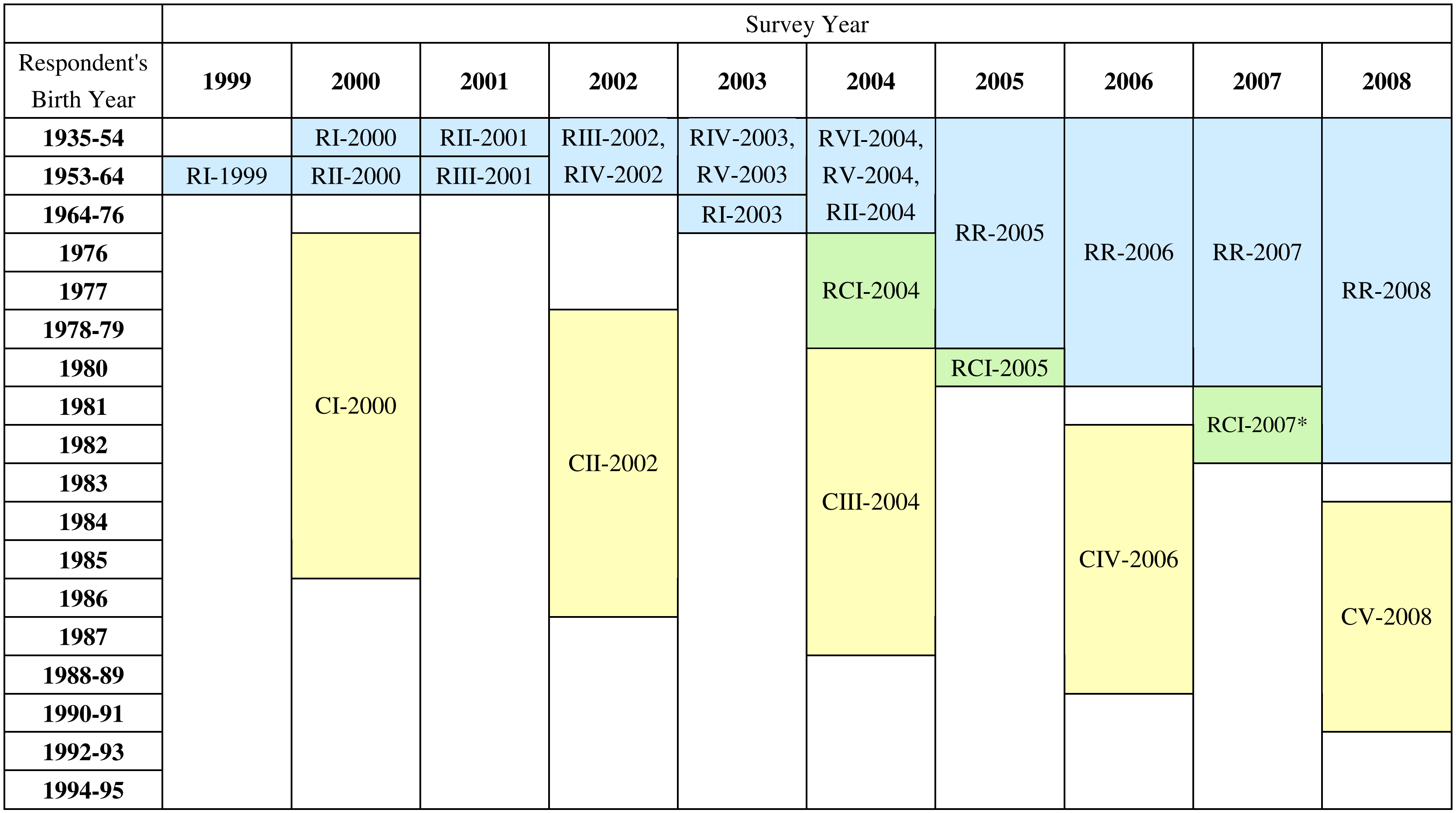
[1] The reports (in Mandarin) can be found in https://www.cher.ntnu.edu.tw/?cat=122.

structure of the surveys used in this paper. The birth cohorts included in the same cell are interviewed with the same survey.[2]

All the surveys, except survey "RIV-2003, RV-2003," collect information on current labor market outcomes, whereas detailed demographic information, such as age, sex, educational attainment, and names of schools attended, are collected in RI-1999, RI-2000, RI-2003, all RCI surveys, and all C surveys. Therefore, we combine information across survey waves to gather information on the earnings and occupations of vocational and academic graduates.

Compared with the TIPED, the advantages of using the PSFD data are as follows: first, the micro-level data of the PSFD is available; and second, we can include both male and female university graduates into our analysis. However, the sample size of the PSFD is considerably smaller—about one hundred respondents in each birth-year cohort. Therefore, we use both the TIPED and the PSFD to gather information on the earnings and the occupational structure of vocational and academic graduates. Nevertheless, as will be seen in Appendix A.3, both data generally provide similar results.

[2] When the PSFD was launched and gradually expanded its scale between 1999 and 2003, since main respondents were recruited in different years and were given different surveys according to their birth year, the nomenclature of the surveys used the Roman numerals to indicate the number of waves from time of recruitment. For example, as can be seen Figure A.1, in 2003, the main respondents who were born in 1935-1954 or 1953-1964 answered one and the same survey, while the main respondents born in 1964-1976 responded to a different survey; in 2004, the main respondents who were born in 1935-1954, 1953-1964, and 1964-1976 all responded to one and the same survey. Since 2005, all the main respondents have been interviewed with the same survey, so the Roman numerals are suppressed.



Source: Adapted from http://psfd.sinica.edu.tw/check_en.htm.
* RCI-2007 is not released yet and thus not used in our studies.

Figure A.1: PSFD Survey Structure

A.2 The Construction of Variables in Equations (1.5) and (1.6)

A.2.1 Equation (1.5)

$$\ln(\frac{W_{kt}^c}{W_{kt}^n}) = \ln(\frac{\theta_{ct}}{\theta_{nt}}) + \ln(\frac{\beta_k}{\alpha_k}) - \frac{1}{\sigma_{Edu}}\ln(\frac{C_t}{N_t}) - \frac{1}{\sigma_{Exp}}[\ln(\frac{C_{kt}}{N_{kt}}) - \ln(\frac{C_t}{N_t})]$$

Before generating variables for Equation (1.5), we first run several wage regressions at the individual level. Only wage and salaried workers are included in the wage regressions, and the wage regressions are run separately by workers' potential experience group and university attainment. For university-educated workers, we regress log hourly wage on the whole interaction terms between gender and year dummies, while in the regressions for non-university-educated workers, the dummies of detailed educational level (dummies for senior high school, vocational senior high school, and junior college, treating junior high school and below as the base group) are also included as explanatory variables. If years of potential experience are grouped by ten years (results labeled as "Ten-Year Group" in the main text, where years of potential experience are grouped as 0-9 years, 10-19 years, ...), dummies of five-year groups (0-4 years, 5-9 years, ...) are also included in the wage regressions.

After running the wage regressions, we set all the year dummies to be zero and predict the log hourly wage for all the employed workers, including the wage and salaried workers, who were included in the regressions, and the employed workers who were not included in the regressions, such as self-employed workers and the unpaid family workers who worked at least 15 hours during the reference week.

Then, after running the individual-level wage regressions and predicting the log hourly wage for all the employed workers, the variables for Equation (1.5) are generated as follows.

- $\ln(\theta_{ct}/\theta_{nt})$ and $\ln(\beta_k/\alpha_k)$: as mentioned in the main text, $\ln(\theta_{ct}/\theta_{nt})$ is represented by a linear or a non-linear time trend, while $\ln(\beta_k/\alpha_k)$ is represented by dummies of potential experience groups.

- $\ln(C_{kt}/N_{kt})$: The unit of C_{kt} and N_{kt} is the number of effective hours worked per week. Therefore, $\ln(C_{kt})$ is measured as the average of predicted log hourly wage plus log total hours worked per week for university-educated workers in potential experience group k in year t. $\ln(N_{kt})$ is constructed in the same manner for non-university-educated workers.

- $\ln(W^c_{kt}/W^n_{kt})$: $\ln(W^c_{kt})$ is the coefficient of the year t dummy in the wage regressions for university-educated workers in potential experience group k, and $\ln(W^n_{kt})$ is created analogously. This measure represents the university wage premium in year t relative to 1978, controlling for gender and detailed educational level.

- $\ln(C_t/N_t)$: $\ln(C_t/N_t)$ is constructed in a two-step procedure, using Equations (11), (12a) and (12b) in Card and Lemieux (2001). The procedure is as follows. First, to generate C_t and N_t, we have to obtain the value of σ_{Exp} before estimating Equation (1.5). Noting that $\ln(C_t/N_t)$ and $\ln(\theta_{ct}/\theta_{nt})$ together in Equation (1.5) can be absorbed by year dummies, we can run the following regression to obtain an estimate of σ_{Exp}:

$$\ln(\frac{W^c_{kt}}{W^n_{kt}}) = d_t + b_k - \frac{1}{\sigma_{Exp}} \ln(\frac{C_{kt}}{N_{kt}}), \tag{A.1}$$

  where d_t and b_k are year dummies and potential experience group dummies, respectively. This equation is the same as Equation (11) in Card and Lemieux (2001).

We also need the values of α_k and β_k to generate C_t and N_t. From Equations (12a) and (12b) in Card and Lemieux (2001), we have

$$\begin{aligned}
\ln(W^c_{kt}) + \frac{1}{\sigma_{Exp}} \ln(C_{kt}) &= \ln(\theta_{ct} C_t^{\rho-\eta} \Psi_t) + \ln(\beta_k) \\
\ln(W^n_{kt}) + \frac{1}{\sigma_{Exp}} \ln(N_{kt}) &= \ln(\theta_{nt} N_t^{\rho-\eta} \Psi_t) + \ln(\alpha_k),
\end{aligned}$$

where $\Psi_t = (\theta_{ct} C_t^\rho + \theta_{nt} N_t^\rho)^{1/\rho - 1}$. Again, the first term in the right-hand side of the equations above can be absorbed by year dummies, so we regress the left-hand side variables on time dummies and potential experience group dummies. The coefficients of the potential experience group dummies (plus constant) are the values of $\ln(\alpha_k)$ and $\ln(\beta_k)$, and the values of α_k and β_k are then obtained by taking exponentials. Now, with the estimates of σ_{Exp}, α_k, and β_k, we can construct C_t and N_t by using Equations (1.2) and (1.3).

A.2.1.1 First-Stage Regression Results

Table A.1 presents the regression results using Equation (A.1). As can be seen, the coefficients of $\ln(C_{kt}/N_{kt}) - \ln(C_t/N_t)$ in the first-stage regressions are very close to that in the second-stage regressions (Table 1.3). Figure A.2 plots the coefficients of year dummies with 95% confidence intervals. As can be seen, the increase in the coefficients of year dummies accelerated since the mid-1990s, implying that in the second-stage regressions, $\ln(\theta_{ct}/\theta_{nt})$ might be better approximated by a non-linear time trend.

A.2.2 Equation (1.6)

$$\ln(\frac{W_{kt}^c}{W_{kt}^n}) = \ln(\frac{\theta_{ct}}{\theta_{nt}}) + \ln(\frac{\beta_k}{\alpha_k}) - \frac{1}{\sigma_{Edu}} \ln(\frac{C_t}{N_t})$$
$$-\frac{1}{\sigma_{Exp}^c}[\ln(C_{kt}) - \ln(C_t)] + \frac{1}{\sigma_{Exp}^n}[\ln(N_{kt}) - \ln(N_t)].$$

All the variables, except $\ln(C_t)$ and $\ln(N_t)$, are constructed the same way as described in the previous subsection, while $\ln(C_t)$ and $\ln(N_t)$ are constructed as follows. Instead of directly using Equation (11) in Card and Lemieux (2001), we run the following regression to estimate σ_{Exp}^c and σ_{Exp}^n:

$$\ln(\frac{W_{kt}^c}{W_{kt}^n}) = d_t + b_k - \frac{1}{\sigma_{Exp}^c} \ln(C_{kt}) + \frac{1}{\sigma_{Exp}^n} \ln(N_{kt}), \qquad \text{(A.2)}$$

which can be obtained directly by noting that $\ln(C_t)$ and $\ln(N_t)$ in Equation (1.6) can also be absorbed by time dummies. The rest of the steps are the same as described in the previous subsection.

A.2.2.1 First-Stage Regression Results

Again, Table A.2 presents the regression results using Equation (A.2), and Figure A.3 plots the coefficients of year dummies with 95% confidence intervals. As can be seen, the results are similar as before: the coefficients of $\ln(C_{kt})$ and $\ln(N_{kt})$ in the first-stage regressions are very close to that in the second-stage regressions (Table 1.4), and the increase in the coefficients of year dummies accelerated since the mid-1990s.

Table A.1: First-Stage Regressions: OLS Regression of Equation (A.1)

Grouping of Potential Experience: Dependent Variable: $\ln(W^c_{kt}/W^n_{kt})$	Five-Year Group (1)	Ten-Year Group (2)
$\ln(C_{kt}/N_{kt})$	-0.146	-0.196
	(0.020)	(0.025)
Observations	272	136
Adjusted R^2	0.694	0.728

Dummies of potential experience groups (b_k) and year dummies (d_t) are included in the regression. In Column (1) (Five-Year Group), years of potential experience are grouped as 0-4 years, 5-9 years, ..., 35-39 years; in Columns (2) (Ten-Year Group), years of potential experience are grouped as 0-9 years, 10-19 years, 20-29 years, 30-39 years. Heteroskedastically-robust standard errors are in parentheses.

Table A.2: First-Stage Regressions: OLS Regression of Equation (A.2)

Grouping of Potential Experience: Dependent Variable: $\ln(W^c_{kt}/W^n_{kt})$	Five-Year Group (1)	Ten-Year Group (2)
$\ln(C_{kt})$	-0.104	-0.149
	(0.021)	(0.029)
$\ln(N_{kt})$	0.232	0.282
	(0.017)	(0.025)
Observations	272	136
Adjusted R^2	0.738	0.784

Dummies of potential experience groups (b_k) and year dummies (d_t) are included in the regression. In Column (1) (Five-Year Group), years of potential experience are grouped as 0-4 years, 5-9 years, ..., 35-39 years; in Columns (2) (Ten-Year Group), years of potential experience are grouped as 0-9 years, 10-19 years, 20-29 years, 30-39 years. Heteroskedastically-robust standard errors are in parentheses.

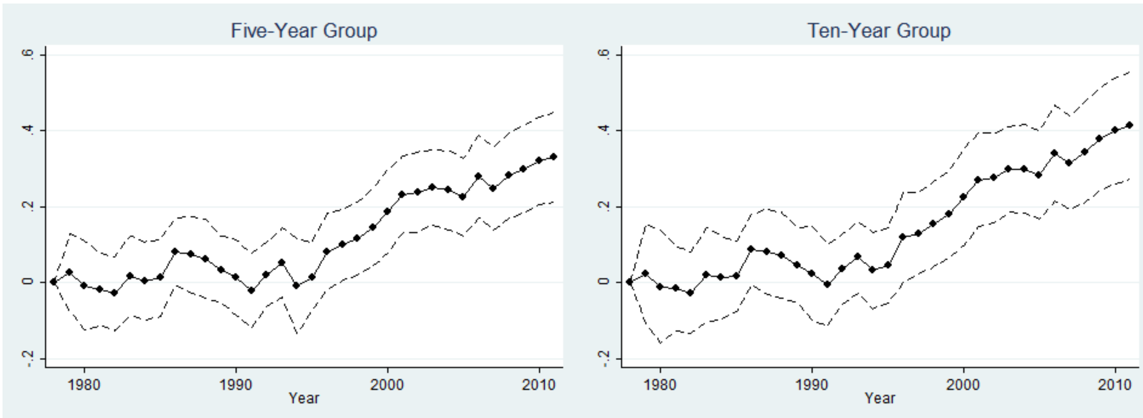


Figure A.2: Coefficients and 95% Confidence Intervals of Year Dummies in Table A.1

Figure A.3: Coefficients and 95% Confidence Intervals of Year Dummies in Table A.2

A.3 The Wage Gap and the Difference in the Occupational Structure between Vocational and Academic Graduates

This section summarizes the results from TIPED and PSFD on the wage gap and the occupational structure of vocational and academic graduates. The micro-level data of TIPED is not released, so our results from TIPED is based on the detailed reports of descriptive statistics released online. Because the frequencies in most of their tables are weighted to population size, we do not have information on the raw sample size. As to PSFD, we restrict our sample to wage and salaried workers with 0-9 years of potential experience who normally work at least 40 hours weekly. Because the sample size of vocational graduates among older cohorts and in earlier years are too small, we only display the results in years 2004-2008. The raw sample size (labeled as "N" in the following tables) of the results from PSFD is provided. "Year" in the following tables represents the year when the survey was administered.

A.3.1 Wage Gap

Because the data structure of TIPED and PSFD are different, the mean wage measures are constructed slightly differently as well. Specifically, the unit of the results from TIPED is log of mean monthly salary in nominal Taiwanese dollars. The reports of TIPED provide weighted-frequency tables of nominal monthly salary by school type, and the amount of monthly salary is grouped into several categories. Therefore, we first calculate the mean monthly salary by averaging the mid-points of the amount categories, weighted by the frequencies as suggested in the frequency tables. Then, we take logs with respect to the mean monthly salary. As to the results from PSFD, the unit is the mean of log monthly salary in real Taiwanese dollars. We calculate the real monthly salary of each individual, take logs, and then calculate the average.

Table A.3 displays the average monthly salary of vocational and academic graduates, in the unit of log Taiwanese dollars. As can be seen, calculations using TIPED suggest that one year or three years after graduating from university, a vocational graduate earns about 10% less than an academic counterpart does, while calculations using PSFD suggest that a vocational graduate with 0-9 years of potential experience earns about 15%-30% lower than an academic counterpart does. Therefore, we set τ to be between 0.7 and 0.95 in Section 1.5.1.

A.3.2 Occupational Structure

Table A.4 displays the proportion of workers by type of occupation and educational attainment. As can be seen, academic graduates are slightly more likely to be found in Managerial and Professional occupations, vocational graduates concentrate in Administrative, Clerical and Sales occupations, and non-university-educated workers concentrate in the occupations of both Administrative, Clerical and Sales and Production Workers and Laborers.

In addition to the occupational structure by educational attainment, we can also use the index of dissimilarity in Duncan and Duncan (1955) to quantify how similar the occupational structure is between academic and vocational graduates. The index of dissimilarity between academic and vocational graduates is defined as

$$\frac{1}{2}\sum_{j=1}^{3}|\frac{a_j}{A}-\frac{v_j}{V}|,$$

where a_j and v_j are the number of academic and vocational graduates in occupation j, respectively, and A and V are the number of academic and vocational graduates, respectively. Therefore, the more similar the occupational distribution between academic and vocational graduates is, the smaller the index of dissimilarity is. The index of dissimilarity between workers with other levels of educational attainment can also be defined analogously.

Table A.5 displays the index of dissimilarity in occupational structure by educational attainment. As can be seen, the index of dissimilarity is quite small between vocational and academic graduates in general (about 0.1), except that the values are larger in the PSFD data in 2004-2006, which might be very likely due to the compositional effect. In the 2004-2006 surveys of the PSFD, among the university graduates with 0-9 years of potential experience, those who are classified as vocational graduates tend to have graduated more recently because the proportion of vocational graduates to the whole university graduates did not reach and plateau at around 50% until the early 2000s. Thus, the larger index might actually reflect the difference between workers with more and fewer years of potential experience within the 0-9-year-of-potential-experience group. When the issue of the compositional effect becomes less severely in later years of the PSFD survey, the results become more similar to the results from the TIPED data.

We might wonder whether vocational graduates are more similar to academic graduates or non-university-educated workers, so we calculate the index of dissimilarity between vocational graduates and non-university-educated workers as well. As can be seen in Table A.5, the index of dissimilarity is generally smaller between vocational and academic graduates than between vocational graduates and non-university-educated workers (about 0.2-0.3), except in 2004-2006 PSFD surveys, where vocational graduates tend to be younger due to the the compositional effect. In addition, to understand better about the magnitudes of the index values, we also calculate the index of dissimilarity between university- and non-university-educated workers as a comparison, and the results suggest that the index of dissimilarity is 0.3-0.4 between university- and non-university-educated workers.

To conclude, our results suggest that the occupational distribution of the vocational graduates is closer to academic graduates than to non-university graduates, so we should aggregate vocational graduates with academic graduates when we calculate the quality-adjusted quantity of labor supply, as did in Section 1.5.1.

Table A.3: Average Monthly Salary of Academic and Vocation Graduates (in Natural Logs)

		TIPED	PSFD	
Year	Type of University Graduate	Log of Mean Monthly Salary	Mean of Log Monthly Salary	N
2004	Vocational		10.26	58
	Academic		10.51	111
2005	Vocational		10.36	49
	Academic		10.53	122
2006	Vocational	10.24	10.24	91
	Academic	10.33	10.54	135
2007	Vocational		10.42	41
	Academic		10.71	95
2008	Vocational	10.23	10.31	85
	Academic	10.35	10.60	125
2009	Vocational	10.20		
	Academic	10.23		
2009*	Vocational	10.27		
	Academic	10.34		
2010	Vocational	10.23		
	Academic	10.32		

Asterisk (*) indicates the TIPED survey which surveys respondents three years after graduation. All the other surveys of the TIPED survey respondents one year after graduation. Results from the PSFD include wage and salaried workers with 0-9 years of potential experience who normally works at least 40 hours per week. The wage measure for the results from the TIPED is log of mean monthly salary in nominal Taiwanese dollars, while the results from the the PSFD is the mean of log monthly salary in real Taiwanese dollars.

Table A.4: Occupational Distributions of Vocational Graduates, Academic Graduates, and Non-University-Educated Workers (Unit: %; Raw Number)

		TIPED			PSFD			
Year	Educational Attainment	Managerial and Professional	Administrative, Clerical and Sales	Production Workers and Laborers	Managerial and Professional	Administrative, Clerical and Sales	Production Workers and Laborers	N
2004	Vocational				26.79	53.57	19.64	56
	Academic				57.29	40.63	2.08	96
	Non-University				11.36	51.14	37.50	352
2005	Vocational				31.25	43.75	25.00	48
	Academic				56.44	42.57	0.99	101
	Non-University				16.59	45.50	37.91	211
2006	Vocational	27.74	69.95	2.31	32.22	52.22	15.56	90
	Academic	35.37	62.15	2.47	55.36	41.07	3.57	112
	Non-University				11.64	46.23	42.14	318
2007	Vocational	32.36	61.59	6.05	46.34	39.02	14.63	41
	Academic	43.57	54.70	1.72	50.68	42.47	6.85	73
	Non-University				16.80	43.20	40.00	125
2008	Vocational	36.58	58.06	5.37	33.33	48.81	17.86	84
	Academic	42.87	54.90	2.23	50.00	48.00	2.00	100
	Non-University				9.05	50.21	40.74	243
2009	Vocational	21.81	72.39	5.80				
	Academic	29.17	68.00	2.83				
	Non-University							
2009*	Vocational	40.92	54.77	4.31				
	Academic	52.62	45.12	2.26				
	Non-University							
2010	Vocational	22.24	70.15	7.60				
	Academic	31.48	65.82	2.70				
	Non-University							

Asterisk (*) indicates the TIPED survey which surveys respondents three years after graduation. All the other surveys of the TIPED survey respondents one year after graduation. Results from the PSFD include wage and salaried workers with 0-9 years of potential experience who normally works at least 40 hours per week.

Table A.5: Index of Dissimilarity in Occupational Structures by Educational Attainment

	Vocational vs Academic			Vocational vs Non-University		University vs Non-University			
	TIPED	PSFD		PSFD		PSFD		MUS	
Year			N		N		N		N
2002								0.4173	6584
2003								0.3995	6392
2004		0.3051	152	0.1786	408	0.3583	530	0.3875	6382
2005		0.2519	149	0.1466	259	0.3341	393	0.4023	6340
2006	0.0780	0.2313	202	0.2658	408	0.3565	557	0.3954	6313
2007	0.1121	0.0778	114	0.2954	166	0.3492	270	0.3842	6225
2008	0.0630	0.1667	184	0.2428	327	0.3720	470	0.3810	5660
2009	0.0735							0.3384	5077
2009*	0.1170								
2010	0.0924							0.3704	5386
2011								0.3822	5534

Asterisk (*) indicates the TIPED survey which surveys respondents three years after graduation. All the other surveys of the TIPED survey respondents one year after graduation. Results from the PSFD and the MUS include wage and salaried workers with 0-9 years of potential experience who normally works at least 40 hours per week.

BIBLIOGRAPHY

BIBLIOGRAPHY

Autor, David H., David Dorn, and Gordon H. Hanson, "The China Syndrome: Local Labor Market Effects of Import Competition in the United States," *American Economics Review*, forthcoming.

Becker, Gary S. and Nigel Tomes, "An Equilibrium Theory of the Distribution of Income and Intergenerational Mobility," *Journal of Political Economy*, 1979, *87*, 1153–1189.

Berman, Eli, John Bound, and Zvi Griliches, "Changes in the Demand for Skilled Labor within U.S. Manufacturing: Evidence from the Annual Survey of Manufacturers," *The Quarterly Journal of Economics*, May 1994, *109* (2), 367–397.

Borjas, George J., Richard B. Freeman, and Lawrence F. Katz, "How Much Do Immigration and Trade Affect Labor Market Outcomes?," *Brookings Papers on Economic Activity*, 1997, *1997* (1), 1–90.

Bound, John and George Johnson, "Changes in the Structure of Wages in the 1980's: An Evaluation of Alternative Explanations," *American Economic Review*, June 1992, *82* (3), 371–392.

Cameron, A. Colin, Jonah B. Gelbach, and Douglas L. Miller, "Robust Inference with Multiway Clustering," *Journal of Business and Economic Statistics*, April 2011, *29* (2), 238–249.

Card, David and Thomas Lemieux, "Can Falling Supply Explain the Rising Return to College for Younger Men? A Cohort-Based Analysis," *The Quarterly Journal of Economics*, May 2001, *116* (2), 705–746.

Carneiro, Pedro and Sokbae Lee, "Trends in Quality-Adjusted Skill Premia in the United States, 1960-2000," *American Economics Review*, October 2011, *101* (6), 2309–2349.

Chen, Been-Lon and Mei Hsu, "Time-Series Wage Differential in Taiwan: The Role of International Trade," *Review of Development Economics*, 2001, *5* (2), 336–354.

Choi, Kang-Shik, "The Impact of Shifts in Supply of College Graduates: Repercussion of Educational Reform in Korea," *Economics of Education Review*, 1996, *15* (1), 1–9.

Driscoll, Jonh C. and Aart C. Kraay, "Consistent Covariance Matrix Estimation with Spatially Dependent Panel Data," *The Review of Economics and Statistics*, November 1998, *80* (4), 549–560.

Duncan, Otis Dudley and Beverly Duncan, "A Methodological Analysis of Segregation Indexes," *American Sociological Review*, April 1955, *20* (2), 210–217.

Feenstra, Robert C. and Gordon H. Hanson, "Globalization, Outsourcing and Wage Inequality," *American Economic Review*, 1996, *86*, 240–245.

Freeman, Richard B., *The Overeducated American*, New York: Academic Press, 1976.

Gindling, T.H. and Way Sun, "Higher Education Planning and the Wages of Workers with Higher Education in Taiwan," *Economics of Education Review*, 2002, *21*, 153–169.

Goldin, Claudia and Lawrence F. Katz, *The Race between Education and Technology*, The Belknap Press of Harvard University Press, 2008.

Johnson, Robert C. and Guillermo Noguera, "Accounting for Intermediates: Production Sharing and Trade in Value Added," *Journal of International Economics*, 2012, *86*, 224–236.

Joreskog, Karl G. and Arthur S. Goldberger, "Estimation of a Model with Multiple Indicators and Multiple Causes of a Single Latent Variable," *Journal of the Ameriecan Statistical Association*, September 1975, *70* (351), 631–639.

Katz, Lawrence F. and Kevin M. Murphy, "Changes in Relative Wages, 1963-1987: Supply and Demand Factors," *The Quarterly Journal of Economics*, February 1992, *107* (1), 35–78.

Kim, Dae-Il and Robert H. Topel, "Labor Markets and Economic Growth: Lessons from Korea's Industrialization, 1970-1990," in Richard B. Freeman and Lawrence F. Katz, eds., *Differences and Changes in Wage Structures*, Chicago: The University of Chicago Press, 1995, pp. 227–264.

Krugman, Paul, "Trade and Wages, Reconsidered," *Brookings Papers on Economic Activity*, 2008, pp. 103–137.

Lin, Chun-Hung A. and Peter F. Orazem, "Wage Inequality and Returns to Skill in Taiwan, 1978-96," *The Journal of Development Studies*, June 2003, *39* (5), 89–108.

Lu, H.C., "The Structure of Wages in Taiwan: the Roles of Female Labor Market Participation and International Competition." PhD dissertation, University of Chicago 1993.

Luoh, Ming-Ching, "Educational Opportunities and Family Background in Taiwan," *Taiwan Economic Review*, 2004, *32* (4), 417–445. (In Mandarin).

Mare, Robert D., "Change and Stability in Educational Stratification," *American Sociological Review*, February 1981, *46* (1), 72–87.

Murphy, Kevin M. and Finis Welch, "Industrial Change and the Rising Importance of Skill," in Shelden Danziger and Peter Gottschalk, eds., *Uneven Tides: Rising Inequality in America*, Russell Sage Foundation, 1993.

Robbins, Donald J., "HOS Hits Facts: Facts Win; Evidence on Trade and Wages in the Developing World," October 1996. Harvard Institute for International Development, Development Discussion Paper No. 557.

Solon, Gary, "A Model of Intergenerational Mobility Variation over Time and Place," in Miles Corak, ed., *Generational Income Mobility in North America and Europe*, Cambridge University Press, 2004, pp. 38–47.

Trefler, Daniel and Susan Chun Zhu, "The Structure of Factor Content Predictions," *Journal of International Economics*, 2010, *82*, 195–207.

Tsai, Shu-Ling and Yossi Shavit, "Taiwan: Higher Education—Expansion and Equality of Educational Opportunity," in Yossi Shavit, Richard Arum, and Adam Gamoran, eds., *Stratification in Higher Education: A Comparative Study*, Stanford University Press, 2007, pp. 140–164.

Vanek, Jaroslav, "The Factor Proportions Theory: The N-Factor Case," *Kyklos*, 1968, *21*, 749–756.

Wood, Adrian, "Openness and Wage Inequality in Developing Countries: The Latin American Challenge to East Asian Conventional Wisdom," *The World Bank Economic Review*, 1997, *11* (1), 33–57.

Wooldridge, Jeffrey M., *Econometric Analysis of Cross Section and Panel Data*, Cambridge, Massachusetts: The MIT Press, 2002.