OUTSOURCING AND WAGE INEQUALITY

IN THE HOME COUNTRY

A Dissertation

by

KUANG-CHUNG HSU

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2007

Major Subject: Economics

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Approved by:

Chair of Committee,	Donald Deere
Committee Members,	Amy Glass
	Manuelita Ureta
	Kishore Gawande
Head of Department,	Amy Glass

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ABSTRACT

Outsourcing and Wage Inequality in the Home Country. (May 2007)

Kuang-Chung Hsu, B.S., National Chung-Hsing University;

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Chair of Advisory Committee: Dr. Donald Deere

This dissertation consists of three essays, which mainly talk about the wage inequality caused by outsourcing in the source countries like the US. The title of the first essay is “Does Outsourcing Always Benefit Skilled Labor? A Dynamic Product Cycle Model Approach.” To understand why outsourcing did not cause wage inequality in the 1970s, I build a dynamic product cycle model with three kinds of labor inputs, scientists, white-collar workers, and blue-collar workers. First, only a homogenous representative producer exists in the model and then the paper allows for producer heterogeneity. According to my theoretical model, outsourcing can hurt skilled labor and does not cause wage inequality if outsourcing industries are absolutely blue-collar worker-intensive compared to non-outsourcing industries. Only scientists who conduct research and development always benefit from outsourcing.

The second essay is an empirical work. The title is “Outsourcing, Innovation, and Wage Inequality in the United States: What Happened to the Outsourcing Effect on Wage Inequality in the 1970s?” I find that, in the 1970s, white-collar workers’ wages deteriorated and blue-collar workers’ wages were non-decreasing. R&D workers always benefit from outsourcing. Except computers and high-technology capital, innovation expenditure on wage payment was an additional source of wage inequality in the 1980s.

The last essay is named “Beyond the Wage Inequality, the Impact of Outsourcing on the U.S. Labor Market.” To understand the impact of outsourcing on employment, I examine laborers’ ages, gender ratio, years of education, and job tenure and retention rates. By employing the January Current Population Survey (CPS) data, the National

Bureau of Economic Research (NBER) production data, and outsourcing data provided by Feenstra and Hanson, I find that outsourcing decreased blue-collar laborers' average years of completed education; increased the hiring of females into white-collar workers, and increased job stability of unskilled and skilled laborers in the 1980s. Thus, outsourcing did not take away unskilled laborers' jobs but hindered new hiring of young unskilled workers

DEDICATION

To my parents,
Hsueh-Tung Hsu and Lan-Fang Dong
For their unconditional and endless love and support.
To my wife, Hui-Chu (Sherry)
for her thoughtful and selfless dedication to our family
and our lovely baby Alice

ACKNOWLEDGMENTS

I greatly appreciate Dr. Donald Deere, the chair of my committee, and other members of my committee, Dr. Amy Glass, Dr Manuelita Ureta, and Dr. Kishore Gawande.

I am also deeply indebted to my classmates, David Brightwell and Megan Leonard, for their kindly help and advice in my writing. Especially, I am grateful to another beautiful and thoughtful classmate who is also my wife, Hui-Chu.

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CHAPTER I

INTRODUCTION

The topic of whether outsourcing contributes to wage inequality between skilled and unskilled labor in industrialized countries has received a great deal of attention from economists. Theoretical speaking, the idea that outsourcing contributes to wage inequality is well supported by previous literatures such as Feenstra and Hanson (1997), Glass and Saggi (2001), and Sayek and Sener (2006). Empirical papers, such as Feenstra and Hanson (1996) and Feenstra and Hanson (1999) also find that outsourcing can explain the increase in the relative wage of skilled workers.

However, some of Feenstra and Hanson's (1996) results are unexpected. In 1972-1979, outsourcing had a statistically insignificant negative effect on the wage share of non-production workers. Consistent with theoretical models, in the 1980s the coefficient of outsourcing was statistically significant and positive. According to Feenstra and Hanson (1996), outsourcing had expanded dramatically in both the 1970s and 1980s.[1] Therefore, the growth rate of outsourcing was not the reason for the divergence from theoretical predictions. The empirical results in the 1970s became another puzzle to economists.

To solve the puzzle in the 1970s, this dissertation uses three papers to analysis this topic. In the first paper, I employ a general equilibrium model to find an explanation to the puzzle. There will be three labor forces and two types of industries in this model. Then, in the second paper, several regressions are employed to test my theoretical predictions. The last paper discusses this topic by analyzing the change of inflows and outflows in employment. By examining the average age, years of completed education, tenure, and retention rate and gender-ratio, the results can let me understand the impacts of outsourcing on employment clearly.

As the discussion above, this dissertation has five chapters. The second chapter is

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This dissertation follows the style and format of the *American Economic Review*.

[1] The annual change of outsourcing in 1972-1990 was 0.331 and in 1979-1990 was 0.313. Please see Feenstra and Hanson (1996) for details.

entitled as “Does Outsourcing Always Benefit Skilled Labor? A Dynamic Product Cycle Model Approach.” The title of Chapter III is “Outsourcing, Innovation, and Wage Inequality in the United States: What Happened to the Outsourcing Effect on Wage Inequality in the 1970s?” The fourth chapter is entitled as Beyond the Wage Inequality, the Impact of Outsourcing on the U.S. Labor Market.” Conclusion is presented in Chapter V.

CHAPTER II

DOES OUTSOURCING ALWAYS BENEFIT SKILLED LABOR?

A DYNAMIC PRODUCT CYCLE MODEL APPROACH

2.1 Introduction

The issue of whether outsourcing contributes to wage inequality between skilled and unskilled labor in industrialized countries has received a great deal of attention from economists. Feenstra and Hanson (1997) build a model with one final good, which is assembled from a continuum of intermediate inputs to analyze this issue. They find that outsourcing shifts production of intermediate inputs from a developed country to a developing country and reduces demand of unskilled labor in the developed country.[2] Glass and Saggi (2001) extend the quality ladders and product cycles model by considering outsourcing and find that increased outsourcing fuels the rate of innovation and lowers the relative wage of labor. Sayek and Sener (2006), also based on the quality ladders and product cycles model, considers two kinds of labor and substitution between them. After an increase in outsourcing, their model shows that the relative wage of skilled labor will increase unambiguously. The idea that outsourcing contributes to wage inequality is well supported theoretically.

Empirical papers, such as Lawrence and Slaughter (1993) and Slaughter (1995), argue that outsourcing can explain little of the change in wages, but Feenstra and Hanson (1996) argue these findings are due to the narrow measure of outsourcing. Feenstra and Hanson (1996) employ a new measure of outsourcing computed as a fraction of imports of intermediate inputs in total consumption in each industry and find that outsourcing accounts for 30.9 % of the change of the non-production wage share. Feenstra and Hanson (1999) employ a two-stage regression to estimate the relative effects that outsourcing and expenditures on high-tech capital had on wages in the United States from 1979-1990. They find that outsourcing explains 15% of the increase in the relative wage of

[2] In their finding, outsourcing also causes a increase in relative demand of skilled labor in a developing country. Please see Feenstra and Hanson (1997) for details.

non-production workers.

However, some of Feenstra and Hanson's (1996) results are unexpected. In 1972-1979, outsourcing had a statistically insignificant negative effect on the wage share of non-production workers. Consistent with theoretical models, in the 1980s the coefficient of outsourcing was statistically significant and positive. According to Feenstra and Hanson (1996), outsourcing had expanded dramatically in both the 1970s and 1980s. Therefore, the growth rate of outsourcing was not the reason for the divergence from theoretical predictions. The empirical results in the 1970s became another puzzle to economists.

In most previous theoretical work, outsourcing means that producers outsource the basic part of production to low wage countries to reduce costs. If a basic part of production also requires skilled labor, outsourcing may not only affect unskilled laborers' jobs, but skilled workers' jobs as well. According to Glass and Saggi (2001), outsourcing increases a firm's profit, which leads to increased expenditures on Research and Development (R&D). Skilled laborers who conduct R&D will benefit from outsourcing. Mixing those R&D workers with other types of skilled workers may generate a misleading conclusion.

The types of industries that outsource can also play an important role in the impact on relative wage. If outsourcing industries are unskilled labor-intensive compared to non-outsourcing industries, outsourcing will cause a decrease in domestic labor demand for unskilled workers. However, outsourcing can also increase the profit of firms in the industries, which may increase the demand of unskilled and skilled labor. These two opposing effects determine the impact of outsourcing on the relative wage of skilled labor.

The keys to the puzzle of the 1970s could be the differences between outsourcing industries and non-outsourcing industries and differences in types of skilled labor. In this study, I construct two theoretical general equilibrium North-South models with innovation, imitation, and outsourcing. Unlike previous works of Glass and Saggi (2001), and Sayek and Sener (2006), both models have three kinds of labor inputs (scientists, white-collar workers, and blue-collar workers) to distinguish the different effects of outsourcing on different types of skilled workers. The second model also allows industry heterogeneity to explore the impacts of outsourcing for different types of industries.

The two theoretical models are presented in section II. Both models have three kinds of workers and the second model is allowed to have heterogeneous producers to examine its impact on wage inequality. Section III verifies the theoretical predictions by employing United States manufacturing industry data from 1972 to 1992. Section IV presents conclusions.

2.2 The Model

There are two countries, the North (N) and the South (S), each with a representative consumer and a continuum of industries. There are many firms in each industry. Firms attempt to develop better quality products to earn higher profits. To produce products and invent new generations of products, firms need to hire labor. There are three kinds of labor, white-collar workers (W), blue-collar workers (B), and scientists (H). Developing higher quality level products, firms need to conduct R&D, which needs scientists that exist only in the North. When a firm in the North invents a new generation product and wins the innovation competition in the North, it becomes a Northern Firm.

The North, compared to the South, is abundant in white-collar workers relative to blue-collar workers. Firms in the North can attempt to outsource part of their production to the South by adapting their production technology. If a Northern Firm successfully outsources its part of production to the South, it becomes an Outsourcing Firm. Although there are no scientists in the South, Southern Firms can adopt new technologies by imitating Outsourcing Firms. Once the state-of-the-art technology fully leaks to the South, it becomes old generation technology and Southern Firms are able to produce it. Therefore, Southern Firms either produce part of the North's outsourced production or old generation products.

This study starts with only one type of producer. Using this simple specification, the model shows us that skilled labor can be hurt by outsourcing. Then, I add an additional type of producer to analyze the impact of outsourcing on wage levels of all kinds of workers in a more complete way. The results of the model with industry heterogeneity tell us that outsourcing affects labor differently when labor intensity varies between the two types of industries. This result explains why the impact of outsourcing on wage inequality in the 1970s is different from the 1980s.

2.2.1 Homogenous Producers

2.2.1.1 Consumer

Following Grossman and Helpman (1991) and Glass and Saggi (2001), consumers who live in one of two countries choose commodities available in discrete quality levels indexed by m from a continuous number of industries indexed by j. The representative consumer in country i has intertemporal preferences given by lifetime utility

(1) $$U_i = \int_0^{\infty} e^{-\rho t} \log u_i(t) dt, \qquad \textit{for } i = N, S \,,$$

where ρ is the subjective discount rate, and instantaneous utility of each consumer is

(2) $$\log u_i(t) = \int_0^1 \log\left[\sum_m \lambda^m x_{im}(j,t)\right] dj \qquad \textit{for } i = N, S,$$

where $x_{im}(j,t)$ is the quantity of commodities demanded by consumers in country i of quality level m of industry j at time t. λ, which is greater than one, represents the size of quality improvement, and λ^m is the assessment of quality level m. Thus, consumers are willing to pay a premium of λ for a one quality level improvement in a good.

The decision of the representative consumer is to maximize lifetime utility, equation (1), subject to the intertemporal budget constraint

(3) $$\int_0^\infty e^{-R(t)}E(t)dt \le A(0) + \int_0^\infty e^{-R(t)}Y(t)dt\ ,$$

where $R(t) = \int_0^t r(s)ds$ is the cumulative interest rate and $A(0)$ is the aggregate value of assets held in time zero. Aggregate labor income, $Y(t)$, is

(4) $$Y(t) = \sum_{i=N,S}\ \sum_{k=H,W,B} L_i^k w_i^k(t),$$

where $w_i^k(t)$ is the k type labor's wage in country i at time t and L_i^k is the k type labor supply in country i. Aggregate spending of the world, $E(t)$, is

(5) $$E(t) = \int_0^1 \left[\sum_m p_m(j,t) x_m(j,t) \right] dj\ ,$$

where $p_m(j,t)$ and $x_m(j,t)$ are the price and product demand of quality level m of industry j at time t. Since all consumers are willing to pay a premium λ for one increment of quality level, $p_m(j,t) = \lambda\, p_{m-1}(j,t)$ for all products. According to the definitions above, the consumers' maximization procedure first allocates lifetime wealth across time evenly. Then, they equally apportion expenditures across products at each instant. Meanwhile, they allocate all their spending for each product at each instant to the highest quality level available.[3]

2.2.1.2 Producer

The North producer's problem has three stages: innovating a new product, producing it, and outsourcing it. In the first stage, innovation races occur simultaneously among all firms in the North. Let w^H represent the wage rate of scientists. Firms in the North undertake innovation intensity r for a time interval dt. This requires $a_r rdt$ units of scientists at a cost of $w_N^H a_r rdt$, where a_r represents the labor requirement per innovation intensity. The probability of successful innovation is rdt. Note that a_r is a function of w^H and, since scientists are the only input in R&D, I assume that its demand elasticity is inelasticity.[4] To ensure a finite intensity of innovation, expected gains from innovation are required not to exceed costs of innovation

$$(6) \qquad V^N \leq w^H a_r \left(w^H\right) \qquad \text{with equality whenever } r > 0,$$

V^N is the market value of an industry-leading Northern Firm that does not outsource part of its production to the South. In the equilibrium, this condition holds with equality.

Once a firm in the North is successful in the innovation race, it begins the second stage, production. Let $w^N = w_N^W / w_N^B$, represent Northern relative wage of white-collar. The unit cost of a Northern Firm is

[3] See Grossman and Helpman (1991) and Glass and Saggi (2001) for details of the consumer's maximization problem.
[4] One can think of capital as the other input in conducting R&D, and firms can purchase capital at a given price. When w^H increases, enterprisers can substitute capital for scientists. However, since scientists are still the main factor in R&D, an increase in w^H still increases total expenditures of R&D. Adding capital in this model yields the same results.

$$(7) \qquad C^N = a^{NW}\left(w^N\right)w_N^W + a^{NB}\left(w^N\right)w_N^B,$$

where C^N is the unit cost of a Northern Firm that does not outsource their part of production. a^{NW} and a^{NB} are the white and blue-collar workers' unit labor requirements of Northern Firms. Note that $\partial a^{NW} / \partial w^N < 0$ and $\partial a^{NB} / \partial w^N > 0$.

With an exogenous probability ϕ, Northern Firms can outsource part of their production to the South successfully and become Outsourcing Firms. The final good then combines inputs produced in the North with inputs outsourced to the South. The exogenously determined North and South input mixes are denoted α and $1-\alpha$ respectively, where $0 < \alpha < 1$. The unit cost for Outsourcing Firms is

$$(8) \qquad C^O = (1-\alpha)\left[a^{NW}\left(w^N\right)w_N^W + a^{NB}\left(w^N\right)w_N^B\right] + \alpha\left[a^{SW}\left(w^S\right)w_S^W + a^{SB}\left(w^S\right)w_S^B\right],$$

where a^{SW} and a^{SB} are Southern white and blue-collar workers' unit labor requirements of Outsourcing Firms in the South. $w^S = w_S^W / w_S^B$, is the relative wage of white-collar workers in the South and $\partial a_j^{SW} / \partial w^S < 0$ and $\partial a_j^{SB} / \partial w^S > 0$. Southern Firms' unit cost of production is normalized to one as the numeraire good

$$(9) \qquad C^S \equiv a^{SW}\left(w^S\right)w_S^W + a^{SB}\left(w^S\right)w_S^B = 1.$$

This normalization makes the product price of Northern Firms' goods λ, the premium for quality, and the quantity of output is $x = E/\lambda$. If $\delta = 1/\lambda$, a Northern Firm makes instantaneous profit

(10) $$\pi^N = (1 - C^N \delta)E\ .$$

An Outsourcing Firm's instantaneous profits are

(11) $$\pi^O = (1 - C^O \delta)E\ .$$

Furthermore, the reward of a Northern Firm for success in an innovation race is

(12) $$V^N = \frac{\pi^N + \phi(V^O)}{\rho + \phi + r},$$

where V^O is market value of an Outsourcing Firm. The V^O is

(13) $$V^O = \frac{\pi^O}{\rho + \mu + r},$$

where μ is an exogenous probability that Southern Firms can fully imitate the state-of-the -art technology. By assuming Southern Firms face perfect competition, their profit are zero, $\pi^S = 0$.

2.2.1.3 Industry Flows and Labor Markets

Let n^N, n^O, and n^S denote the fractions of Northern Firms, Outsourcing Firms, and Southern Firms. Note that $n^N + n^O + n^S = 1$. In the steady-state equilibrium, industry fractions remain constant. That means the flows in must the equal flows out of each type of industry. First, Northern Firms capture production from Southern Firms and they successfully become Outsourcing Firms with a given probability ϕ

(14) $$rn^S = \phi n^N .$$

With exogenous probability, Southern Firms fully learn the state-of-the-art technology and force Outsourcing Firms out of market. The fraction of Outsourcing Firms also needs to remain constant, which implies

(15) $$\phi n^N = \mu n^O .$$

In the Northern labor market, the fixed supply of scientists, L_N^H, must equal the labor demand for innovation department in equilibrium

(16) $$n^S a_r\left(w^H\right)r = L_N^H . \qquad \text{LH}$$

I named equation (16) LH, which is used to solve the equilibrium values of w^H and w_N^W. Since w_N^W has no effect in equation (16) if w^N is fixed, LH is a horizontal line in a graph with w^H and w_N^W as its coordinates' axes.[5] The equilibrium in the white-collar labor market requires that the fixed supply of white-collar workers in the North and South (L_N^W and L_S^W) is equal to the demand by Northern Firms, Outsourcing Firms, and Southern Firms.

(17) $$\left[a_N^W\left(w^N\right)n^N + (1-\alpha)a_N^W\left(w^N\right)n^O\right]E\delta = L_N^W$$

(18) $$\alpha\, a_S^W\left(w^S\right)n^O E\delta + n^S a_S^W\left(w^S\right)E = L_S^W\ .$$

The fixed supply of blue-collar workers in the North and South (L_N^B and L_S^B) must equal the demand by Northern Firms and Outsourcing Firms in the North, and Outsourcing Firms and Southern Firms in the South

(19) $$\left[a_N^B\left(w^N\right)n^N + (1-\alpha)a_N^B\left(w^N\right)n^O\right]E\delta = L_N^B\,,$$

(20) $$\alpha a_S^B\left(w^S\right)n^O E\delta + n^S a_S^B\left(w^S\right)E = L_S^B\,.$$

Note that since I focuse on the North, I simplify the settings in the South. The unit labor requirements for white-collar and blue-collar workers of Outsourcing Firms in the South are the same as those of Southern Firms.

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[5]Under a given w_N^W, equation (16) can solve equilibrium value of w^H .

2.2.1.4 Steady-State Equilibrium

Equations (14) and (15), and $n^{O}+n^{N}+n^{S}=1$ can be used to derive the following fractions

(21) $$n^{O}=\frac{\phi r}{\phi\mu+r(\mu+\phi)},\quad n^{N}=\frac{r\mu}{\phi\mu+r(\mu+\phi)},\quad n^{S}=\frac{\phi\mu}{\phi\mu+r(\mu+\phi)}.$$

Solving equations (17), (18), (19), and (20) provides solutions of innovation intensity r for any labor market combination between the North and South in four terms. They are

(22) $$r_{L_N^W-L_S^W}\left(w^N,w^S;\alpha,\phi,\mu\right)=\frac{\phi\tau a_S^W L_N^W}{\delta\left[a_N^W L_S^W(\mu+\phi)-\alpha\phi\left(a_N^W L_S^W+a_S^W L_N^W\right)\right]},$$

$$r_{L_N^B-L_S^B}\left(w^N,w^S;\alpha,\phi,\mu\right)=\frac{\phi\tau a_S^B L_N^B}{\delta\left[a_N^B L_S^B(\mu+\phi)-\alpha\phi\left(a_N^B L_S^B+a_S^B L_N^B\right)\right]},$$

$$r_{L_N^W-L_S^B}\left(w^N,w^S;\alpha,\phi,\mu\right)=\frac{\phi\tau a_S^B L_N^W}{\delta\left[a_N^W L_S^B(\mu+\phi)-\alpha\phi\left(a_N^W L_S^B+a_S^B L_N^W\right)\right]},\text{ and}$$

$$r_{L_N^B-L_S^W}\left(w^N,w^S;\alpha,\phi,\mu\right)=\frac{\phi\tau a_S^W L_N^B}{\delta\left[a_N^B L_S^W(\mu+\phi)-\alpha\phi\left(a_N^B L_S^W+a_S^W L_N^B\right)\right]}.$$

In equation (22), α has a positive relationship with innovation intensity, r, and μ has a negative relationship with innovation intensity. This result for α is consistent with Glass and Saggi (2001), but differs from Sayek and Sener (2006) who argue α has no effect on r . The intuition behind this result is that by increasing outsourcing, Outsourcing Firms gain more profit, which leads to increased expenditures on R&D to augment the probability of inventing a state-of–the-art technology in the next generation. However, the higher level of μ means Outsourcing Firms have a higher risk of losing their leadership and their profit, which motivates them to reduce their R&D. After solving for r, the solution of aggregate spending for the world is

$$(23) \qquad E\left(w^N, w^S; \alpha, \phi, \mu\right) = \frac{L_N^W}{a_N^W\left(\mu + \phi\left(1-\alpha\right)\right)}\left[\phi\mu\, r^{-1} + \left(\mu + \phi\right)\right],$$

where $\partial E/\partial r < 0$, and $\partial E/\partial \alpha < 0$.

To find the solutions of two endogenous variables, w^N and w^S, one can pick two solutions from (22) and set them equal to each other. To avoid using any of the labor market restrictions twice, I use $r_{L_N^W - L_S^W}$ and $r_{L_N^B - L_S^B}$ to derive equation (24) and $r_{L_N^W - L_S^B}$ and $r_{L_N^B - L_S^W}$ to derive equation (25).

$$(24) \qquad \left.\frac{L_N^W}{L_N^B}\right._{WW-BB} = \frac{a_S^B\left(w^S\right)a_N^W\left(w^N\right)L_S^W}{a_S^W\left(w^S\right)a_N^B\left(w^N\right)L_S^B},$$

$$(25) \qquad \left.\frac{L_N^W}{L_N^B}\right._{WB-BW} = \frac{a_S^W\left(w^S\right)a_N^W\left(w^N\right)L_S^B}{a_S^B\left(w^S\right)a_N^B\left(w^N\right)L_S^W},$$

Equation (24) shows a positive relationship between w^N and w^S, and equation (25) implies a negative relationship between w^N and w^S. The intersection of these two equations determines the equilibrium level of w^N and w^S. Figure 1 illustrates the equilibrium level of w^{N*} and w^{S*}, the relative wage of white-collar workers in the North and South.[6] Note that α, ϕ, and μ have no effect on w^{N*} and w^{S*}. The intuition behind equations (24) and (25) is that, although outsourcing reduces both Northern white-collar and blue-collar workers' labor demand, it does not change the hiring ratio of white-collar and blue-collar labor. The relative wage of white-collar workers in the North and South is still determined by the labor endowment of these two countries.

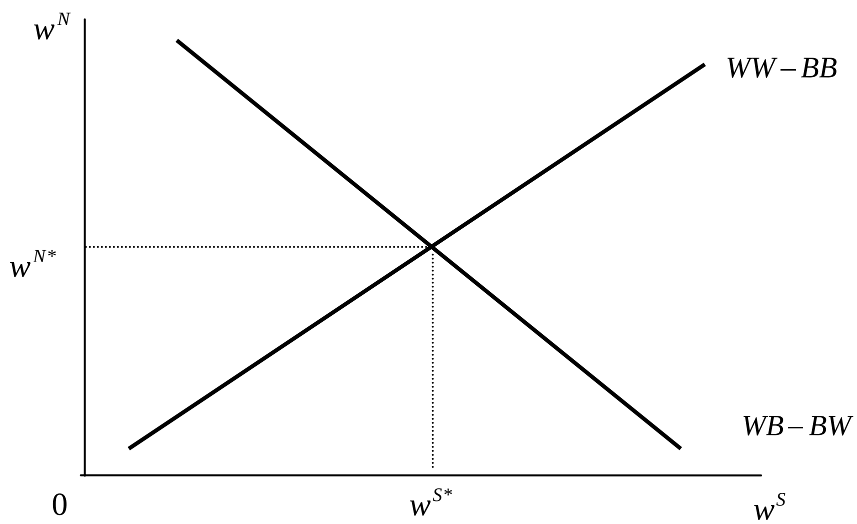

Figure 1. Relative Wages of White-Collar Workers in the North and the South

After determining the equilibrium level of the relative wage of white-collar workers, I use them to solve the equilibrium levels of $E^*\left(w^{N*}, w^{S*}\right)$, $r^*\left(w^{N*}, w^{S*}\right)$ in equation(22) and (23). E^*, r^*, and unit cost equations (7) and (8) are used to rewrite equation (6) as

---

[6] I add "*" on endogenous variables to represent equilibrium values.

$$\frac{E^{*}\left(r^{*}+\mu+\rho+\phi\right)-E^{*}\delta\left[\left(r^{*}+\mu+\rho\right)C^{N*}+\phi\, C^{O*}\right]w_{N}^{W}}{\left(r^{*}+\mu+\rho\right)\left(\rho+r^{*}+\phi\right)}=w^{H}a_{r}\left(w^{H}\right),\quad \text{HW} \tag{26}$$

where $C^{N*}=C^{N}\left(w^{N*}\right)/w_{N}^{W}$ and $C^{O*}=\left(C^{O}\left(w^{N*}\right)-\alpha\right)/w_{N}^{W}$, which are functions of w^{N*}. Equation (26) indicates a negative relationship between w^{H} and w_{N}^{W} for a given w^{N*}. The intuition behind equation (26) is that under a fixed w^{N*}, an increasing w_{N}^{W} will lead to increased production costs. Since firms have less profit, they will reduce R&D and their demand for scientists. The equilibrium wages of scientists and white-collar workers are shown in Figure 2. The equilibrium occurs at the wage level where equation (16), the labor market condition of scientists, is equal to equation (26).[7] The equilibrium wage of blue-collar workers, w_{N}^{B*}, is then w_{N}^{W*}/w^{N*}.

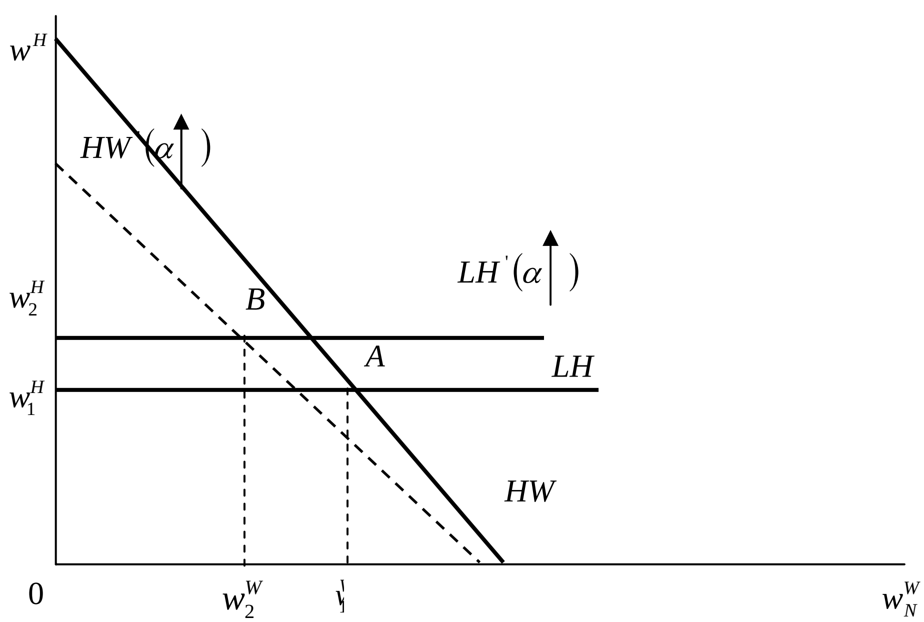

Figure 2. Northern Wages of Scientists and White-Collar Workers

[7] Also, the procedure of determining equilibrium values of w^{H} and w_{N}^{W} first uses equation (16) to settle w^{H}, then by a given w^{H}, uses equation (26) to solve w_{N}^{W}.

$E^*, r^*, w^{N*}, w^{S*}, w^{H*}, w_N^{B*}$, and w_N^{W*} are now solved. Using r^* in equation (21) yields the equilibrium fraction of Northern Firms, Outsourcing Firms, and Southern Firms n^{N*}, n^{O*}, and n^{S*}, respectively. To determine equilibrium wages in the South, one can use the numeraire equation (9), which implies a negative relationship between w_S^W and w_S^B, combinined with the definition of relative wage in the South, $w^{S*} = w_S^W / w_S^B$. The intersection in Figure 3 illustrates the equilibrium wage levels in the South, w_S^{W*} and w_S^{B*}.

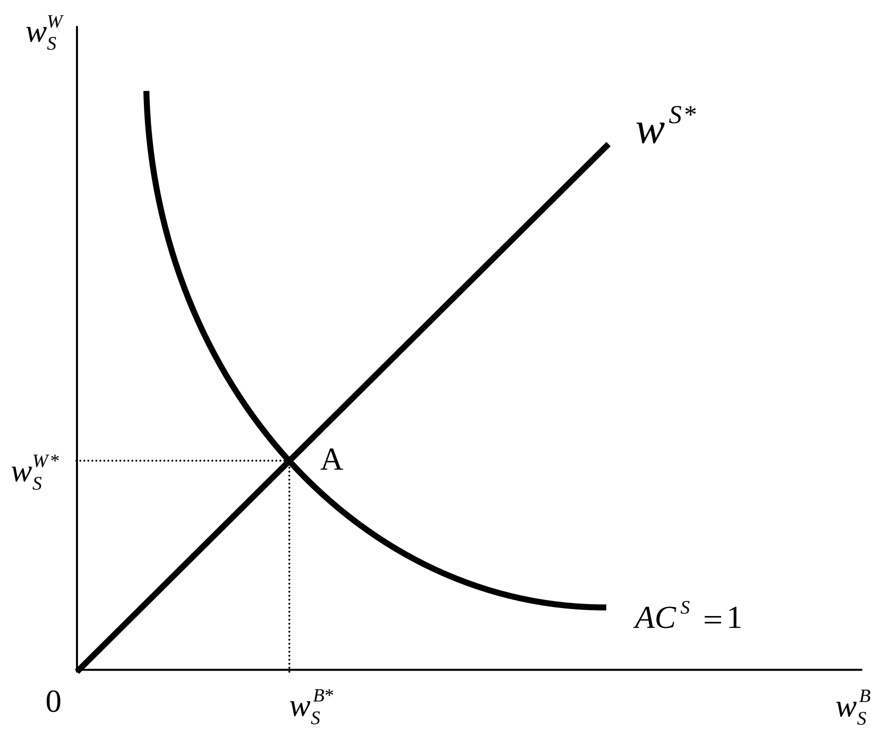

Figure 3. Southern Wages of White-Collar Workers and Blue-Collar Workers

2.2.1.5 Comparative Static Analysis

What will happen if Outsourcing Firms decide to increase the fraction of production they outsource to the South? First, when α increases, according to equations (24) and (25), it will not affect the relative wage of white-collar workers in the North and South. However, the increasing α has a positive effect on r and leads to increased n^N and n^O, but decreased E and n^S. In figure 2 the LH line, which represents the labor market of scientists will shift up since $r\ n^S$ is equivalent to $\mu\ n^O$, which is increasing, and only an increase in w^H can balance equation (16). As for HW line, which represents the balance between innovation and production, increasing α decreases both its intercept and slope. Therefore, in Figure 2 the equilibrium will move from point A to point B, which definitely yields a higher w^H and a lower w_N^W. This means that, if there is an increase in outsourcing, the wages of scientists will increase and the wages of white-collar and blue-collar workers in the North will fall. As for Southern workers, since the relative wage of white-collar workers in the South does not change, the wage levels of both white-collar and blue-collar workers remain constant.

Define the extent of international outsourcing as the fraction of all production outsourced to the South, $\chi \equiv \alpha n^O$. The extent of international outsourcing, χ, will increase certainly because both α and n^O are increasing n^O.

Proposition 1. An increase in the outsourcing fraction of production will increase the wages of scientists. Although the relative wage of white-collar workers remains constant, outsourcing decreases the wage level of white-collar and blue-collar workers in the North. The extent of international outsourcing will certainly increase.

2.2.2 Heterogeneous Producers

2.2.2.1 Producer Behavior

In section 2.1, I only allowed for one type of industry. In this section, by allowing for two types of industries, industry heterogeneity is added. However, only firms in type 1 industries can outsource part of their production to the South. Type 2 industries can not outsource production. By assuming Southern Firms can only access the state-of-the-art technology of products by Outsourcing Firms in the South, Southern Firms can only imitate type 1 industries. Although Southern Firms can only access the state-of-the-art products from type 1 industries, they are still aware of the technology of old generation products from both types of industries. After relaxing the homogenous restriction on producers, some assumptions also need to be changed to allow us to focus on the difference between these two kinds of producers. First, the unit labor requirement of innovation is no longer a function of w^H. Labor demand of scientists now depends on the decision of R&D intensity in these two types of industries. Second, in the last section, outsourcing means firms in the North outsource part of their production to the South. In this section, outsourcing means firms outsource their basic part of production to the South. This implies that outsourcing makes Outsourcing Firms concentrate on skilled-labor-intensive production. Last, for focusing on the difference of labor usage between different industry types, this study assumes the price elasticity of substitution of white-collar workers and blue-collar workers between industries are the same. That means $a_1^{'NW} = a_2^{'NW}$ and $a_1^{'NB} = a_2^{'NB}$.

Under this heterogeneous setting, the benefits and costs of innovation become

(27) $\quad V_l^N \leq w_N^H a_l^r \qquad$ with equality whenever $r > 0$ & $l = 1, 2$,

where V_l^N is the market value of an industry-leading Northern Firm in type l

industries and a_l^r is the unit labor requirement for R&D of type l industries. The unit cost of an industry-leading Northern Firm is

$$(28) \qquad C_l^N = a_l^{NW}\left(w^N\right)w_N^W + a_l^{NB}\left(w^N\right)w_N^B \qquad 0 < a_l^N < 1 \ \& \ l = 1, 2$$

where C_l^N is the unit cost of type l industry Northern Firms that do not outsource their basic part of production. a_l^{NW} and a_l^{NB} are the white and blue-collar workers unit labor requirements of type l industries.

Northern Firms in type 1 industries can outsource their basic part of production to the South. The exogenous probability a firm is successful in outsourcing is ϕ as in 2.1.2. By denoting the exogenous proportions α and $1-\alpha$, the unit cost of an Outsourcing Firm is[8]

$$(29) \qquad C_1^O = (1-\alpha)[a_1^{OW}\left(w^N;\alpha\right)w_N^W + a_1^{OB}\left(w^N;\alpha\right)w_N^B] + \alpha\,[a^{SW}\left(w^S\right)w_S^W + a^{SB}\left(w^S\right)w_S^B],$$

where a_1^{OW} and a_1^{OB} are the unit labor requirements of white and blue-collar workers by Outsourcing Firms in type 1 industries. α, in the function of unit labor requirements, is to illustrate the fact that outsourcing makes firms concentrate on producing the advanced part of production, which is skilled-labor-insensitive. Therefore, $\partial a_1^{OW} / \partial\alpha > 0$ and $\partial a_1^{OB} / \partial\alpha < 0$. Again, Southern Firms' unit cost of production is equation (9), which is employed as the numeraire and normalized to one. The Northern Firms that yield instantaneous profits

[8] For simplification, I assume that the firms in industry 1 use the same way they produce advanced production to produce basic production before they become outsourcing firms. The reason is that the adjusting process costs a lot and they know they will outsource their basic production sooner or later.

(30) $$\pi_l^N = \left(1 - AC_l^N \delta\right)E \qquad l = 1, 2,$$

where π_l^N is the profits of Northern Firms in type l industries. Outsourcing Firms in type 1 industries yield the instantaneous profits

(31) $$\pi_1^O = \left(1 - AC_1^O \delta\right)E .$$

For type 1 industries, the reward of a Northern Firm that is successful in the innovation race is

(32) $$V_1^N = \frac{\pi_1^N + \phi\left(V_1^O\right)}{\rho + \phi + r_1}.$$

V_1^O is market value of a Northern Firm in type 1 industries that successfully outsource their basic part of production to the South. It is

(33) $$V_1^O = \frac{\pi_1^O}{\rho + r_1 + \mu}.$$

For industry 2, the reward of a Northern Firm that is successful in the innovation race is

(34) $$V_2^N = \frac{\pi_2^N}{\rho + r_2}.$$

2.2.2.2 Industry Flows and Labor Markets

Assume n_1 and n_2 denote two fractions of type 1 and type 2 industries and the sum of $n_1 + n_2 + n^S$ is one. Letting n^N represent Northern Firms in type 1 industries and n^O denote Outsourcing Firms in type 1 industries, the total fractions constraint is $n^O + n^N + n_2 + n^S = 1$. For simplicity, n_2 is fixed, but n_1 and n^S remain endogenous. In the steady state, for the fraction of both Northern and Outsourcing Firms to remain constant, the inflow of Northern Firms or Outsourcing Firms in type 1 industries must be equal to the outflow in type 1 industries. Since Northern Firms capture production from Southern Firms at a rate $r_1 n^S$ and transfer into Outsourcing Firms at a rate ϕn^N, equation (14) now becomes

(35) $$r_1 n^S = \phi n^N$$

and equation (15) remains the same.

The supply of scientists equals the demand for R&D departments across firms in each industry. That is,

(36) $$n^S a_1^r r_1 + n_2 a_2^r r_2 = L_N^H.$$

The fixed supply of Northern white-collar and blue-collar workers equals the demand of production of two industries, including Northern and Outsourcing Firms

(37) $$[a_2^{NW}\left(w^N\right)n_2 + a_1^{NW}\left(w^N\right)n^N + (1-\alpha)a_1^{OW}\left(w^N\right)n^O]E\delta = L_N^W$$

(38) $$[a_2^{NB}\left(w^N\right)n_2 + a_1^{NB}\left(w^N\right)n^N + (1-\alpha)a_1^{OB}\left(w^N\right)n^O]E\delta = L_N^B .$$

The labor market in the South is the same as in equations (18) and (20).

2.2.2.3 Steady-State Equilibrium

Some assumptions are helpful to simplify solutions. According to equations (28) and (29), there are two kinds of unit labor requirements in type 1 industries, which complicate the solution. Therefore, this study assumes that the unit labor requirements of Northern Firms in type 1 industries are also affected by α, which means that $a_1^{NW} = a_1^{OW}$ and $a_1^{NB} = a_1^{OB}$. A new generation of products means a higher level of technology. These products need a higher skilled/unskilled-labor input intensity. If an increase in outsourcing enhances the skilled/unskilled-labor ratio of the present generation product, then the next generation will use a higher skilled/unskilled-labor ratio. Therefore, outsourcing affects the unit labor requirements of Northern Firms as well.

To find the steady-state solutions, use equations (15) and (35) and the relation, $n^O + n^N + n_2 + n^S = 1$

(39) $$n^O = \frac{\phi\, r_1\left(1-n_2\right)}{\phi\mu + r_1\left(\mu+\phi\right)}, \quad n^N = \frac{r_1\mu\left(1-n_2\right)}{\phi\mu + r_1\left(\mu+\phi\right)}, \quad n^S = \frac{\phi\mu\left(1-n_2\right)}{\phi\mu + r_1\left(\mu+\phi\right)},$$

where $\partial n^N / \partial r_1$ and $\partial n^O / \partial r_1$ are positive, but $\partial n^S / \partial r_1$ is negative. If an increase in α leads to an increase in r_1, n^N and n^O will increase and n^S will decrease. Using equation (39) in (37) and (38) and solving simultaneously yields total expenditure E

$$(40) \qquad E(w^N;\alpha) = \frac{L_N^W a_1^{NB} - L_N^B a_1^{NW}}{\delta\, n_2 \left(a_2^{NW} a_1^{NB} - a_2^{NB} a_1^{NW}\right)} \ ,$$

and innovation intensity r_1

$$(41) \qquad r_1\left(w^N;\alpha\right) = \frac{\phi\mu\kappa\, n_2}{(1-n_2)\theta - (\phi+\mu)\kappa\, n_2} \, ,$$

where $\kappa = a_2^{NW} L_N^B - a_2^{NB} L_N^W / a_1^{NB} L_N^W - a_1^{NW} L_N^B$ and $\partial r_1 / \partial \kappa >$ 0 and $\theta = \mu + (1-\alpha)\phi$. The influence of w^N and α on r_1 can be seen as the influence of w^N and α on κ. According to the calculation in Appendix A, the impact of w^N and α on E and κ, which are $\partial E/\partial w^N$, $\partial E/\partial \alpha$, $\partial \kappa/\partial w^N$, and $\partial \kappa/\partial \alpha$, depends on the difference of unit labor requirements between these two types of industries. If the unit labor requirements of white-collar workers in type 1 industries is larger than it is in type 2 industries, and unit labor requirements of blue-collar workers in type 1 industries are smaller than it is in type 2 industries, $\partial r_1/\partial w^N > 0$, $\partial E/\partial w^N < 0$ and $\partial E/\partial \alpha > 0$. If the opposite is true, $\partial r_1/\partial w^N < 0$, $\partial E/\partial w^N > 0$ & $\partial E/\partial \alpha < 0$. I refer to the first situation as case I and the second situation as case II. Restating this: in case I, type 1 industries are absolutely white-collar-worker-intensive compared to type 2 industries. In case II, type 1 industries are absolutely-blue-collar-worker-intensive compared to type 2 industries. As for the impact of α on r_1, it can be divided into two effects. The first is called the direct effect, in which α influences r_1 through θ. The second is the indirect effect, in which α influences r_1 through k. The direct effect is positive, but the indirect effect depends on $\partial\kappa/\partial\alpha$, which is negative in case I and positive in case II. Thus, in case II, $\partial r_1/\partial\alpha$ is definitely positive. Even for case I, the effect of w^N on r_1 can offset the indirect effect and the total effect of an increase in α on r_1 can be positive. The next section shows this result.

Concerning the intuition behind the results of $\partial E/\partial\alpha$, if type 1 industries are white-collar-intensive compared with type 2 industries, the cost reduction caused by outsourcing will be smaller than the increased benefit from innovation. Since consumers are willing to pay a higher price for a better quality commodity, expenditures will rise. On the contrary, if type 1 industries are blue-collar-intensive compared with type 2 industries, the effect of cost reduction caused by outsourcing could suppress the effect of innovation. Thus, consumers pay less for the same purchase and reduce their expenditure.

To see the intuition behind $\partial E/\partial w^N$, consider an increase in expenditures, holding w^N constant first. The change encourages Northern Firms to increase production and outsourcing industries to choose a higher level of outsourcing fraction. If type 1 industries, compared to type 2 industries, are white-collar-intensive, the effect of increasing production, which leads to hiring more white-collar workers in both type 1 and type 2 industries, will be offset by the effect of choosing a higher level of outsourcing. Thus, a decrease in w^N can result after an increase in expenditures. On the contrary, if type 1 industries, relative to type 2 industries, are blue-collar-intensive, an increase in expenditures leads to a rising w^N. Furthermore, firms that put more resources in manufacturing products must reduce spending on R&D. Thus, the impact of w^N on E is opposite to the impact on r_1 in each case.

Next, by employing equations (39), (40), and (41), one can transform equations (18) and (20) into two equations, which helps us determine the two relative wages of white-collar workers, w^N and w^S. Transforming equation (18) yields:

$$(42) \qquad L_S^W\left(w^N, w^S; \alpha\right) = a_S^W(w^S)\left[\alpha\, n^O(w^N;\alpha)\delta + n^S(w^N;\alpha)\right]E(w^N;\alpha)\,, \qquad \text{SW}$$

and transforming equation (20) yields:

$$(43) \qquad L_S^B\left(w^N, w^S; \alpha\right) = a_S^B(w^S)\left[\alpha\, n^O(w^N;\alpha)\delta + n^S(w^N;\alpha)\right]E(w^N;\alpha)\,. \qquad \text{SB}$$

Separating $a_S^W(w^S)$ and $\eta\left(w^N\right)$, which represents the remaining variables related to w^N in equations (42) and (43), helps determine the slope of SW and SB. According to Appendix B, $\partial\eta/\partial w^N$ depends on $\partial r_1/\partial w^N$ and $\partial E(w^N)/\partial w^N$. If $\partial E(w^N)/\partial w^N$ is negative and $\partial r_1/\partial w^N$ is positive, as in case I, $\partial\eta/\partial w^N$ is negative. When w^N increases, w^S must decrease to restore equilibrium in equation (42), which leads to a downward-sloping line SW. Similarly, line SB is upward-sloping in case I. If $\partial E(w^N)/\partial w^N$ is positive and $\partial r_1/\partial w^N$ is negative, as in case II, $\partial\eta/\partial w^N$ is positive. The SW line is upward-sloping and the SB line is downward-sloping. When lines SW and SB are combined, one determines the equilibrium relative wages of white-collar workers in the North and South, w^N and w^S. Figure 4-1 and 4-2 illustrate the steady-state equilibrium levels, w^{N*} and w^{S*}, which occur at the intersection of SW and SB. Note that this equilibrium differs from that of the homogenous firm model in 2.1, and the relative wages of white-collar workers in the North and South are now determined by the outsourcing fraction.

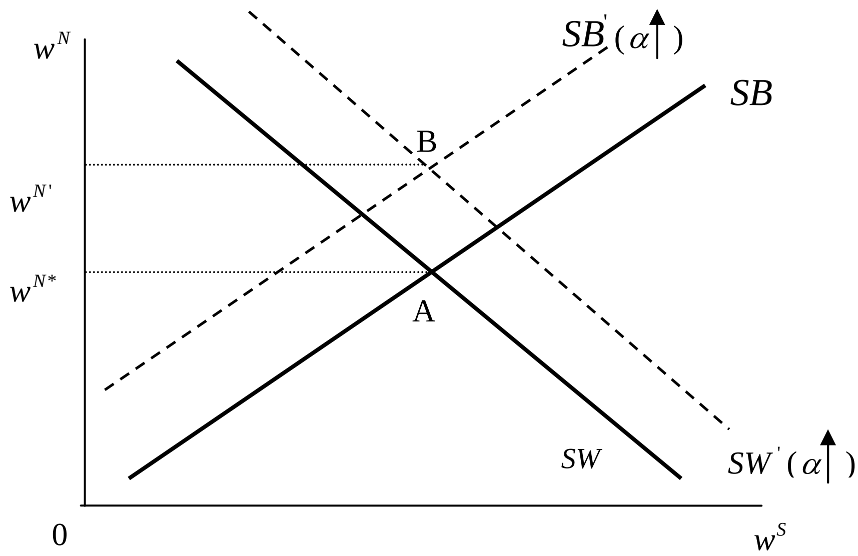

Figure 4-1. Relative Wages of White-Collar Workers
in the North and the South (case I)

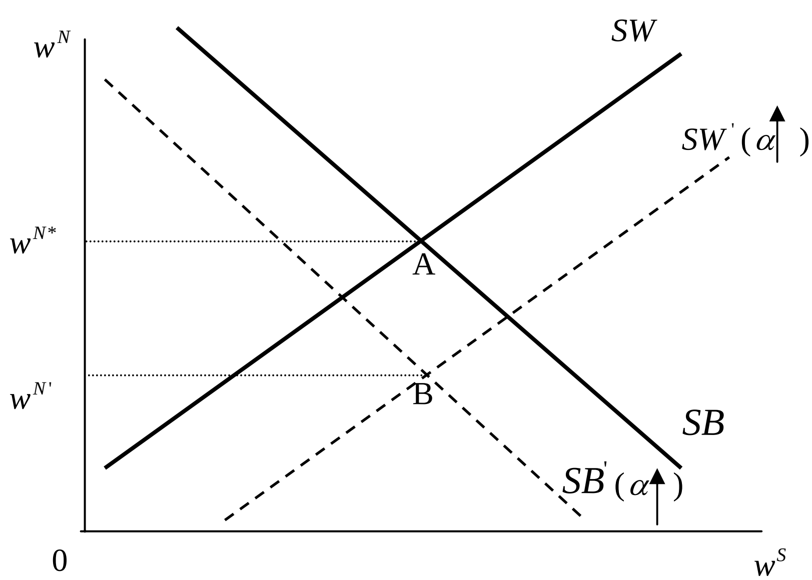

Figure 4-2. Relative Wages of White-Collar Workers
in the North and the South (case II)

The resource constraint (36) is used to solve r_2 in terms of r_1

(44) $$r_2 = \frac{L_N^H}{a_2^r n_2} - \frac{a_1^r}{a_2^r} * \frac{n^S}{n_2} r_1 = \gamma(r_1),$$

where $\partial\gamma/\partial\alpha$ is negative due to the limited quantity of high-skilled technology labor. If type 1 industries increase intensity of R&D and hire more high-skilled technology workers, it will force type 2 industries to decrease the intensity of their R&D. Using w^{N*} into equation (32) and substituting r_2 with $\gamma(r_1)$ yields

(45) $$\frac{E^*\omega}{(\rho + r_1^* + \phi)a_1^r} - \frac{E^*\delta\left[(r_1^* + \mu + \rho)C_1^{N*} + \phi\, C_1^{O*}\right]}{(r_1^* + \mu + \rho)(\rho + r_1^* + \phi)\,a_1^r} w_N^W = w^H ,$$ [9] H1

(46) $$\frac{E^*}{(\gamma^* + \rho)a_2^r} - \frac{E^*\delta\left(C_2^{N*}\right)}{(\gamma^* + \rho)\,a_2^r} w_N^W = w^H$$ H2

where $C_l^{N*} = C_l^N\left(w^{N*}\right)/w_N^W$ and $C_l^{O*} = \left(C^O\left(w^{N*}\right) - \alpha\right)/w_N^W$ for type l industries, which are functions of w^{N*}. By naming equation (45) and (46), which represent the relationship between innovation and production, H1 and H2, both H1 and H2 state the negative relationship between w^H and w_N^W under the equilibrium level and the intersection of these two lines gives the equilibrium levels of w^{H*} and w_N^{W*}.

According to Appendix C, there are two possible equilibria. The first is that the H1 line has a larger intercept and a steeper slope than the H2 line. The second one is that

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[9] ω stands for $\rho + r_1 + \mu + \phi / \rho + r_1 + \mu$ in this equation. And, since $\partial\omega/\partial r_1 < 0$, it can be treated as a constant and doesn't affect our analysis.

the H2 line has a larger intercept and a steeper slope than the H1 line. However, only one of these two equilibria is stable. The reason is as follows. Between these two types of industries, type 1 industries are leaders, since type 1 industries can use α to reduce cost, which leads to changes in the wages of white-collar workers and blue-collar workers. On the contrary, type 2 industries, which do not have the strategic ability, are followers. Starting with the case where H1 has a larger intercept and steeper slope, in Figure 5, under w_1^H type 1 industries would like to pay white-collar workers w_1^W. Type 2 industries can only offer w_2^H under w_1^W. Therefore, firms in type 1 industries can hire scientists at w_2^H and increase their production by hiring more workers, which raises the wages from w_1^W to w_2^W. Under w_2^W, to hire scientists type 2 industries can only offer w_3^H. Since w_3^H is lower than the willingness-to-pay for hiring scientists of firms in type 1 industries, they can expand their production until attaining the equilibrium wages.

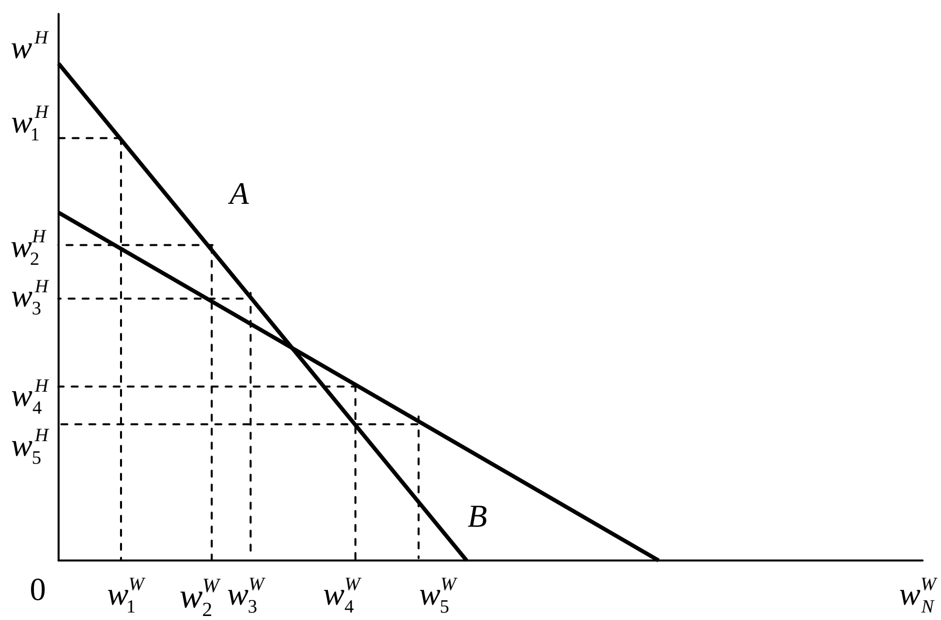

Figure 5. The Stability of Northern Wages of Scientists and White-Collar Workers

Starting from the other side in Figure 5, under w_5^W, type 2 industries are willing to pay w_5^H, which is much higher than the offering wages of type 1 industries. To compete with type 2 industries, type 1 industries need to reduce wage expenditures from w_5^W to w_4^W. Under w_4^W, type 1 industries are willing to pay w_5^H, which is still lower than the willingness-to-pay of type 2 industries. Type 1 industries again need to reduce their production costs. The wages of white-collar workers will continue to decrease and the wages of scientists will continue to increase, until the wages reach equilibrium. The equilibrium formed by H1, with a larger intercept and steeper slope and H2, with a smaller intercept and flatter slope, is stable.

Conversely, if H2 has a steeper slope and higher intercept (line A) than H1 (line B), the equilibrium located at the intersection of H1 and H2 is not stable. To see this, starting with w_2^W, type 1 industries are willing to pay w_3^H, but type 2 industries are willing to pay w_2^H. In order to compete with type 2 industries, type 1 industries need to reduce the wages of white-collar workers from w_2^W to w_1^W. However, under w_1^W, type 2 industries are willing to offer w_1^H, which induces type 1 industries to adjust outsourcing fraction more and the equilibrium will never be attained.

Figure 6 illustrates the equilibrium level of w^H and w_N^W at the intersection of H1 and H2. The equilibrium level of blue-collar workers in the North is equal to w_N^{W*} / w^{N*}. Finally, the determination of equilibrium levels of wages of white-collar workers and blue-collar workers in the South is the same as in the discussion in 2.1.3.

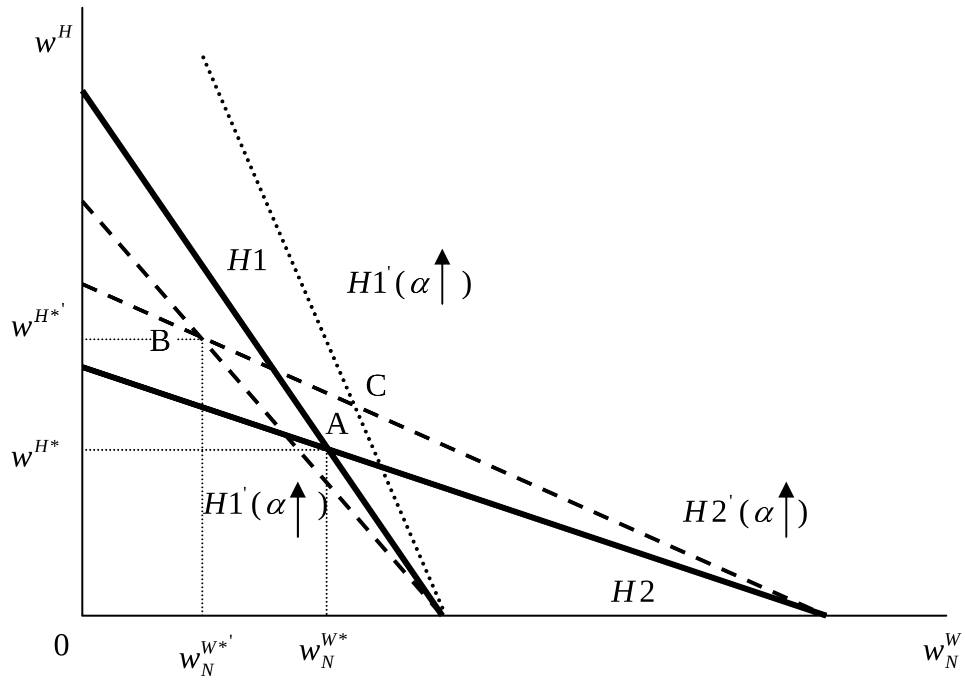

Figure 6. The Changes of Northern Wages of Scientists and White-Collar Workers

2.2.2.4 Comparative Static Analysis

When type 1 industries increase the outsourcing fraction of production to the South, it will increase the labor demand of both Southern white-collar and blue-collar workers. For a given w^N, the increasing demand of white-collar workers will push the relative wage of white-collar workers in the South to a higher level. Therefore, the SW line will shift to the right. On the other hand, the increasing demand for blue-collar workers decreases the relative wage of white-collar workers in the South. Therefore, line SB shifts to the left. The change in relative wage of white-collar workers in the North depends on the slopes of lines SW and SB. In case I, the change in α makes the equilibrium of the relative wage of Northern white-collar workers increase unambiguously (from point A to B in Figure 4.a.). This case is much like the solution of

Sayek and Sener (2006), in which they use this case to explain the wage inequality between skilled labor and unskilled labor caused by outsourcing. The wage gap could be even larger if scientists also benefit from outsourcing or smaller if scientists do not benefit from outsourcing. In case II, an increase in α decreases the equilibrium of the relative wage of Northern white-collar workers (from point A to B in Figure 4.b.).

The results above tell us that if outsourcing firms, compared to non-outsourcing firms, are white-collar-workers-intensive, outsourcing will raise the relative wage of white-collar workers and cause wage inequality. Conversely, if outsourcing firms, compared to non-outsourcing firms, are blue-collar-intensive, outsourcing will not cause the deterioration of blue-collar wages. The intuition behind this result is as follows. There are three effects of outsourcing on labor demand. The first one is the substitution effect. This effect, caused by outsourcing industries shifting labor demand from the North to the South, decreases the labor demand of both white-collar and blue-collar workers. The second is the skill effect. The skill effect can increase labor demand of white-collar workers since outsourcing pushes Northern and Outsourcing Firms toward skilled-labor-intensive production. The third is the scale effect. Outsourcing can increase the profit of outsourcing firms, which leads to increased production. Therefore, the labor demand, especially the labor used intensively by outsourcing firms, will increase as well. Thus, after an increase in α, if the total effect of the skill effect and scale effect are larger than the substitution effect, as in case I, the relative wage of Northern white-collar workers will increase. On the other hand, if the total effect of the skill effect and scale effect are smaller than the substitution effect, as in case II, outsourcing will decrease the relative wage of Northern white-collar workers.

After determining the relative Northern wage, w^N, I can investigate the change in the innovation intensity of type 1 industries. In case I, an increase in α raises r_1 by the direct effect and reduces r_1 by the indirect effect. However, if the negative indirect effect caused by an increase in α on r_1 can be offset by the effect of increasing w^N, the total effect of α on r_1 in case I is positive. Considering the influence of α on unit labor requirements of production is greater than or equal to the influence of w^N on unit labor requirements of production,[10] Appendix A.3 shows that in case 1, the negative indirect effect caused by an increase in α on r_1 will be offset by the effect of increasing w^N. This means an increase in α raises innovation intensity of type 1 industries and increases the fraction of Northern Firms and Outsourcing Firms. It decreases the fraction of Southern Firms.

To determine the change of w^H and w_N^W, I need to examine equations (45) and (46). In case I, an increase in α raises E and r_1, but reduces the unit cost of outsourcing firms. Meanwhile, the rising w^N will diminish E, increase the innovation intensity of type 1 industries, and reduce the innovation intensity of type 2 industries. According to equation (45), since total effects of an increase in α on E are negative, which is always smaller than the positive total effects of an increase in α on r_1, the intercept of H1 will decrease and the slope becomes flatter. The movement of H2 is the opposite. Since r_2 is decreasing, according to equation (46), the intercept of H2 will be larger and the slope becomes steeper. The new H1 and H2 yield a higher level of equilibrium w^H unambiguously. As for w_N^W, to get a positive w_N^W, it not only requires that the total of the skill effect and the scale effect dominate the substitution effect, but it also requires that the cost reduction caused by outsourcing is sufficient. According to Appendix D, if the condition w_N^W is not satisfied, the equilibrium moves from point A to B in Figure 6. If the condition w_N^W is satisfied, the intercept of H1 will increase and the slope can be steeper and the intersection of H1 and H2 results in higher equilibrium levels of both w^H and w_N^W. The movement from point A to C in Figure 6 illustrates this result.

Proposition 2. If outsourcing industries are white-collar-intensive relative to

[10] It is reasonable since that the impact from outsourcing on labor demand is more direct than the one from the relative wage.

non-outsourcing industries, an increase in the outsourcing fraction of production will increase scientists' wages unambiguously. The wage level of white-collar workers can be increased or decreased. Blue-collar workers' wages relative to skilled workers in the North, will decrease unambiguously.

Under the circumstances of case II, an increase in α will diminish E, but still increase r_1 and reduce the unit cost of outsourcing firms. Meanwhile, the falling relative Northern wage w^N will increase the innovation intensity of type 1 industries, but reduce E and the innovation intensity of type 2 industries. Thus, even though the relative wage of white-collar workers in the North decreases, r_1 is still increasing and E is still decreasing. This leads to the increasing fraction of Northern Firms and Outsourcing Firms and the decreasing fraction of Southern Firms. According to equations (45) and (46), the change of H1 and H2 are still from point A to point C in Figure 6. The wages of blue-collar workers may rise or fall after an increase in α, as the relative wage of white-collar workers is increasing. Table 1 is the summary of the comparative Static Analysis under an increase in outsourcing.

Proposition 3. If outsourcing industries relative to non-outsourcing industries are blue-collar-workers-intensive, an increase in the outsourcing fraction of production will increase scientists' wages and decrease white-collar wages in the North unambiguously. The wage of blue-collar workers in the North may not deteriorate.

As for Southern workers, since I simplify the setting of unit labor requirements between Outsourcing Firms and Southern Firms in the South, there will be no effect on the relative wage of white-collar workers or wage levels of either white-collar or blue-collar workers in the South after an increase in α.[11] From equation (39) and the discussion of equation (39), I know that if r_1 increases, both n^N and n^O are increasing, but n^S is decreasing. The extent of international outsourcing will definitely increase because both α and n^O are increasing.

Table 1. Summary of Possible Situations and Comparative Static Analysis Results

	Case I		Case II
	$a_1^{NB} < a_2^{NB}$ & $a_1^{NW} > a_2^{NW}$		$a_1^{NB} > a_2^{NB}$ & $a_1^{NW} < a_2^{NW}$
	$\frac{\partial E}{\partial w^N} < 0;\ \frac{\partial E}{\partial \alpha} > 0;\ \frac{\partial r_1}{\partial w^N} > 0$		$\frac{\partial E}{\partial w^N} > 0;\ \frac{\partial E}{\partial \alpha} < 0;\ \frac{\partial r_1}{\partial w^N} < 0$
	$f\left(\frac{\partial E}{\partial w^N} + \frac{\partial E}{\partial \alpha} + \frac{\partial AC_1}{\partial \alpha}\right) < g\left(\frac{\partial r_1}{\partial w^N} + \frac{\partial r_1}{\partial \alpha}\right)*$	$f\left(\frac{\partial E}{\partial w^N} + \frac{\partial E}{\partial \alpha} + \frac{\partial AC_1}{\partial \alpha}\right) > g\left(\frac{\partial r_1}{\partial w^N} + \frac{\partial r_1}{\partial \alpha}\right)*$	$f\left(\frac{\partial E}{\partial w^N} + \frac{\partial E}{\partial \alpha} + \frac{\partial AC_1}{\partial \alpha}\right) < g\left(\frac{\partial r_1}{\partial w^N} + \frac{\partial r_1}{\partial \alpha}\right)*$
w^N	↑	↑	↓
w^H	↑	↑	↑
w_N^W	↓	↑	↓
w_N^B	↓	↓	↑ or ↓

"*" stands for condition w_N^W in Appendix D.

w^N : The relative wage of white-collar workers in the North.

w^H : The wage of scientists.

w_N^W : The wage of Northern white-collar workers.

w_N^B : The wage of Northern blue-collar workers.

[11] These results can be verified by a simple comparative static. If one sets up a model with different unit labor requirements between Outsourcing Firms in the South and Southern Firms, the change of relative wage of white-collar workers in the South will change, depending on the whose unit labor requirements are higher. Sayek and Sener (2006) can illustrate this idea.

2.3 Concluding Remarks

The argument of whether outsourcing causes wage deterioration for unskilled labor has been much supported by the new evidence proposed by Feenstra and Hanson (1996;1999). In their papers, outsourcing can explain 30.9% of the increase in the non-production wage share and 15% of the increase in the relative wage of non-production workers from 1979 to 1990. The empirical results of 1972-1979, however, are completely different from those for 1979-1990 and seem to contradict the concepts of the outsourcing theory.

In this chapter, a dynamic product cycle model with three kinds of labor inputs, scientists, white-collar workers, and blue-collar workers, is constructed. It is shown that only scientists unambiguously benefit from outsourcing. Other skilled laborers are hurt by outsourcing. After relaxing the assumption of homogenous producers, if outsourcing industries, compared to non-outsourcing industries, are absolutely white-collar-intensive, an increase in the outsourcing fraction will raise the relative wage of white-collar workers. If outsourcing industries, compared to non-outsourcing industries are absolutely blue-collar-intensive, an increase in the outsourcing fraction will decrease the relative wage of white-collar workers.

The wage level of white-collar laborers can be increased by outsourcing if the total effect of the skilled effect and the scale effect dominates the substitution effect, and the cost reduction caused by outsourcing is sufficient. The wage level of blue-collar workers may rise after an increase in outsourcing if outsourcing industries, compared to non-outsourcing industries are absolutely blue-collar-intensive.

CHAPTER III
OUTSOURCING, INNOVATION, AND WAGE INEQUALITY IN THE UNITED STATES: WHAT HAPPENED TO THE OUTSOURCING EFFECT ON WAGE INEQUALITY IN THE 1970S?

3.1 Introduction

Jones (2005) proposes an idea that argues outsourcing could raise the wage of unskilled labor relative to skilled labor. This new idea contradicts traditional thinking about outsourcing. If what Jones (2005) proposes is true, then the phenomenon in the 1970s is part of the impact of outsourcing on wages. A fitting question to the puzzle is, what makes the difference? What factor causes outsourcing to have different influences on relative wages? The answer to that question is the primary focus of this chapter.

Further, if outsourcing does decrease the relative wage of skilled labor, I investigate this issue by two additional questions: first, did all skilled labor's wages decrease because of outsourcing? Second, is the decreased relative wage of skilled labor to unskilled labor caused by increasing wages of unskilled labor or decreasing wages of skilled labor?

The first question comes from the belief that outsourcing, which pushes production toward skilled labor, should benefit skilled labor the most. Even though the impacts of outsourcing somehow change and parts of skilled laborers do not benefit from outsourcing, parts of them should still benefit. In Grossman and Helpman's (1991) quality ladders and product cycles model, a new generation of products is innovated in developed country, the North. After the production of this new product is mature, the producers in a developing country, the South, can imitate the state-of-the-art technology and learn the production processes. Glass and Saggi (2001) extend Grossman and Helpman's (1991) model by considering outsourcing. Before Southern producers learn the technology, entrepreneurs in the North can outsource part of production to the South to arbitrage the wage difference between these two countries. One of their findings is that outsourcing can increase firms' innovation intensity. Therefore, if the skilled workers who conduct research and development (R&D) are different from the skilled workers in manufacturing production, outsourcing may have a different impact on these two groups of skilled workers. This study will decompose skilled workers into two groups, one of them working for inventing new products and the other working for manufacturing production. If the increasing profit caused by outsourcing leads to higher wages of R&D workers, I expect to see a positive and significant effect on workers' wages even in the 1970s.

For the second question, knowing the impacts of outsourcing on the relative wage is not enough. A rising relative wage of unskilled workers to skilled workers could mean either wages of unskilled worker were increased or decreased. The two-stage regression proposed by Feenstra and Hanson (1999) can answer this question.

Section II is the theoretical discussion in which I borrow the framework of international fragmentation from Jones and Kierzkowski (2001) and Jones (2005) to find possible explanations for the outsourcing puzzle. In Section III, I investigate which explanation found in Section II is supported by U.S. manufacturing data. Then I employ regression estimation to check the influence of structural variables, including outsourcing on workers' wages. As discussed above, I consider three kinds of labor. However, most data sources sort labor into two groups: skilled/unskilled or production/non-production. I decompose the skilled-labor data to separate out a R&D workers. Having done that, simple wage regressions of R&D workers can help us to check whether they always benefit from outsourcing. The two-stage regression is employed to answer the second question in this section. Section IV presents the conclusions.

3.2 Theoretical Framework

In this section, I employ the idea of international fragmentation, which was proposed by Jones and Kierzkowski (2001) and Jones (2005) to explain the impact of outsourcing on wage inequality. To simply demonstrate the story of Jones and

Kierzkowski (2001) and Jones (2005) in discussing wage premiums, I assume that there are two productive factors, skilled labor (S) and unskilled labor (U), in this economy. Industries' owners employ both kinds of labor to produce two fragments of production, a skilled-labor-intensive fragment and an unskilled-labor-intensive fragment. In Figure 1, for example, to produce $1 worth of final good B requires both skilled-labor-intensive fragment $\overline{0E}$ and unskilled-labor-intensive fragment $\overline{0D}$. The price of the fragment can not be observed since they are non-tradable, but based on the factor price, $\overline{0G}$ and $\overline{0F}$ can show us the input requirement to produce $1 worth of component. Therefore, the slope of $\overline{FG}$ reflects the wage of unskilled labor relative to skilled labor in this country. After an improvement of international communication and transportation, those fragments become internationally tradable. A skilled-labor-abundant country will outsource their unskilled-labor-intensive fragment to a developing country and concentrate on producing the more competitive, skilled-labor-intensive segment. In Figure 7, if the fragments of B commodities can be traded internationally, the producer of commodity B will forgo unskilled-labor- intensive production $\overline{0D}$ and produce skilled-labor-intensive fragment $\overline{0H}$. $\overline{0H}$ is shorter than $\overline{0F}$, which means that this country has an advantage in producing the skilled-labor-intensive good and the price of this fragment increases after outsourcing.

Concerning wage premiums, if the endowment ratio is the ray labeled λ_1, international trade with fragments will deteriorate the relative wage of unskilled labor relative to skilled labor. If a country has a sufficiently high endowment ratio, like the ray labeled λ_2, the wages of unskilled labor relative to skilled labor will increase after outsourcing. Jones (2005) uses this case to explain the idea that international trade with fragmentation or outsourcing in a specific condition can benefit unskilled labor.

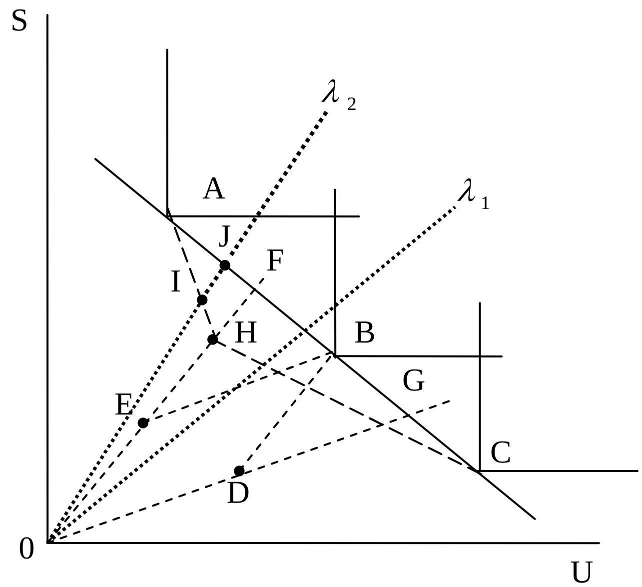

Figure 7. Hicksian Unit-Value Isoquant with Outsourcing

This result contradicts conventional thought about the effects of outsourcing on unskilled labor. An easy explanation provided by Jones and Kierzkowski (2001) is that, because the price of higher skilled-labor-intensive commodity A does not change, the price of skilled labor must decrease after outsourcing the fragment of commodity B. Jones (2005) uses another explanation that focuses on the employment fraction. After outsourcing, the fraction of the unskilled labor that is employed in the skilled-labor-intensive fragment (AI/AH) is greater than that employed in commodity B (AJ/AB). Therefore, when the endowment ratio is high enough, outsourcing creates more hiring of unskilled labor than skilled labor.

From Figure 7, it can also be seen that if commodity C is the product which can outsource its relatively unskilled-labor-intensive fragments, it will be easier to find an endowment ratio to satisfy the condition that outsourcing can benefit unskilled labor. Therefore, it seems that outsourcing industry’s skilled/unskilled-labor ratio also matters. To see this, this chapter simplifies the framework of Jones and Kierzkowski (2001) and Jones (2005) to a model with only two products. One of them is a relatively skilled-labor-intensive commodity (product A) and the other is a relatively unskilled-labor-intensive commodity (product B). Suppose only one of them is willing to or able to outsource its segment to the other countries. First, if the only one commodity is product A and the producer of product A starts concentrating on producing its relative skilled-labor-intensive segment, the Hicksian composite unit-value isoquant becomes the broken solid line $\overline{ECBF}$ in Figure 8. If the only product that can trade its segment is product B, the Hicksian composite unit-value isoquant will become line $\overline{EADF}$ in Figure 8.

The α cone in Figure 8 tells us where the possible endowment ratio can be. It can be seen that only when the outsourcing industry is relatively unskilled-labor-intensive, outsourcing can benefit unskilled labor.[12] Furthermore, if I divide all possible endowment ratios into two areas according to the slope of the unit-value isoquant, only area I in Figure 8 can raise the wages of unskilled labor relative to skilled labor after outsourcing. In other words, in the case that the endowment ratio is not high enough, even though the outsourcing industry is relatively unskilled-labor-intensive, it is possible that outsourcing benefits skilled labor.

[12] Jones (2005) points out that this result also illustrates a common proposition in the theory of international trade that technical progress in a country’s labor-intensive activity improves the country’s real wage rate.

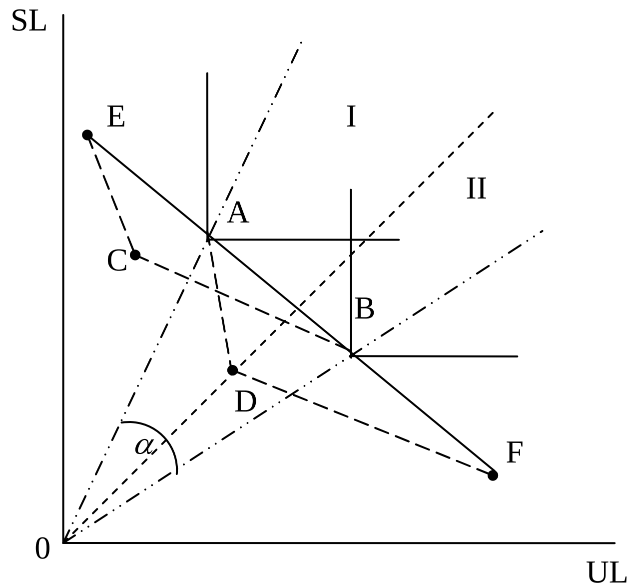

Figure 8. Different Hicksian Unit-Value Isoquant under
Different Types of Outsourcing Products

In sum, according to the theoretical prediction, there are two possible explanations for the different effects of outsourcing on wage inequality in the 1970s and 1980s. The first is the move of endowment in the skilled/unskilled-labor ratio. It means that, ceteris paribus, the difference in endowment of the skilled/unskilled labor ratio causes the different effects of outsourcing on unskilled labors' wages relative to skilled labor. In other words, during the 1970s the skilled/unskilled ratio in the United States was high enough for outsourcing to benefit unskilled labor, but it was not during the 1980s. The second explanation is that the difference in wage effects caused by outsourcing between the 1970s and 1980s was mainly generated by the shift of the structure of employment in the outsourcing industry. In the 1970s, the outsourcing industry was relatively unskilled-labor-intensive and in the 1980s it was skilled-labor-intensive. If the first prediction is right, one should see a decreasing endowment ratio from 1970 to 1990. If the second explanation is appropriate, one should find that the outsourcing goods were produced mainly by relatively unskilled-labor-intensive industries in the 1970s, and produced by relatively skilled-labor-intensive industries in the 1980s. I name the first explanation “endowed explanation” and the second explanation “labor-intensity explanation.” In the next section, the empirical data will be examined to determine which factor causes the different impacts of outsourcing on relative wage.

Those explanations, however, could still be challenged by the thinking of outsourcing as a technological improvement. Another interpretation is needed to explain why a technological improvement decreased skilled labor’s wages. This chapter considers that perhaps some skilled workers did benefit from outsourcing in the 1970s, but most of them did not benefit. In other words, the skilled labor in the theoretical model may not represent all “skilled labor.” They are a parts of skilled labor that might be hurt by outsourcing. Naturally the question is, “which workers?” following the discussion in Section I, the beginning of the life of a commodity with a brand new state-of-the-art technology first needs some innovation work. Then, if the producer wins the innovation competition, the product can be sold in North and South markets. Therefore, I can break the whole production procedure into two parts. The first part is to invent a new technology and the second is to produce it. By assuming that skilled workers working in the Innovation Department are separated from workers working in the Production Department, outsourcing may cause different effects on their labor demand. Glass and Saggi (2001) find that outsourcing increases the innovation intensity. Thus, in the 1970s the skilled workers in the Innovation Department benefited from outsourcing, even though the rest of skilled labor were harmed by outsourcing. This idea will be tested empirically in the next section.

3.3 Empirical Evidence

3.3.1 Tests of the Theories

To test which explanation in the last section best explains the impact of outsourcing during the 1970s and 1980s, this study will employ data from manufacturing industries of the United States to test these two explanations. The NBER Productivity

Database [Bartelsman and Gray, 1996] can provide the information. Starting with endowment explanation, drawing the U.S. non-production/production-labor ratios from 1970 to 1990 can see the change during these two decades. In Figure 9, the answer to the question of whether the first explanation is supported by the data of the United States is doubted. It can be seen that the employment ratio of non-production workers relative to production labor keeps going up from 1970 to 1990. It may not be sensible to think that the relative wage of skilled labor did not increase by outsourcing in the 1970s is due to the shifting employment ratio. Therefore, I move on to testing the second explanation.

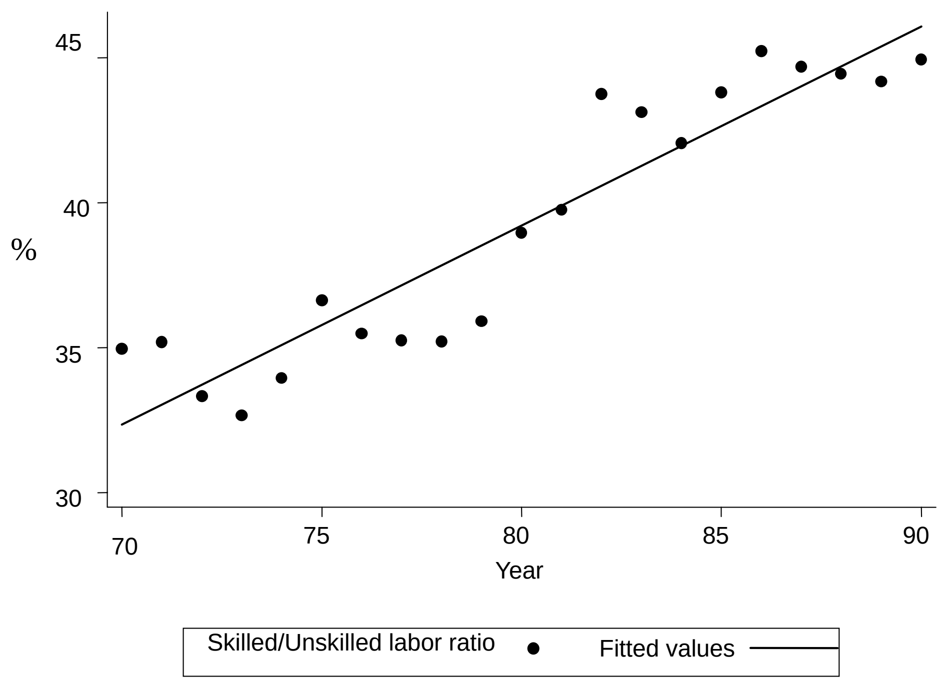

Figure 9. Skilled/Unskilled Labor Ratio in the U.S. Manufacturing Industries: 1970-1990

In the second explanation, two industries are distinguished by their skilled/unskilled-labor ratios. This study sorts all manufacturing industries' non-production/production-labor ratio from lowest to highest, and simply divides them into two groups.[13] By naming the first 50% of all manufacturing industries relatively unskilled-labor-intensive industries (hereafter RU industry), and the rest of them relatively skilled-labor-intensive industries (hereafter RS industry), and by letting the industry that outsources more of its part of production than the other does be the relatively outsourcing industry, this study can compute the weighted average outsourcing fraction of each group to check which one of them is relatively an outsourcing industry.

Feenstra and Hanson (1996; 1999) propose a new method to estimate outsourcing, which is constructed by outsourcing intermediate-material purchases divided by total consumption. Material purchase data comes from the Census of Manufactures and is collected every five years in those years ending with 2 and 7. Therefore, outsourcing data are available in 1972, 1977, 1982, 1987, and 1992, during 1970 to 1992. Feenstra and Hanson (1996) kindly provide us with intermediate-material purchase data. I can compute the outsourcing fraction of each manufacturing industry by using their data and U.S. imports data captured from the NBER collection.[14] According to Feenstra and Hanson (1999), outsourcing can be measured in two ways. The broad measure of outsourcing considers all industries' inputs purchased from other four-digit SIC manufacturing industries and the narrow measure of outsourcing considers only the industries' inputs purchased from the same two-digit SIC industries. Both types of outsourcing are considered when I compute weighted average outsourcing fractions.

Table 2 lists all weighted averages of the skilled/unskilled-labor ratio and outsourcing fractions of both the RS industry and the RU industry in the years 1972, 1977, 1982, 1987, and 1992.[15] According to the numbers of weighted averages of skilled/unskilled-labor ratio, the difference of skilled-labor intensity between the RS industry and the RU industry increases over the same period. The skilled/unskilled-labor ratio of the RS industry in 1992 is almost one-and-a-half times larger than in 1972. The skilled/unskilled-labor ratio of the RU industry only grows a little from 1972 to 1992. In

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[13] After sorting and drawing the data, it can be seen that there is a smoothing increasing curve. Thus, a workable and clear way to divide them in groups is to separate them as in the theoretical analysis in the Section 2.

[14] Please see Feenstra and Hanson (1996) regarding the formula for computing outsourcing.

[15] Both weighted fractions and ratios are weighted by industries' share of total manufacturing shipments.

general, although the numbers in the broad measure are larger than the narrow measure, the two measures tell the same story about the RS and RU industry during these two decades.

Table 2. Comparison of Weighted Outsourcing Fraction in Different Types of Industries

Year	Weighted skilled/unskilled Labor ratio		Weighted outsourcing fraction -narrow measure		Weighted outsourcing fraction -broad measure	
	RS industry	RU industry	RS industry	RU industry	RS industry	RU industry
72	59.76	19.44	2.02	2.48	4.86	5.92
77	63.00	21.00	2.74	2.49	6.72	6.44
82	73.28	24.68	3.80	2.37	8.50	7.15
87	84.12	23.87	5.19	4.44	12.36	10.09
92	86.53	24.12	7.49	5.38	14.18	11.39

Notes: RS industry is Relative-Skilled-labor-intensive industry. RU industry is Relative-Unskilled-labor-intensive industry. All ratios and fractions are computed over 445 four-digit SIC industries (excluding 2067, 2794, and 3483) and weighted by the industry share of total manufacturing shipments.

According to Table 2, the RU industry has a larger outsourcing fraction only in 1972. After 1972, outsourcing predominantly occurs in the RS industry and its outsourcing fraction increases rapidly. The RU industry's outsourcing fraction rises as well, but at a slower rate than the RS industry, regardless of the measure used. My explanation to this point is lacking. Based on the data in Table 2, outsourcing had already become predominant in the RS industry by 1977. However, the methodology is problematic if the outsourcing industry outsources the basic part of production that is performed by unskilled labor. The weighted skilled/unskilled-labor ratio computed in the first column of Table 2 can only represent the skilled/unskilled-labor ratio of the RS and RU industry in base years, 1972 and 1982. After an increase in outsourcing, the skilled/unskilled-labor ratio will be higher since the basic part of production has already been outsourced to the South. Thus, some industries in the RS industry in 1977 could be part of the RU industry in 1972. Table 3 illustrates the same thing as Table 2 but is based on the skilled/unskilled-labor ratio from five years ago when I split them into the RS/RU industry. In 1977, the weighted outsourcing fraction of the RU industry was greater than the fraction of the RS industry. After 1982, the results are similar to those in Table 2; the

RS industry's outsourcing fraction was greater than the RU industry no matter what measure of outsourcing I use. Thus, I can say that the outsourcing industry was the RU industry in the 1970s and was the RS industry in the 1980s, and the labor-intensity explanation is more sensible to explain the different influences caused by outsourcing between the 1970s and 1980s.

Table 3. Comparison of Weighted Outsourcing Fraction in Different Types of Industries -Based on the Rank 5 Yrs. Ago

Year	Weighted skilled/unskilled labor ratio		Weighted outsourcing fraction -narrow measure		Weighted outsourcing fraction -broad measure	
	RS industry	RU industry	RS industry	RU industry	RS industry	RU industry
77	60.75	20.89	2.52	2.78	6.46	6.79
82	72.85	25.18	3.57	2.75	8.35	7.39
87	83.05	24.49	5.72	3.71	12.44	9.95
92	86.38	24.37	7.41	5.49	14.18	11.40

Notes: RS industry is Relative-Skilled-labor-intensive industry. RU industry is Relative-Unskilled-labor-intensive industry. All ratios and fractions are computed over 445 four-digit SIC industries (excluding 2067, 2794, and 3483) and weighted by the industry share of total manufacturing shipments.

Although Figure 9 and Tables 2 and 3 help us understand that the labor-intensity change in the outsourcing industry caused the different influence of outsourcing on wages in the 1970s and 1980s, this issue still needs more evidence and empirical results to realize the full effect of outsourcing on wage inequality. In the next step, I answer the following two questions, first, did outsourcing worsen all skilled workers' wages in the 1970s? and second, was the decreasing relative wage of skilled labor caused by decreasing the wage level of skilled workers or increasing the wage level of unskilled workers? In the next section, I address these two questions through regression estimation.

3.3.2 Regression Estimations

As discussed in the last chapter, a life cycle of a product starts with innovation. After winning the innovation competition, the product can be produced and sold. Thus, the influence of outsourcing on a manufacturing industry can be split into two parts. First, outsourcing increases R&D intensity and also raises R&D workers' wages. Second, outsourcing improves the productivity and the improvement makes the prices of commodities and relative wage of white-collar workers change. This study will verify the first statement by wage regression estimation and employ two-stage regression to deal with the second issue. This study needs data which have two groups of skilled labor; those in the Production Department, such as managers and secretaries, and those in the Innovation Department. The procedure of construction new data is introduced in the next.

3.3.2.1 Data Construction and Decomposition

According to the National Science Foundation (NSF), R&D is mainly done by R&D workers, who are scientists and engineers, and supporting personnel, like technicians and craftsmen.[16] Although NSF can provide the wage cost and employment of R&D in each two or three-digit industry from 1953, their data still can not be employed in this study. First, even though NSF can provide us the number of full-time-equivalent (FTE) scientists and engineers by industry, NSF has not separated wage data of scientists and engineers and supporting personnel since 1976. This makes the wages of R&D workers unknown. Second, to avoid possible disclosure of information about operations of individual companies, some industries' data are being withheld for a few years. Thus, this study has to employ another data source to decompose skilled labor.

Current Population Survey (CPS) data provide the information this study needs about the workers in the United States, including occupation, industry, and wage income. The occupation information can be employed to distinguish R&D workers and other skilled workers. In addition, March CPS data since 1976 can tell us how many weeks the respondent worked last year and how many hours they usually worked in a week in the last year. The product of these two can be seen as working-hour data. The NBER

[16] Their definition of scientists and engineers are those persons employed by the company who are engaged in scientific or engineering work at a level that requires knowledge of physical, life, engineering, or mathematical science equivalent. Please refer to NSF website for details.

Productivity Database includes the value of shipment, price deflator for value of shipments, number of employees, number of production worker hours, and number of production workers of 445 industries in the 1972 four-digit SIC.[17] Since the NBER Productivity Database has all the information this study needs about industries in the United States except the separated information of workers in Innovation and the Production Department, this study employs CPS data as an auxiliary data source to decompose non-production workers in the NBER Productivity Database. However, there are some data consistency issues that need to be dealt with before performing the decomposition.

First, the production/non-production data in the NBER Productivity Database comes from the Annual Survey Manufactures (ASM), and its production/non-production classification may not be the same as the white-collar/blue-collar classification in CPS. Berman, Bound, and Griliches (1994) compared CPS data with ASM data and found that these two categories are similar in that they rose together from 1973 until 1987 with the discrepancy never more than two percentage points. Although they have similar trends and a small discrepancy, their classifications still need to be reviewed and some workers in CPS white-collar classification need to be switched to blue-collar to make the discrepancy as small as possible since this study actually combines these two datasets. Second, from 1970 to 1990 there are three kinds of classifications of occupations in CPS data, 1970 classification, 1980 classification, and 1990 classification. I choose the 1980 classification as the main one and applies it to the others. Third, similarly, CPS has its classification of industries and amended industry classification every ten years during 1970-1990. The 1980 classification was also chosen as a benchmark and 1970 and 1990 were modified to be the same as the 1980 classification.[18] The benefit of choosing 1980

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[17] Originally, there are 450 industries in four-digit 1972 SIC. By following Feenstra and Hanson (1999), I exclude three industries (SIC 2067, 2794, 3483) due to missing data on material purchases or prices. Additionally, two industries' (SIC 3672, 3673) data are not available in the recent version of the NBER Productivity Database.

[18] For consistency with 1970 and 1990 classification, some industries in 1980 need to be merged with another industry. They are census code 122 (merging with 121), 211 (merging with 210), 232 (merging with 241), 301 (merging with 300), 322 (merging with 321), 332 (merging with 331), 350 (merging with

CPS classification of industries is that it provides a “bridge” between CPS codes and three-digit SIC codes for converting CPS data into three-digit SIC. Fourth, March CPS asks respondents about their wages and working hours last year. Thus, if one wants to collect data of wages and working hours, for example, in 1990, he needs to employ March CPS data in 1991. Nevertheless, March 1990 still gives us the information of employee numbers in each industry, which is the total numbers of respondents in each industry, for 1990. For consistency, this study keeps those respondents who are looking for a job or not working, but excludes those respondents who did not have wage income last year. With this modification, all the information on wages, employments, and working hours in 1991 tells us the information for 1990.

Unlike NSF data, even if a respondent’s occupation in CPS data tells us that he or she should be classified as R&D worker, he or she is not necessarily doing R&D. Engineers, for example, are not all involved in R&D. Besides, some skilled workers who do not belong to this classification of R&D workers actually are involved in R&D. Economists, for example, are in charge of doing economic analysis of implementation and planning of R&D projects. A designer who is responsible for designing the appearance of new products should be also considered a R&D worker. Therefore, this study has two definitions of R&D workers. The first group, named narrow definition of R&D workers, includes those occupations in which a high proportion of workers are doing R&D. In the 1980 CPS classification of occupations, they are computer scientists (64-65), mathematical scientists (68), and natural scientists (69-82).[19] The second group is broad definition of R&D workers that include both narrow definition of R&D workers and occupations in which a lower proportion of workers are doing R&D. In 1980 CPS classification, they are scientists (64-65, 68, 69-83), engineers (44-62), economists (166), and designers (185). I also consider educational qualification. Respondents who are R&D workers must at least have finished high school.[20] The rest of skilled workers are

342), 362 (merging with 370), 382 (merging with 381), 390 (merging with 391), and 392 (merging with 391).

[19] Medical scientists (83) are been excluded for consistence purpose with 1970 classification.

[20] The education qualification in NSF data for a R&D worker is a college degree. Since occupations of R&D workers in this study have more variety, the education qualification in this study is lower.

white-collar workers. The regression results under a decomposition rule of the narrow definition of R&D workers can be thought of as lower-bound results and under the broad definition of R&D workers can be thought of as upper-bound results. The broad definition of R&D may cause estimation problems if a considerable fraction of engineers, economists, and designers are not doing R&D jobs. The narrow definition of R&D may cause underestimation if in fact most engineers, economists, and designers are R&D workers. Thus, comparing results from both specifications can give us a better answer to the questions.

The decomposition procedure can be divided into two parts. First, by employing March CPS data, this study computes both the R&D workers' and white-collar workers' shares in total skilled laborers' employment and wage by industries. If the data year is later than 1976, R&D workers' and white-collar workers' shares in total skilled laborers' working hours are also computed. Average working hours of all skilled workers in each industry are also needed for converting employment data of non-production labor in the NBER Productivity Database into working-hour data. Second, multiplying the shares of wage and number of employment in the first step by wage payment and number of employment of non-production workers of the NBER Productivity Database, yields R&D workers' wage, white-collar workers' wage, R&D workers' number of employment, and white-collar workers' number of employment. As for the data after 1976, employment data of non-production workers from the NBER Productivity Database are multiplied by average working hours of all skilled workers from the March CPS data to get skilled laborers' working-hour data. Then, the second step is redone with R&D workers' and white-collar workers' shares in working-hour computed from March CPS data to get the working-hour wages and employment for R&D workers and white-collar workers. Last, this study names all production workers in the NBER Productivity Database blue-collar workers.

As mentioned before, the two classifications need to be coordinated. Drawing these two data sets together helps us to check the discrepancy between them. Figure 10 illustrates non-production workers' share in the wage bill. It can be seen that the wage shares computed from CPS data are obviously higher than those computed from the NBER Productivity Database. That means some occupations in CPS classification of white-collar workers should be members of the production workers. Technicians (213-235) who are also in charge of maintenance and repair are members of white-collar workers in classification of occupation in CPS, but according to the definition of production workers in ASM,[21] they are production workers. After switching technicians to blue-collar workers, the wage shares computed from CPS data are closer to those computed from the NBER Productivity Database.[22] Non-production workers' share in total employment has the same problem as workers' share in the wage bill. This study also shifts technicians from white-collar workers to blue-collar to deal with that problem. In Figure 10, it can be seen that the adjustment can narrow the discrepancy.[23]

White-collar workers' share of the wage bill in Figure 10 and white-collar workers' share of total employment in Figure 11 illustrate the difference in white-collar workers' wages between the 1970s and 1980s. In Figure 10, it can be seen that the wage share of white-collar workers was non-increasing in 1970s. Figure 11 also shows that the employment share of white-collar workers was increasing in the 1970s. Thus, one can guess that wages for white-collar workers in 1970 were decreasing. White-collar workers' share in the wage bill and total employment were both increasing in the 1980s. This is a well-known issue about the deterioration of the relative wage of low-skilled workers to high-skilled workers. Compared to white-collar workers, R&D workers' share in the wage bill and total employment is much more stable no matter what definition this study uses. Their share in the wage bill and total employment slightly increased during these two decades.

[21] Quoting from the website of the U.S. Census Bureau, production workers includes workers (up through the line-supervisor level) engaged in fabricating, processing, assembling, inspecting, receiving, storing, handling, packing ware-housing, shipping (but not delivering), maintenance, repair, janitorial and guard services, and product development. Please see http://www.census.gov/mcd/asm-as1.html for details.
[22] The correlation coefficient of weighted shares in the wage bill from these two sources is 0.970.
[23] The correlation coefficient of weighted shares in employment from these two sources is 0.967.

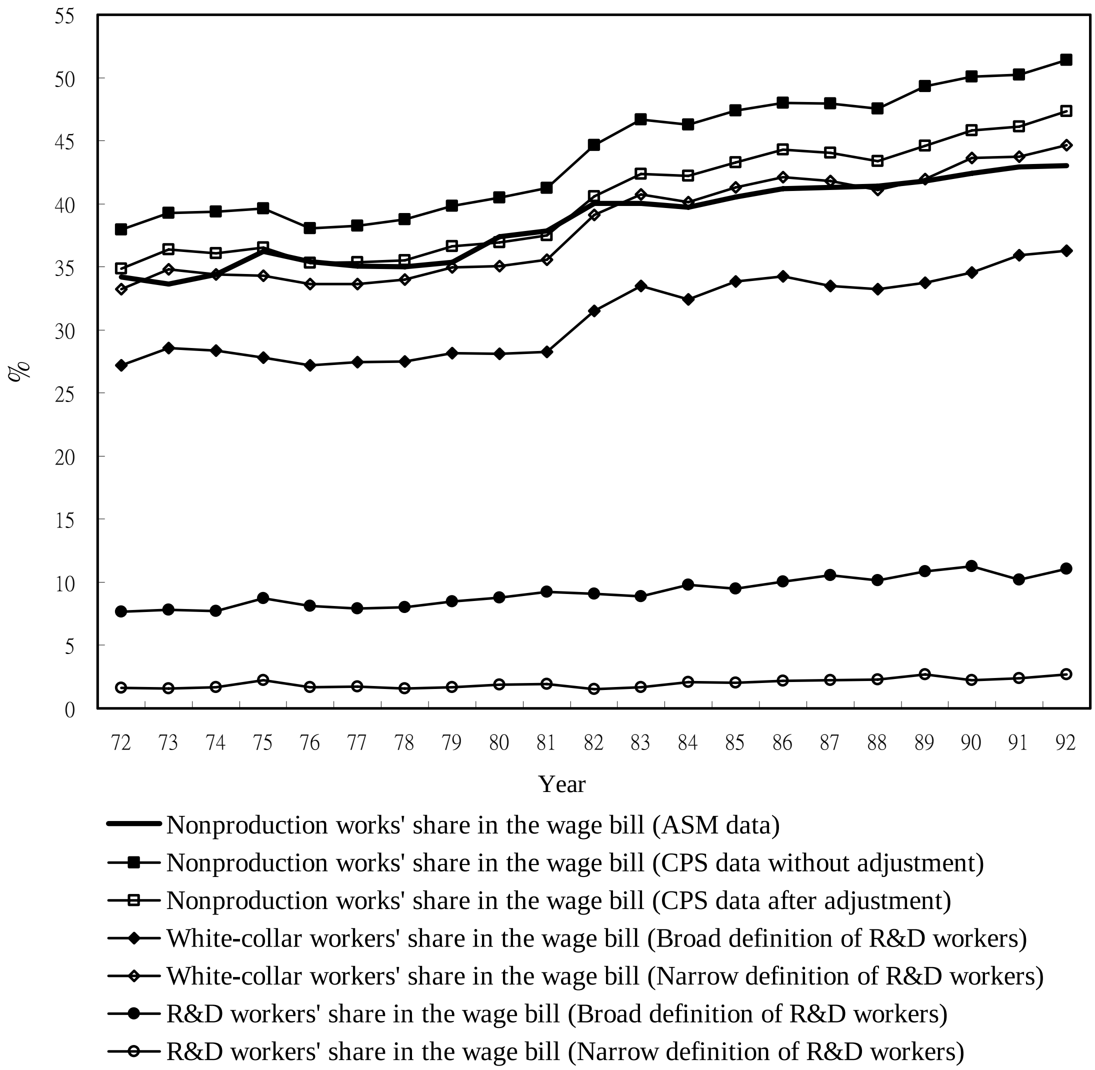

Figure 10. Non-production Workers’ Share in the Wage Bill

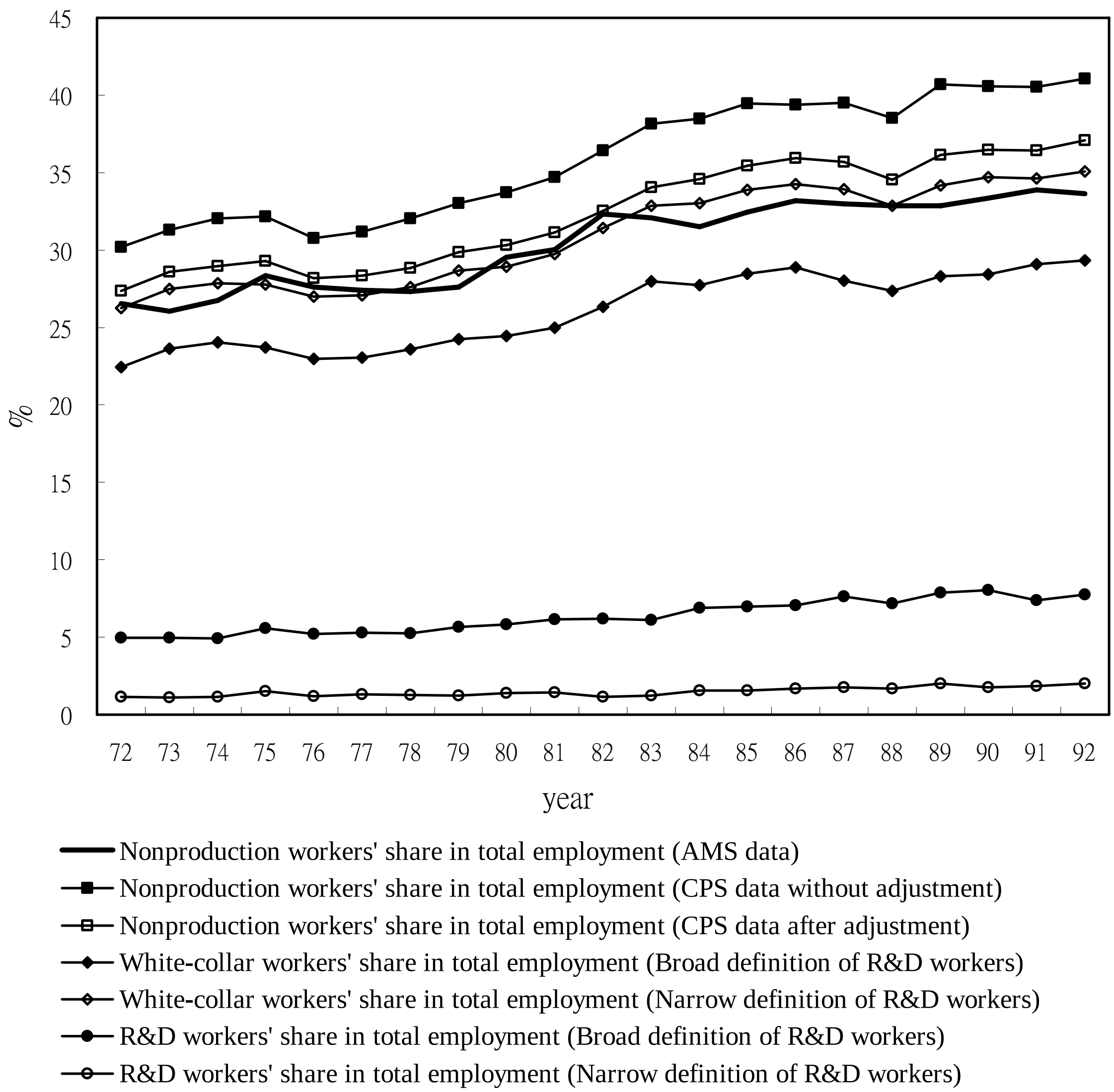

Figure 11. Non-production Workers’ Share in Total Employment

Table 4 gives summary statistics for the workers' data which I constructed from the NBER Productivity Database and CPS data for 1972-1979 and 1979-1990. R&D workers who have high-technology skills and are usually well-educated should get the highest pay among other kinds of workers. The numbers in Table 4 confirm this idea. In every period, R&D workers get the highest average pay per year. If I employ working-hour data, R&D workers still get the highest pay per hour. Annual changes of workers' wages in 1972-1979 tell almost the same story. R&D workers' pay grew the fastest in that time period. During 1979-1990, however, if I use the data counting workers by number of employment, R&D workers' pay did not grow the fastest. In fact, their pay in 1979-1990 grew the slowest under the broad definition of R&D workers. If narrow definition of R&D workers and working-hour data are used, R&D workers' pay still grew the fastest.

It's not surprising that low-skilled labor (blue-collar workers) got the lowest pay during these two decades. The annual change, however, was higher than for white-collar and non-production workers in 1972-1979. The question now is which structural variable caused this unusual phenomenon? This puzzle can be solved by employing two-stage regression. In 1979-1990, the annual change in wages of blue-collar workers' was smaller than the one of white-collar workers. Note that the difference in annual change between white-collar and blue-collar workers in 1979-1990 becomes smaller when I use working-hour data. Feenstra and Hanson (1999) use number of employment data in non-production workers and working-hour data in production workers in their study. If working-hour data of non-production workers are employed, it may be possible to get a weaker effect of outsourcing on relative wage of non-production workers.

Table 4. Summary Statistics

	1972-1979		1979-1990	
	Average USD/year	Annual change	Average USD/year (USD/ hour)	Annual change
Average and change in log workers' prices:				
Blue-collar workers	11443	7.460	19641	4.964
			(10)	(4.705)
Non-production	16648	7.201	29324	5.432
			(14)	(5.025)
White-collar workers:	15666	7.052	27438	5.517
Broad definition of R&D			(13)	(5.060)
White-collar workers:	16449	7.179	28939	5.441
Narrow definition of			(14)	(4.980)
R&D workers:	21571	7.668	37076	4.780
Broad definition of			(26)	(4.074)
R&D workers:	20665	7.741	34159	4.843
Narrow definition of R&D workers			(32)	(6.160)
Factor cost-shares:	Average (percent)	Annual change	Average (percent)	Annual change
Blue-collar workers	12.470	-0.299	10.185	-0.152
Non-production	6.653	-0.201	6.442	-0.006
White-collar workers (Broad definition)	5.292	-0.113	4.984	-0.009
White-collar workers	6.399	-0.129	6.194	0.002
R&D workers (Broad definition)	1.361	-0.024	1.458	0.022
R&D workers	0.253	-0.009	0.248	-0.001
TFP :				
TFP				
(Broad R&D workers definition)		0.587		0.864
				(0.880)
(Narrow R&D workers definition)		0.537		0.839
				(0.913)

Note: Numbers in parentheses are calculated from working-hours data. Workers' average wage are computed over the first and last year of each period and weighted by the industry share of total manufacturing payments to that factor. Those numbers are USD per person per year or per hour if using hourly data. The annual change of TFP is weighted by the industry share of total manufacturing shipments. Numbers of TFP are computed from primary factors excluding R&D workers, which are blue-collar workers, white-collar workers, and capital. Please see Feenstra and Hanson (1996) for the rest of the summaries of variables, such as outsourcing and capital services.

The second part of Table 3 contains summaries of workers' cost share in the industry's value of shipment. Both production and non-production workers' share in costs were decreasing, but R&D workers are relatively stable in their cost shares. Following Feenstra and Hanson (1999), this study measures Total Factor Productivity (TFP) by the primal Tornqvist Index, which equals the log change of output minus the share-weighted log change of primary inputs. The difference in this paper is primary factors. Primary factors in Feenstra and Hanson (1999) are non-production workers, production workers, and capital. Ours are white-collar workers, blue-collar workers, and capital. In the bottom of Table 3, it can be realized that TFP grews much faster in the 1980s than the TFP in the 1970s, and including some possible R&D workers increased TFP. In this study, the wage cost of R&D should be thought of as a sunk cost. Producers spend it before producing their product. Thus, value-added prices in this study are also different from those in Feenstra and Hanson (1999).

3.3.2.2 R&D Workers' Wage Regression

Since outsourcing can raise R&D intensity, one expects to see an increase in wages of R&D workers after outsourcing industries increase their outsourcing fraction. Unlike the impact of outsourcing on primary factors, outsourcing affects R&D workers directly, not via value-added price and productivity. The dependent variable in the wage regression is the change in R&D workers' wages, and independent variables are outsourcing (narrow), outsourcing (difference), which is the difference between the narrow measure of outsourcing and the broad measure of outsourcing, change in log real output, change in the log capital/output ratio, computer share, and high-tech share (difference).

The measurement and source of outsourcing are the same as in Section 3.3.1. Real output and capital/output ratio can be computed from the NBER Productivity Database. Computer share measures the share of office, computing, and accounting machinery in total capital. High-tech capital (difference) computes the share of communications equipment; science and engineering instruments; and photo-copy and related equipment in total capital. The ex post rental price and ex ante rental price are employed in computing computer share and high-tech share (difference).[24] Note that since computer share and high-tech share are only available at two-digit SIC level, the wage regressions allow the errors to be correlated across four-digit industries with each two-digit industry. Furthermore, this paper uses CPS data to decompose non-production workers and CPS classification can be converted into three-digit SIC. A dummy variable which corresponds to three-digit CPS is needed to capture the grouping effects.[25]

Starting with the same period as Feenstra and Hanson (1999), Table 5-1 illustrates the regression of changes in R&D workers' wages in 1979-1990. NP stands for non-production workers; BRD is broad definition of R&D workers, and NRD is narrow definition of R&D workers.

[24] Data of high-technology capital come from the Bureau of Labor Statistics (BLS). Ex post rental prices are computed as in Hall and Jorgenson (1967). Ex ante rental prices are calculated by Berndt and Morrison (1995). All high-tech capital data in this study are kindly provided by Robert C. Feenstra and Gordon H. Hanson who obtained the data from Catherine Morrison and Don Siegel.

[25] The Dummy variable is log of CPS three-digit code. I'll verify that the grouping effect does not hinder my regressions in two-stage regression models.

Table 5-1. Changes in R&D Workers' Wages: 1979-1990

	Dependent variables: average wage-changes per					
	NP	BRD	NRD	NP	BRD	NRD
Independent variables:						
Outsourcing (narrow)	0.375	0.438	0.063	0.405	0.530	-0.002
	(1.49)	(0.98)	(0.14)	(1.63)	(1.17)	(0.01)
Outsourcing (difference)	0.088	1.332	0.165	0.145	1.447	0.217
	(0.52)	(2.11)	(0.22)	(0.89)	(2.25)	(0.29)
Capital services (ex post rental prices):						
Computer share	0.038	0.668	-1.614			
	(0.14)	(0.67)	(1.47)			
High-tech share (difference)	0.317	-0.680	3.060			
	(0.74)	(0.54)	(2.72)			
Capital services (ex ante rental prices):						
Computer share				0.803	2.551	-0.289
				(1.81)	(1.25)	(0.09)
High-tech share (difference)				0.924	-0.736	4.835
				(3.80)	(0.52)	(2.35)
$\Delta \ln(y)$	0.069	0.064	0.000	0.051	0.039	-0.064
	(2.69)	(1.31)	(0.00)	(2.02)	(0.72)	(0.96)
$\Delta \ln(k/y)$	0.036	0.182	-0.063	0.017	0.148	-0.141
	(0.86)	(1.31)	(0.62)	(0.40)	(1.85)	(1.39)
Constant	0.048	0.040	0.047	0.047	0.040	0.042
	(25.66)	(6.15)	(7.56)	(31.52)	(7.21)	(7.32)
R^2	0.095	0.057	0.083	0.127	0.063	0.091
N	445	445	445	445	445	445

Note: Dependent variable NP is the changes of all non-production workers' wages. Dependent variable BRD is the changes of R&D workers' wages, which is measured in broad definition. Dependent variable NRD is the changes of R&D workers' wages, which is measured in narrow definition. Numbers in parentheses are the absolute values of t statistics and standard errors in all regressions are robust to heteroskedasticity and correlation in the errors within two-digit industry groups. Besides, a dummy variable, which is log of the 1980 CPS industry classification, is also included in each regression. All dependent and independent variables are measured as annual changes and weighted by average industry share of all manufacturing wage bills.

Before splitting non-production workers, neither outsourcing (narrow) nor outsourcing (difference) has a significant positive effect on the change in non-production workers' wages. After filtering R&D workers from non-production workers, it can be seen that outsourcing (difference) has a significant positive effect on the changes in R&D workers' wages under broad definition of R&D workers. Scientists' wages, however, did not significantly increase with outsourcing. This means that the impact of outsourcing on scientists can not be captured by the employment data. I check those effects by using working-hour data.

In Table 5-2, it can be seen that scientists' wages were significantly affected by outsourcing (narrow). Therefore, this study finds some evidence to support the idea that outsourcing increased R&D workers' wages during 1979-1990. As for other independent variables, only high-tech share (difference) has significantly positive effects on average R&D workers' wage change per capita and per working-hour. It can be concluded that outsourcing is a main factor of rising R&D workers' wages in 1979-1990.

The argument that outsourcing raises R&D workers' wages is robust if R&D workers' wages were also significantly affected by outsourcing in 1972-1979. Feenstra and Hanson (1996) found that outsourcing has an insignificantly negative effect on non-production workers' shares in the wage bill in 1972-1979. If R&D workers' wages benefit from outsourcing as the theory predicts, separating R&D workers from other non-production workers can explain why not all of skilled labor is hurt by outsourcing. In Table 6, no matter which definition of R&D workers is employed, both outsourcing (narrow) and outsourcing (difference) have a positive significant effect on R&D workers' wages. Computers in this period have insignificant effects on R&D workers' wages. High-technology capital (difference) has a significant effect if capital is measured in ex post rental prices. This study finds some proof to support the argument that outsourcing increases R&D workers' wages. Although it seems that outsourcing had no effect on all skilled workers in 1972-1979, outsourcing still increases R&D workers' wages.

Table 5-2. Changes in the R&D Workers' Wage: 1979-1990

	Dependent variables: annual wage-changes per working hour					
	NP	BRD	NRD	NP	BRD	NRD
Independent variables:						
Outsourcing (narrow)	0.415	0.853	4.626	0.420	0.583	4.782
	(1.33)	(0.64)	(2.07)	(1.43)	(0.40)	(2.16)
Outsourcing (difference)	-0.326	0.378	-0.149	-0.307	-0.372	0.451
	(1.67)	(0.24)	(0.04)	(1.65)	(0.20)	(0.11)
Capital services (ex post rental prices):						
Computer share	-0.195	-5.640	-3.650			
	(0.56)	(1.59)	(0.84)			
High-tech share (difference)	0.639	-0.594	7.299			
	(1.30)	(0.19)	(0.84)			
Capital services (ex ante rental prices):						
Computer share				-0.214	-4.506	10.969
				(0.45)	(0.57)	(1.24)
High-tech share (difference)				1.648	2.866	13.414
				(7.46)	(0.79)	(2.00)
$\Delta \ln(y)$	0.051	0.343	-0.014	0.042	0.253	-0.389
	(1.76)	(1.40)	(0.02)	(1.78)	(1.00)	(0.49)
$\Delta \ln(k/y)$	-0.004	0.372	-0.198	-0.009	0.224	-0.686
	(0.08)	(0.82)	(0.22)	(0.17)	(0.54)	(0.69)
Constant	0.046	0.044	0.062	0.044	0.033	0.043
	(20.84)	(1.76)	(1.01)	(26.74)	(1.26)	(0.72)
R^2	0.088	0.015	0.039	0.127	0.007	0.058
N	445	445	445	445	445	445

Note: Dependent variables NP are the changes of all non-production workers' wages. Dependent variables BRD are the changes of R&D workers' wages, which is measured in broad definition. Dependant variable NRD is the changes of R&D workers' wages, which is measured in narrow definition. Numbers in parentheses are the absolute values of t statistics and standard errors in all regressions are robust to heteroskedasticity and correlation in the errors within two-digit industry groups. Besides, a dummy variable, which is log of the 1980 CPS industry classification, is also included in each regression. All dependent and independent variables are measured as annual changes and weighted by average industry share of all manufacturing wage bills.

Table 6. Changes in the R&D Workers' Wage: 1972-1979

	Dependent variable: annual wage-changes per					
	NP	BRD	NRD	NP	BRD	NRD
Independent variables:						
Outsourcing (narrow)	-0.168	1.232	1.943	-0.070	1.480	2.304
	(0.84)	(3.14)	(2.28)	(0.40)	(3.40)	(2.39)
Outsourcing (difference)	-0.152	0.113	1.100	-0.126	0.089	1.021
	(1.47)	(0.47)	(1.92)	(1.14)	(0.33)	(2.07)
Capital services (ex post rental prices):						
Computer share	-0.027	0.042	-5.033			
	(0.06)	(0.05)	(2.13)			
High-tech share (difference)	0.785	1.750	0.836			
	(2.65)	(1.93)	(0.81)			
Capital services (ex ante rental prices):						
Computer share				0.270	0.519	-9.615
				(0.42)	(0.26)	(1.98)
High-tech share (difference)				1.155	1.742	0.384
				(2.43)	(1.95)	(0.30)
$\Delta \ln(y)$	-0.020	-0.187	-0.131	-0.017	-0.180	-0.092
	(0.53)	(2.62)	(0.75)	(0.47)	(2.34)	(0.53)
$\Delta \ln(k / y)$	-0.006	-0.257	-0.057	-0.005	-0.258	-0.033
	(0.14)	(4.16)	(0.27)	(0.13)	(4.16)	(0.16)
Constant	0.075	0.072	0.068	0.076	0.074	0.069
	(19.69)	(11.12)	(5.15)	(19.86)	(11.57)	(5.03)
R^2	0.082	0.086	0.135	0.100	0.076	0.155
N	445	445	445	445	445	445

Note: Dependent variable NP is the changes of all non-production workers' wages. Dependent variable BRD is the changes of R&D workers' wages, which is measured in broad definition. Dependent variable NRD is the changes of R&D workers' wages, which is measured in narrow definition. Numbers in parentheses are the absolute values of t statistics and standard errors in all regressions are robust to heteroskedasticity and correlation in the errors within two-digit industry groups. Besides, a dummy variable, which is log of the 1980 CPS industry classification, is also included in each regression. All dependent and independent variables are measured as annual changes and weighted by average industry share of all manufacturing wage bills.

3.2.2.3 Two-Stage Regression

Continuing Feenstra and Hanson's (1996) work on the impact of outsourcing on wages in 1972-1979 and 1979-1990, Feenstra and Hanson (1999) employ two-stage mandated price regressions to test the impact of outsourcing and high-technology on wages in 1979-1990. In their paper, the results support the idea that outsourcing and computers raised the relative wage of high-skilled labor and caused wage inequality in the United States during 1979-1990. The main reason for employing two-stage regression to this topic is that outsourcing and other structural variables, including high-technology capital, affect factor prices by influencing the price of the commodity and productivity first, and then the changes in the commodity's price and productivity implied by those structural variables influence factor prices. The changes in the commodity's price and productivity implied by those structural variables, however, are not measurable, but can be estimated by regressing commodities' prices and productivity on the changes of structural variables. Thus, if one wants to know the impact of structural variables on factor prices, first, run the first-stage regression in which the dependent variable is value-added prices of commodities plus productivity and independent variables are structural variables. The estimated coefficients from first-stage regression, and their corresponding structural variables, consist of the dependent variable in the second-stage regression. Using the dependent variable and regressing it on the factor-shares, the coefficients of second-stage regressions show how a factor's price changes due to those structural variables' changes.

For first-stage regression, Feenstra and Hanson (1999) argue that structural variables, including outsourcing, are non-neutral technological progresses having a direct impact on prices, over and above the indirect impact via productivity. The sign of product prices, however, can't be easily predicted since the closed-form solution does not exist. Intuitively speaking, if outsourcing industries produce low-skilled labor-intensive goods, outsourcing part of production to developing countries should reduce its cost on the wage bill and will probably reduce product prices. On the contrary, if outsourcing industries produce high-skilled labor-intensive goods, the effect of cost reduction may not suppress the effect of technological improvement.

This study will employ the same two-stage regression, but use different primary factors and structural variables. R&D expenses should be thought of as a sunk cost, which is paid before production. The primary factors in this study are white-collar workers, blue-collar workers, and capital. Value-added prices that exclude R&D workers can be obtained by:

$$(47) \qquad \Delta \ln P_{it}^{VA-NRD} = \left[\Delta \ln P_{it}^{Y} - 0.5\left(S_{it}^{ME} + S_{it-1}^{ME}\right)\Delta \ln P_{it}^{ME}\right] / 0.5\left(S_{it}^{VA-NRD} + S_{it-1}^{VA-NRD}\right)$$

where P_{it}^{VA-NRD} and P_{it}^{Y} are value-added price without considering R&D workers and output price in industry i =1,…,N. S_{it}^{ME} denotes the cost-share of intermediate input, which also includes energy, in industry i =1,…,N. P_{it}^{ME} denotes intermediate input prices, and S_{it}^{VA-NRD} denotes cost-share of value-added, excluding R&D cost. The new product and new state-of-the-art technology invented by R&D workers can progress the industry's productivity and increase product prices. Thus, R&D expenditure should be included in the structural variables when I run the two-stage regression. Conducting R&D requires lots of high-technology facilities and R&D workers. High-technology capital can be captured by high-technology share (difference) and computer share. The wage cost of R&D can be represented by R&D payment share, which is computed by total expense in the wage bill of R&D workers divided by industry's value of shipment. R&D payment share, however, is also influenced by outsourcing, computer, and high-technology share (difference). The relationship of R&D share in the wage bill to other structural variables is:

$$(48) \qquad S_{it}^{RD} = \alpha' \, \Delta Z_{it} + RD_{it}$$

where S_{it}^{RD} is R&D workers' payment share in total value of shipment; Z_{it} is a vector of structural variables; α is a vector of coefficients, and RD_{it} is a residual term that captures all the other determinants to R&D payment share, which is assumed orthogonal to Z_{it}. If first-stage regression also takes R&D payment share into consideration, then the regression becomes:[26]

$$(49) \qquad \Delta \ln P_{it}^{VA} + ETFP_{it} = \beta' \Delta Z_{it} + \gamma' S_{it}^{RD} + \varepsilon_{it}.$$

Putting equation (2) in Feenstra and Hanson's (1999) first-stage regression gives the following equation:

$$(50) \qquad \Delta \ln P_{it}^{VA} + ETFP_{it} = \phi' \Delta Z_{it} + \gamma' RD_{it} + \varepsilon_{it},$$

where $\phi = \beta + \alpha\gamma$. I name RD_{it} as R&D factors and its coefficient γ can tell us the impact of R&D wage payment on dependent variables. Since spending on R&D can enhance technology, the coefficient γ is expected to be positive.

Feenstra and Hanson (1999) assume a linear relationship between value-added prices plus effective TFP and structural variables. It is possible that the relationship between outsourcing and value-added prices plus effective TFP is non-linear.[27] A simple way to check the assumption is to put a quadratic term of each outsourcing (narrow) and outsourcing (difference) in equation (4). For keeping RD_{it} unrelated to all structural variables, quadratic terms of outsourcing are also considered in estimating equation (2). As in the R&D workers' wage regression, a dummy variable that captures grouping effects is also added and correlation between two-digit industries is allowed when I estimate equations (2) and (4).

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[26] P_{it}^{VA} is value-added price and $ETFP_{it}$ is effective productivity. For details about how to compute these two variables, please see Feenstra and Hanson (1999).

[27] For focusing mainly on outsourcing, this paper only relaxes the linear assumption on outsourcing. The results of two-stage regression show that adding quadratic terms of outsourcing does not affect computer share and high-tech share.

To proceed in second-stage regression, there is an estimation issue addressed by Feenstra and Hanson (1999) that needs to addressed. Since the dependent variable in the second-stage regression is constructed from the first-stage regression, the disturbance terms in the second-stage regression will be correlated across observations. Feenstra and Hanson (1999) suggest a procedure to correct the standard errors in the second-stage regression. Dumont et al. (2005) find their correcting method is negatively biased and leads to overestimation of the inferred significance. The better way to get accurate standard errors in the second-stage regression is to compute an unconditional variance.[28] Standard errors in the second-stage regression of this paper will follow Dumont et al's (2005) idea instead of the one proposed by Feenstra and Hanson (1999).

3.2.2.4 Regression Results

This chapter starts by reporting the results of the two-stage regression over the same period as Feenstra and Hanson (1999), which is 1979-1990 and then switches to 1972-1979. Results of first-stage regression and second-stage regression are both reported. Since there are two definitions of R&D workers in this paper and R&D workers' payment needs to be excluded when I compute valued-added price, each first-stage regression result has two Tables to illustrate the estimation results under the narrow definition and the broad definition of R&D workers. In addition, the working-hour data are available for 1979-1990. Therefore, there will be four Tables, the first two of them use employment data and the other two illustrate the results from the regressions using working-hour data. For comparison purposes, this study also replicates the first-stage regression with the same specification as Feenstra and Hanson (1999).

By using my data set, whose skilled labor was split into R&D workers and white-collar workers, there are three different first-stage regressions according to the discussion above, which are the basic regression, a regression including R&D factors, and a regression with R&D factors and quadratic terms of outsourcing. The basic regression includes all structural variables as independent variables. Quadratic terms of outsourcing

[28] The author gratefully thanks Dumont et al. for providing help.

are used to check the linearity of the relationship between outsourcing and dependent variables. In the results of second-stage regression, this study focuses mainly on outsourcing and R&D factors. The results of second-stage regression are the focus of this paper. The coefficients of the difference between white-collar and blue-collar workers show the changes of relative wage of white-collar workers. The order and brief description of tables is as follows: Table 7-1, 7-2, 8-1, and 8-2 are first-stage regressions in 1979-1990. Regressions in Table 6 use employment data and those in Table 8 use working-hour data. Tables 9-1 to 9-4 are second-stage regressions in 1979-1990. Then, Tables 10-1 and 10-2 are first-stage regressions in 1972-1979. Finally, Tables 11-1 and 11-2 report the results of second-stage regressions in 1972-1979. To distinguish which splitting rule is being used in the first-stage regression, the letter “n” denotes narrow definition of R&D workers. That means the value-added price plus effective TFP computed from all primary factors, exclude the narrow definition of R&D workers. The letter “b” stands for broad definition of R&D workers. The letter “h” means working-hour data is employed.

The question of whether outsourcing and R&D factors are non-neutral technological progress in 1979-1990 can be answered by Table 7. Regression 7a.1 and 7a.2 are replications and get almost the same results as Feenstra and Hanson (1999).[29] As expected, all coefficients of outsourcing (narrow) are positive. When the ex ante rental price is used for measuring high-tech capital share, outsourcing (difference) has a significant positive effect on dependent variables. In addition, the coefficients on the quadratic terms of outsourcing (narrow) show that outsourcing (narrow) affects value-added price plus effective TFP non-linearly. The positive influence of outsourcing on dependent variables is increasing with industry’s rising outsourcing fraction.

[29] Also, to check the difference caused by the decomposing procedure, I also try a first-stage regression using my data set, which excludes R&D workers when I calculate value-added price and effective TFP, but add R&D workers back into the regression. That is, dependent variable without R&D workers, plus dependent variable with only R&D workers. I get almost the same results as Feenstra and Hanson (1999) after putting in a grouping dummy variable.

Computers also can raise value-added prices plus effective TFP, if ex post rental prices are used for measuring, but the positive effect will vanish with different measuring prices. R&D factors are significantly positive in all specifications.

When the broad definition of R&D workers is employed, the significantly positive effects of outsourcing (narrow) disappear, but outsourcing (difference) still has a significant effect on dependent variables. In Table 7-2, if ex ante rental prices are used in measuring high-tech capital, outsourcing (difference) still has a significant positive effect on dependent variables. Computers increase value-added price plus effective TFP if ex post rental prices are used in measuring high-tech capital shares. No matter what kind of high-tech capital prices are used, it does not affect the significantly positive coefficients of R&D factors.

This study also has working-hour data of white-collar workers in this period. Comparing the results in Table 8-1 and Table 7-1, the significant coefficients of outsourcing (narrow) become weak. These results are sensible since the difference of annual change in wages between blue-collar and white-collar workers is smaller when using working-hour data than using employment data. After decomposing skilled labor, computers are also significant if the measuring prices are ex post rental prices. R&D factors are significant as well. Similar to the results in Table 7-2, Table 8-2 illustrates that outsourcing becomes insignificant and so do computers, while R&D factors are significant in most specifications.

Table 7-1. First-Stage Regression with Narrow Definition of R&D Workers: 1979-1990

	Dependent variable: change in value-added prices plus effective TFP							
	7a.1	7n.1	7n.2	7n.3	7a.2	7n.4	7n.5	7n.6
Independent variables:								
Outsourcing (narrow)	0.064	0.073	0.072	0.063	0.078	0.087	0.085	0.076
	(2.00)	(2.10)	(2.12)	(2.22)	(2.24)	(2.42)	(2.36)	(2.53)
Outsourcing (difference)	0.075	0.068	0.067	0.085	0.106	0.098	0.096	0.112
	(1.50)	(1.60)	(1.69)	(1.67)	(2.34)	(2.55)	(2.64)	(2.35)
[Outsourcing]^2 (narrow)				2.348				2.331
				(2.31)				(2.15)
[Outsourcing]^2 (difference)				-1.248				-1.182
				(0.46)				(0.41)
Capital services (ex post rental prices):								
Computer share	0.147	0.154	0.153	0.151				
	(2.24)	(2.31)	(2.35)	(2.34)				
High-tech share (difference)	0.067	0.053	0.052	0.051				
	(0.85)	(0.67)	(0.64)	(0.63)				
R&D factors			0.595	0.594				
			(2.23)	(2.20)				
Capital services (ex ante rental prices):								
Computer share					0.166	0.198	0.196	0.192
					(1.46)	(1.84)	(1.87)	(1.84)
High-tech share (difference)					-0.064	-0.093	-0.099	-0.096
					(0.75)	(1.12)	(1.22)	(1.20)
R&D factors							0.654	0.651
							(2.79)	(2.74)
Constant	0.042	0.042	0.042	0.042	0.043	0.042	0.042	0.042
	(119.22)	(78.93)	(80.47)	(81.29)	(108.17)	(80.00)	(80.77)	(81.39)
R^2	0.163	0.226	0.240	0.249	0.121	0.198	0.214	0.223
N	445	445	445	445	445	445	445	445

Notes: Dependent variables starting with 7a are computed from all primary factors, including R&D workers, but dependent variables starting with 7n are computed from primary factors, excluding R&D workers in the narrow definition. Numbers in parentheses are the absolute values of t statistics and standard errors in all regressions are robust to heteroskedasticity and correlation in the errors within two-digit industry groups. Besides, a dummy variable, which is log of the 1980 CPS industry classification, is also included in each regression. All variables are measured as annual changes and weighted by average industry share of all manufacturing shipments.

Table 7-2. First-Stage Regression with Broad Definition of R&D Workers: 1979-1990

	Dependent variable: change in value-added prices plus effective TFP					
	7b.1	7b.2	7b.3	7b.4	7b.5	7b.6
Independent variables:						
Outsourcing (narrow)	0.040	0.040	0.036	0.051	0.050	0.047
	(1.34)	(1.39)	(1.41)	(1.72)	(1.77)	(1.85)
Outsourcing (difference)	0.058	0.058	0.082	0.082	0.081	0.105
	(1.35)	(1.46)	(1.63)	(2.12)	(2.24)	(2.17)
[Outsourcing]^2 (narrow)			1.422			1.371
			(1.43)			(1.39)
[Outsourcing]^2 (difference)			-2.358			-2.313
			(0.88)			(0.83)
Capital services (ex post rental prices):						
Computer share	0.125	0.124	0.124			
	(1.93)	(2.04)	(2.04)			
High-tech share (difference)	0.045	0.044	0.041			
	(0.55)	(0.52)	(0.49)			
R&D factors		0.265	0.261			
		(4.83)	(5.00)			
Capital services (ex ante rental prices):						
Computer share				0.174	0.173	0.169
				(1.49)	(1.56)	(1.53)
High-tech share (difference)				-0.103	-0.107	-0.106
				(1.23)	(1.31)	(1.31)
R&D factors					0.282	0.278
					(6.06)	(6.68)
Constant	0.042	0.042	0.042	0.042	0.042	0.042
	(79.36)	(80.89)	(80.970)	(83.05)	(84.21)	(83.76)
R^2	0.194	0.220	0.226	0.181	0.210	0.216
N	445	445	445	445	445	445

Notes: Dependent variables starting with 7b are computed from primary factors, excluding R&D workers in the broad definition. Numbers in parentheses are the absolute values of t statistics and standard errors in all regressions are robust to heteroskedasticity and correlation in the errors within two-digit industry groups. Besides, a dummy variable, which is log of the 1980 CPS industry classification, is also included in each regression. All independent variables are measured as annual changes and weighted by average industry share of all manufacturing shipments.

Table 8-1. First-Stage Regression with Narrow Definition of R&D Workers Using Working-Hour Data in White-Collar Workers: 1979-1990

	Dependent Variable: changes in value-added prices plus effective TFP							
	8h.1	8nh.1	8nh.2	8nh.3	8h.2	8nh.4	8nh.5	8nh.6
Independent variables:								
Outsourcing (narrow)	0.051	0.056	0.055	0.063	0.062	0.066	0.065	0.076
	(1.80)	(1.91)	(1.92)	(2.22)	(2.04)	(2.19)	(2.15)	(2.53)
Outsourcing (difference)	0.063	0.053	0.053	0.085	0.087	0.075	0.074	0.112
	(1.35)	(1.42)	(1.48)	(1.67)	(2.06)	(2.22)	(2.29)	(2.35)
[Outsourcing]^2 (narrow)				2.348				2.331
				(2.31)				(2.15)
[Outsourcing]^2 (difference)				-1.248				-1.182
				(0.46)				(0.41)
Capital services (ex post rental prices):								
Computer share	0.111	0.108	0.108	0.151				
	(1.91)	(1.96)	(1.97)	(2.34)				
High-tech share (difference)	0.064	0.051	0.050	0.051				
	(0.83)	(0.66)	(0.64)	(0.63)				
R&D payment share			0.377	0.594				
			(2.14)	(2.20)				
Capital services (ex ante rental prices):								
Computer share					0.107	0.120	0.119	0.192
					(1.04)	(1.27)	(1.28)	(1.84)
High-tech share (difference)					-0.058	-0.081	-0.085	-0.096
					(0.73)	(1.07)	(1.15)	(1.20)
R&D payment share							0.459	0.651
							(3.24)	(2.74)
Constant	0.042	0.041	0.041	0.042	0.042	0.042	0.042	0.042
	(126.39)	(87.69)	(88.86)	(81.29)	(118.39)	(89.21)	(89.87)	(81.39)
R^2	0.135	0.199	0.206	0.249	0.097	0.175	0.186	0.223
N	445	445	445	445	445	445	445	445

Notes Dependent variables starting with 8h are computed by all primary factors, including R&D workers, but dependent variables starting with 8nh are computed from primary factors, excluding R&D workers in the narrow definition. Numbers in parentheses are the absolute values of t statistics and standard errors in all regressions are robust to heteroskedasticity and correlation in the errors within two-digit industry groups. Besides, a dummy variable, which is log of the 1980 CPS industry classification, is also included in each regression. All independent variables are measured as annual changes and weighted by average industry share of all manufacturing shipments.

Table 8-2. First-Stage Regression with Broad Definition of R&D Workers Using Working-Hour Data of White-Collar Workers: 1979-1990

	Dependent variable: changes in value-added prices plus effective TFP					
	8bh.1	8bh.2	8bh.3	8bh.4	8bh.5	8bh.6
Independent variables:						
Outsourcing (narrow)	0.036	0.035	0.032	0.044	0.043	0.041
	(1.34)	(1.38)	(1.44)	(1.67)	(1.70)	(1.84)
Outsourcing (difference)	0.047	0.047	0.074	0.066	0.065	0.092
	(1.18)	(1.26)	(1.65)	(1.81)	(1.89)	(2.15)
[Outsourcing]^2 (narrow)			1.309			1.266
			(1.45)			(1.41)
[Outsourcing]^2 (difference)			-2.682			-2.735
			(1.13)			(1.11)
Capital services (ex post rental prices):						
Computer share	0.092	0.091	0.091			
	(1.67)	(1.73)	(1.73)			
High-tech share (difference)	0.047	0.046	0.043			
	(0.58)	(0.55)	(0.52)			
R&D factors		0.192	0.188			
		(4.08)	(4.58)			
Capital services (ex ante rental prices):						
Computer share				0.109	0.108	0.104
				(1.08)	(1.11)	(1.08)
High-tech share (difference)				-0.089	-0.092	-0.092
				(1.16)	(1.22)	(1.23)
R&D factors					0.215	0.210
					(4.59)	(5.68)
Constant	0.041	0.041	0.041	0.042	0.042	0.042
	(87.21)	(88.46)	(88.84)	(91.07)	(92.16)	(91.93)
R^2	0.176	0.194	0.203	0.163	0.185	0.194
N	445	445	445	445	445	445

Notes: Dependent variables starting with 8bh are computed from primary factors, excluding R&D workers in the broad definition. Numbers in parentheses are the absolute values of t statistics and standard errors in all regressions are robust to heteroskedasticity and correlation in the errors within two-digit industry groups. Besides, a dummy variable, which is log of the 1980 CPS industry classification, is also included in each regression. All independent variables are measured as annual changes and weighted by average industry share of all manufacturing shipments

In sum, there are some important findings from the first-stage regressions in 1979-1990. First, with the narrow definition of R&D workers, outsourcing (narrow) has a significantly positive effect on value-added prices plus productivity, but with the broad definition of R&D workers, the effect of outsourcing (narrow) is not significant. This does not mean that the effects of outsourcing (narrow) are uncertain, since this study also can not find a significant coefficient of outsourcing (narrow) in R&D workers' wage regressions with the broad definition of R&D workers. One should focus on narrow definition of R&D workers in 1979-1990. Second, R&D factors, which subtract from R&D workers' payment share in the industry's value of shipment, increase value-added price plus effective TFP. Computer share also has a significantly positive effect on dependent variables, but rental price used for measuring capital shares also matters.

After running the first-stage regression, the second-stage regression of the estimation can be done to interpret the change of primary factors' price due to structural variables. I rerun Feenstra and Hanson's (1999) second-stage regression, but employ working-hour data from 1979 to 1990. The results are reported in Table 9-1. It can be seen that none of the structural variables significantly increase non-production workers' wages or significantly increase the difference between non-production and production workers' wages. This implies that using employment data in non-production workers might overestimate the effects. Nevertheless, computer share and outsourcing (narrow) are still important structural variables in discussing wage inequality.

The results of estimating the changes of blue-collar and white-collar workers' wages due to outsourcing are reported in Table 9-2. The dependent variable for each second-stage regression comes from a first-stage regression, including R&D factors and quadratic terms of outsourcing as independent variables. Under the narrow definition of R&D workers, outsourcing (narrow) is significantly positive even when the working-hour data are used. If R&D workers are defined by the broad definition of R&D workers, the effects of outsourcing vanish. Furthermore, outsourcing increases the difference in wages between skilled labor and unskilled labor by raising the wages of skilled workers. As for other structural variables, Table 9-3 tells us that by employing number-of-employment data, computers are significant, but are insignificant if working-hour data are used. R&D factors increase white-collar workers' wages significantly and diminish blue-collar workers' wages if the definition of R&D workers is a broad one. Table 9-4 reports the results of R&D factors.

Table 9-1. Second-Stage Regression: Estimated Factor-Price Changes Using Working-Hour Data in 1979-1990

Dependent variables in first-stage regressions:	8h	8h	8h	8h
(1) Employing ex post rental prices for computer share and high-tech share				
Dependent variable: change in share-weighted factor prices explained by:	Outsourcing (narrow)	Outsourcing (difference)	Computer share	High-tech Share (difference)
Independent variables:				
Production labor share	-0.007	0.016	-0.003	0.022
	(0.80)	(1.15)	(0.34)	(0.82)
Non-production labor share	0.078	0.050	0.165	0.006
	(1.74)	(1.29)	(1.88)	(0.58)
Difference between production and non-production share	0.085	0.034	0.168	-0.016
	(1.70)	(1.12)	(1.86)	(0.72)
(2) Employing ex ante rental prices for computer share and high-tech share				
Difference between production and non-production share	0.104	0.047	0.080	-0.005
	(1.89)	(1.43)	(1.03)	(0.49)

Notes: The letters and numbers in the first row stand for their dependent variables in their first-stage regressions. Numbers in parentheses are the absolute values of t statistics.

Table 9-2. Second-Stage Regression: Estimated Factor-Price Changes Due to Outsourcing in 1979-1990

Dependent variables in first-stage regressions:	7n	7n	7b	7b	7nh	7nh	7bh	7bh
(1) Employing ex post rental prices for computer share and high-tech share								
Dependent variable: change in share-weighted factor prices explained by:	Outsourcing (narrow)	Outsourcing (difference)	Outsourcing (narrow)	Outsourcing (difference)	Outsourcing (narrow)	Outsourcing (difference)	Outsourcing (narrow)	Outsourcing (difference)
Independent variables:								
Blue-collar labor share	-0.009	0.026	0.008	0.024	-0.007	0.026	0.007	0.023
	(0.68)	(1.18)	(0.91)	(1.30)	(0.67)	(1.40)	(0.92)	(1.43)
White-collar labor share	0.129	0.049	0.041	0.052	0.102	0.032	0.037	0.038
	(2.21)	(1.33)	(1.32)	(1.19)	(2.06)	(0.98)	(1.34)	(0.94)
Difference between white-collar and blue-collar share	0.138	0.024	0.033	0.029	0.109	0.006	0.030	0.015
	(2.12)	(0.56)	(1.11)	(0.65)	(1.99)	(0.17)	(1.13)	(0.38)
(2) Employing ex ante rental prices for computer share and high-tech share								
Difference between white-collar and blue-collar share	0.160	0.040	0.041	0.049	0.125	0.017	0.036	0.030
	(2.29)	(0.83)	(1.26)	(1.03)	(2.16)	(0.42)	(1.26)	(0.71)

The letters and numbers in the first row stand for their dependent variables in their first-stage regressions. All dependent variables are computed from the regressions, including quadratic terms of outsourcing (narrow) and outsourcing (difference). Numbers in parentheses are the absolute values of t statistics.

Table 9-3. Second-Stage Regression: Estimated Factor-Price Changes Due to Computers in 1979-1990

Dependent variables in first-stage regressions:	7n	7b	8nh	8bh
Dependent variable: change in share-weighted factor prices explained by computer share in wage bills:				
(1) Employing ex post rental prices for computer share and high-tech share				
Independent variables:				
Blue-collar labor share	-0.007	0.002	-0.005	0.001
	(0.54)	(0.16)	(0.53)	(0.16)
White-collar labor share	0.230	0.204	0.162	0.150
	(2.29)	(1.99)	(1.93)	(1.70)
Difference between white-collar and blue-collar share	0.237	0.202	0.167	0.148
	(2.25)	(1.96)	(1.91)	(1.68)
(2) Employing ex ante rental prices for computer share and high-tech share				
Difference between white-collar and blue-collar share	0.150	0.155	0.090	0.095
	(1.79)	(1.50)	(1.22)	(1.07)

Notes: The letters and numbers in the first row stand for their dependent variables in their first-stage regressions. All dependent variables are computed from the regressions, including quadratic terms of outsourcing (narrow) and outsourcing (difference). Numbers in parentheses are the absolute values of t statistics.

Table 9-4. Second-Stage Regression: Estimated Factor-Price Changes Due to R&D Factors in 1979-1990

Dependent variables in first-stage regressions:	7n	7b	8nh	8bh
Dependent variable: change in share-weighted factor prices explained by R&D share in wage bill:				
(1) Employing ex post rental prices for computer share and high-tech share				
Independent variables:				
Blue-collar labor share	-0.017	-0.026	-0.011	-0.019
	(1.67)	(2.74)	(1.62)	(2.67)
White-collar labor share	0.051	0.099	0.032	0.071
	(2.00)	(3.79)	(1.92)	(3.60)
Difference between white-collar and blue-collar share	0.067	0.125	0.043	0.090
	(1.98)	(3.74)	(1.90)	(3.56)
(2) Employing ex ante rental prices for computer share and high-tech share				
Difference between white-collar and blue-collar share	0.058	0.058	0.041	0.087
	(2.18)	(2.18)	(2.37)	(3.68)

Notes: The letters and numbers in the first row stand for their dependent variables in their first-stage regressions. All dependent variables are computed from the regressions including quadratic terms of outsourcing (narrow) and outsourcing (difference). Numbers in parentheses are the absolute values of t statistics.

Theoretically speaking, the working-hour data provide more accurate information about workers' wages. Without decomposing non-production workers into R&D and white-collar workers, outsourcing (narrow) has a weak effect on wage inequality if working-hour data are employed. While after decomposing, outsourcing (narrow) is significant in influencing workers' wages even if working-hour data are used.[30] Outsourcing, computer share and R&D factors increase the wages of white-collar workers and then enlarge the difference in wages between skilled labor and unskilled labor. The broad definition may not be ideal to see the impact of outsourcing on workers in the 1980s, based on the fact that not only the results of R&D workers' wages but the first-stage regressions are out of line with the theoretical prediction.

The puzzle of outsourcing is why the phenomenon found in most empirical studies and theoretical models in the 1980s can not be seen in the 1970s. As the regression results of 10a.1 and 10a.2 in Table 10-1 show, outsourcing not only does not increase value-added prices plus effective TFP, but might actually decrease them. High-tech share has similar results as well. In Section 3.1, this study verified that the outsourcing industry in the 1970s is the unskilled-labor intensive industry and by economic intuition, predicts that the price of products will decrease after an increase in outsourcing in Section 3.2.2.3. The results in Table 10-1 accord with expectations, but are not significant. It might be that some R&D workers are included in white-collar workers and I underestimate the effects. In Table 10-2, I report the results of first-stage regression, under the specification of the broad definition of R&D workers. After decomposing skilled labor, adding R&D factors, and relaxing the linear relationship assumption, outsourcing (difference) influences value-added prices plus effective TFP, significantly negatively.[31] The quadratic term of outsourcing (difference) is also positive and

[30] In unreported results, no matter what kind of data, working-hour data or employment data, I use and whether a quadratic term is included or not, outsourcing (narrow) is significant in increasing white-collar workers' wages and the coefficients of difference between white-collar workers and blue-collar workers if the measuring price of high-tech capital is ex ante rental prices.

[31] The other reason for the insignificant coefficient of outsourcing of regressions 9b.2 and 9b.5 is about the dependent variable. What theoretical or intuition predict about the negative impact from outsourcing if the outsourcing industry is unskilled-labor-intensive, is price not price plus TFP. If I switch effective TFP from dependent variables back to independent variables, like estimation equation (6) in Feenstra and Hanson (1999), which they use it to justify their approach, the coefficients of outsourcing (difference) become significantly negative.

significant at the 90% level. The results of outsourcing (difference) tell us that, as predicted, outsourcing (difference) influences value-added prices plus effective TFP negatively in 1972-1979, but the effects decrease with the increase in outsourcing. Based on the results of R&D workers' wages regressions in 1972-1979 and the comparison between Tables 10-1 and 10-2, the narrow definition of R&D workers seems to underestimate the effects of outsourcing and might not be suitable in 1972-1979. In the second-stage regression, the focus is the broader definition of R&D workers.

Before reporting results on second-stage regressions, I employ employment data in 1972-1979 and follow Feenstra and Hanson's (1999) specification to estimate second-stage regression. Table 11-1 reports these results. The coefficient, as expected, on non-production workers is negative under outsourcing influence, but none of these structural variables significantly affect workers' wages. That doesn't mean the theoretical prediction is problematic. The increased wages of R&D workers might mislead the result. In Table 11-2, with my new specification, the wages of white-collar workers was fall by outsourcing (difference). That also makes the wages of white-collar relative to blue-collar workers decreased. This result supports my argument that the skilled laborers of the theoretical model in Section 2 are white-collar workers only. As for other structural variables, like the results in Table 11-1, they have no significant effects on workers' wages.

Table 10-1. First-Stage Regression with Broad Definition of R&D Workers: 1972-1979

	Dependent variable: change In value-added prices plus effective TFP							
	10a.1	10n.1	10n.2	10n.3	10a.2	10n.4	10n.5	10n.6
Independent variables:								
Outsourcing (narrow)	-0.003	0.001	0.001	-0.001	-0.007	-0.003	-0.003	-0.006
	(0.76)	(0.32)	(0.35)	(0.34)	(0.99)	(0.52)	(0.59)	(0.87)
Outsourcing (difference)	-0.013	-0.007	-0.007	-0.018	-0.011	-0.005	-0.005	-0.017
	(1.55)	(1.53)	(1.56)	(1.59)	(1.49)	(1.37)	(1.42)	(1.68)
$[\text{Outsourcing}]^2$ (narrow)				0.013				0.055
				(0.21)				(0.54)
$[\text{Outsourcing}]^2$ (difference)				0.208				0.228
				(1.50)				(1.53)
Capital services (ex post rental prices):								
Computer share	-0.008	-0.009	-0.009	-0.008				
	(0.85)	(0.88)	(0.85)	(0.81)				
High-tech share (difference)	-0.013	-0.015	-0.016	-0.016				
	(2.05)	(2.29)	(2.30)	(2.29)				
R&D factors			0.016	0.021				
			(1.07)	(0.50)				
Capital services (ex ante rental prices):								
Computer share					0.005	0.005	0.005	0.008
					(0.29)	(0.38)	(0.40)	(0.58)
High-tech share (difference)					-0.006	-0.010	-0.011	-0.012
					(0.54)	(1.27)	(1.34)	(1.51)
R&D factors							0.023	0.049
							(1.39)	(1.42)
Constant	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072
	(773.31)	(371.97)	(372.29)	(361.05)	(764.52)	(371.16)	(370.87)	(356.48)
R^2	0.039	0.051	0.052	0.059	0.024	0.031	0.034	0.043
N	445	445	445	445	445	445	445	445

Notes: Dependent variables starting with 10a are computed from all primary factors, including R&D workers but dependent variables starting with 10n are computed from primary factors, excluding R&D workers in the narrow definition. Numbers in parentheses are the absolute values of t statistics and standard errors in all regressions are robust to heteroskedasticity and correlation in the errors within two-digit industry groups. Besides, a dummy variable, which is log of the 1980 CPS industry classification, is also included in each regression. All independent variables are measured as annual changes and weighted by average industry share of all manufacturing shipments.

Table 10-2. First-Stage Regression with Narrow Definition of R&D Workers: 1972-1979

	Dependent variable: change in value-added prices plus effective TFP					
	10b.1	10b.2	10b.3	10b.4	10b.5	10b.6
Independent variables:						
Outsourcing (narrow)	0.000	0.000	-0.004	-0.004	-0.004	-0.008
	(0.09)	(0.11)	(0.93)	(0.62)	(0.72)	(1.12)
Outsourcing (difference)	-0.009	-0.009	-0.023	-0.008	-0.008	-0.023
	(1.70)	(1.75)	(1.97)	(1.57)	(1.64)	(2.11)
[Outsourcing]^2 (narrow)			0.036			0.074
			(0.56)			(0.71)
[Outsourcing]^2 (difference)			0.280			0.298
			(1.88)			(1.88)
Capital services (ex post rental prices):						
Computer share	-0.007	-0.007	-0.005			
	(0.62)	(0.60)	(0.50)			
High-tech share (difference)	-0.013	-0.013	-0.014			
	(1.80)	(1.83)	(1.88)			
R&D factors		0.026	0.024			
		(1.49)	(1.34)			
Capital services (ex ante rental prices):						
Computer share				0.009	0.009	0.012
				(0.64)	(0.68)	(0.91)
High-tech share (difference)				-0.007	-0.007	-0.009
				(0.84)	(0.92)	(1.24)
R&D factors					0.032	0.030
					(1.71)	(1.61)
Constant	0.072	0.072	0.072	0.072	0.072	0.072
	(349.75)	(350.37)	(339.55)	(350.77)	(351.29)	(338.32)
R^2	0.054	0.057	0.069	0.041	0.046	0.060
N	445	445	445	445	445	445

Notes: Dependant variables starting with 10b are computed from primary factors excluding R&D workers in the broad definition. Numbers in parentheses are the absolute values of t statistics and standard errors in all regressions are robust to heteroskedasticity and correlation in the errors within two-digit industry groups. Besides, a dummy variable, which is log of the 1980 CPS industry classification, is also included in each regression. All independent variables are measured as annual changes and weighted by average industry share of all manufacturing shipments.

Table 11-1. Second-Stage Regression: Estimated Factor-Price Changes in 1972-1979

Dependent variables in first-stage regressions:	9a	9a	9a	9a
(1) Employing ex ante rental prices for computer share and high-tech share				
Dependent variable: Change in share-weighted factor prices explained by:	Outsourcing (narrow)	Outsourcing (difference)	Computer share	High-tech Share (difference)
Independent variables:				
Production labor share	0.000	0.001	-0.001	0.004
	(0.41)	(0.69)	(0.29)	(0.54)
Non-production labor share	-0.009	-0.023	0.000	0.002
	(0.97)	(1.45)	(0.28)	(0.53)
Difference between production and non-production share	-0.009	-0.024	0.001	-0.001
	(0.96)	(1.43)	(0.29)	(0.48)
(2) Employing ex post rental prices for computer share and high-tech share				
Difference between production and non-production share	-0.005	-0.028	-0.002	-0.011
	(0.75)	(1.49)	(0.57)	(1.62)

Notes: The letters and numbers in the first row represent their dependent variables in their first-stage regressions. Numbers in parentheses are absolute value of t statistics.

Table 11-2. Second-Stage Regression: Estimated Factor-Price Changes Due to Outsourcing in 1972-1979

Dependent variables in first-stage regressions:	9n	9n	9b	9b
(1) Employing ex post rental prices for computer share and high-tech share				
Dependent variable: change in share-weighted factor prices explained by:	Outsourcing (narrow)	Outsourcing (difference)	Outsourcing (narrow)	Outsourcing (difference)
Independent variables:				
Blue-collar labor share	0.000	0.002	0.000	0.001
	(0.42)	(0.98)	(0.37)	(0.50)
White-collar labor share	-0.007	-0.028	-0.008	-0.040
	(0.86)	(1.68)	(1.07)	(2.10)
Difference between white-collar and blue-collar share	-0.008	-0.030	-0.007	-0.041
	(0.86)	(1.67)	(1.03)	(2.07)
(2) Employing ex ante rental prices for computer share and high-tech share				
Difference between white-collar and blue-collar share	-0.002	-0.032	-0.003	-0.043
	(0.35)	(1.57)	(0.88)	(1.90)

Notes: All dependent variables are computed from the first-stage regressions, including quadratic terms of outsourcing. The letters and numbers in the first row stand for their dependent variables in their first-stage regressions. Numbers in parentheses are the absolute value of t statistics.

3.2.2.5 Including Interaction Terms

Another setting of two-stage regression in Feenstra and Hanson (1999) is including interaction terms in the first-stage regression.[32] The coefficients on the interaction terms can help us know the magnitude of non-neutral technological change.[33] In this study, interaction terms include all structural variables interacted with the average quantities of blue-collar workers, white-collar workers, and capital. R&D factors, which are obtained by equation (2), will also be included in structural variables. In addition, quadratic terms of outsourcing will appear in alternative regressions to check the linear relationship between outsourcing and value-added prices plus effective TFP. For parsimony and focusing on outsourcing and innovation, only the results of interaction terms of outsourcing and R&D factors are reported. Table 12 reports the estimation results of the first-stage regression with interaction terms using data from 1979 to 1990. It can be seen that white-collar workers and capital have a complementary relationship with outsourcing (narrow) in increasing productivity. The coefficients obtained from interaction terms of blue-collar workers and R&D factors tell us that there is a *substitutional* relationship between them in increasing productivity. Similar to the results of Feenstra and Hanson (1999), it is hard to explain the coefficients of the outsourcing (difference). About outsourcing (narrow), the results of second-stage regression from a first-stage regression with interaction terms are almost the same as the results from a first-stage regression without interaction terms. In Table 13, it can be seen that outsourcing (narrow) is still significant in increasing white-collar workers' wages and causes wage inequality. R&D factors, however, have no effect on wages if the definition of R&D workers is the narrow definition. If the broad definition of R&D is used, R&D factors still raised the difference in wages between white-collar workers and blue-collar workers.

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[32] This specification can be derived explicitly from a translog production function. Please refer to Feenstra and Hanson (1999) for details.

[33] Feenstra and Hanson also remind us of the possibility that the interaction terms would be correlated with disturbance terms. However, there is no solution to this problem because of a lack of good instruments for factor quantities. It is important to interpret the coefficient estimates carefully.

Table 12. First-Stage Regression with Interacted Independent Variables, 1979-1990

Regression:		Broad definition of R&D workers		Narrow definition of R&D workers	
Dependent variables: change In value-added prices plus effective TFP		12n.1	12n.2	12b.1	12b.2
Independent variables:	Interacted with the average log quantities of:				
Outsourcing (narrow)		0.480	0.711	0.312	0.658
		(3.33)	(3.20)	(2.26)	(3.03)
	Blue-collar labor	0.013	0.014	0.042	0.011
		(0.25)	(0.22)	(0.92)	(0.20)
	White-collar Labor	0.099	0.114	0.036	0.084
		(3.31)	(3.09)	(1.06)	(2.44)
	Capital	-0.093	-0.127	-0.069	-0.110
		(2.52)	(2.68)	(2.06)	(2.60)
$[\text{Outsourcing}]^2$ (narrow)			-18.043		-33.145
			(1.02)		(2.11)
Outsourcing (difference)		-0.332	-0.453	-0.253	-0.388
		(1.54)	(2.00)	(1.15)	(1.66)
	Blue-collar labor	0.173	0.199	0.209	0.234
		(3.31)	(1.87)	(3.84)	(2.62)
	White-collar Labor	-0.094	-0.109	-0.093	-0.122
		(2.19)	(1.37)	(1.95)	(2.01)
	Capital	-0.013	0.001	-0.048	-0.029
		(0.40)	(0.03)	(1.35)	(0.91)
$[\text{Outsourcing}]^2$ (difference)			46.756		35.433
			(1.85)		(1.69)
R&D factors		-4.503	-4.510	-2.532	-2.419
		(1.54)	(1.57)	(2.21)	(1.85)
	Blue-collar labor	-0.824	-0.738	-0.443	-0.437
		(2.32)	(1.87)	(2.36)	(2.17)
	White-collar Labor	0.304	0.249	-0.177	-0.188
		(1.22)	(1.16)	(1.67)	(1.55)
	Capital	0.894	0.859	0.634	0.618
		(1.68)	(1.62)	(2.71)	(2.28)
Constant		0.042	0.042	0.042	0.042
		(106.64)	(113.53)	(101.93)	(106.21)
R^2		0.632	0.649	0.605	0.622
N		445	445	445	445

Notes: Dependent variables are computed from primary factors, excluding R&D workers. Numbers in parentheses are the absolute values of t statistics and standard errors in all regressions are robust to heteroskedasticity and correlation in the errors within two-digit industry groups. Besides, a dummy variable, which is log of the 1980 CPS industry classification, is also included in each regression. All independent variables are measured as annual changes and weighted by average industry share of all manufacturing shipments. All regressions also include computer share and high-tech share, which are measured using ex post rental prices, as independent variables. For parsimony, only variables related to outsourcing and R&D factors are reported.

Table 13. Estimated Factor-Price Changes: 1979-1990

Dependent variables in first-stage regressions:	12n	12n	12b	12b	12n	12b
(1) Employing ex post rental prices for computer share and high-tech share						
Dependent variable: change in share-weighted factor prices explained by:	Outsourcing (narrow)	Outsourcing (difference)	Outsourcing (narrow)	Outsourcing (difference)	R&D payment share	R&D payment share
Independent variables:						
Blue-collar labor share	-0.098	0.168	-0.016	0.173	0.015	0.001
	(2.09)	(3.30)	(0.50)	(3.44)	(0.91)	(0.06)
White-collar labor share	0.446	-0.085	0.194	-0.144	0.038	0.080
	(3.82)	(1.71)	(1.97)	(2.00)	(1.70)	(2.56)
Difference between white-collar and blue-collar share	0.544	-0.253	0.210	-0.318	0.023	0.079
	(3.41)	(2.74)	(1.68)	(2.82)	(0.70)	(2.13)
(2) Employing ex ante rental prices for computer share and high-tech share						
Difference between white-collar and blue-collar share	0.571	-0.059	0.301	-0.104	0.032	0.059
	(3.81)	(1.24)	(2.52)	(1.69)	(1.37)	(1.94)

Notes: All dependent variables are computed from the regressions, including quadratic terms of outsourcing (narrow) and outsourcing (difference). Numbers in parentheses are the absolute values of t statistics.

Table14. First-Stage Regression with Interacted Independent Variables, 1972-1979

Regression:		Broad definition of R&D workers		Narrow definition of R&D workers	
Dependent variables: change In value-added prices plus effective TFP		14n.1	14n.2	14b.1	14b.2
Independent variables:	Interacted with the average log quantities of:				
Outsourcing (narrow)		0.005	0.159	0.023	0.171
		(0.11)	(1.60)	(0.43)	(1.85)
	Blue-collar labor	0.009	0.003	0.004	0.003
		(1.04)	(0.48)	(0.61)	(0.43)
	White-collar Labor	-0.010	0.009	-0.006	0.010
		(0.96)	(1.02)	(0.61)	(0.99)
	Capital	-0.002	-0.023	-0.004	-0.026
		(0.28)	(1.61)	(0.46)	(1.81)
$[\text{Outsourcing}]^2$ (narrow)			-7.783		-9.121
			(1.79)		(2.02)
Outsourcing (difference)		0.062	0.185	0.055	0.166
		(1.17)	(1.26)	(1.06)	(1.07)
	Blue-collar labor	0.018	0.044	0.027	0.057
		(1.83)	(2.00)	(2.25)	(2.47)
	White-collar Labor	-0.011	-0.026	-0.021	-0.044
		(1.35)	(2.23)	(1.99)	(3.31)
	Capital	-0.016	-0.043	-0.018	-0.044
		(1.53)	(1.49)	(1.62)	(1.44)
$[\text{Outsourcing}]^2$ (difference)			-3.514		-4.401
			(1.36)		(1.43)
R&D factors		0.434	0.380	0.293	0.160
		(1.34)	(1.24)	(1.26)	(0.90)
	Blue-collar labor	-0.110	-0.091	0.015	0.016
		(1.32)	(1.22)	(0.26)	(0.27)
	White-collar Labor	0.066	0.060	0.027	0.002
		(1.03)	(0.91)	(0.68)	(0.06)
	Capital	-0.015	-0.016	-0.053	-0.029
		(0.36)	(0.33)	(1.12)	(0.78)
Constant		0.072	0.072	0.072	0.072
		(495.44)	(456.58)	(476.75)	(435.63)
R^2		0.218	0.249	0.260	0.295
N		445	445	445	445

Notes: Dependent variables are computed from primary factors excluding R&D workers. Numbers in parentheses are the absolute values of t statistics and standard errors in all regressions are robust to heteroskedasticity and correlation in the errors within two-digit industry groups. In addition, a dummy variable, which is log of the 1980 CPS industry classification, is also included in each regression. All independent variables are measured as annual changes and weighted by average industry share of all manufacturing shipments. All regressions also include computer share and high-tech share, which are measured using ex post rental prices, as independent variables. For parsimony, only variables related to outsourcing and R&D factors are reported.

Table 15. Estimated Factor-Price Changes: 1972-1979

Dependent variables in first-stage regressions:	14n	14n	14b	14b	14n	14b
(1) Employing ex post rental prices for computer share and high-tech share						
Dependent variable: Change in Share-weighted Factor Prices explained by:	Outsourcing (narrow)	Outsourcing (difference)	Outsourcing (narrow)	Outsourcing (difference)	R&D payment share	R&D payment share
Independent variables:						
Blue-collar labor share	0.003	0.019	0.002	0.025	0.000	-0.002
	(0.74)	(1.97)	(0.59)	(2.54)	(0.03)	(0.64)
White-collar labor share	-0.007	-0.051	-0.013	-0.077	-0.002	0.000
	(0.66)	(1.79)	(0.99)	(2.28)	(0.48)	(0.02)
Difference between white-collar and blue-collar share	-0.010	-0.070	-0.016	-0.102	-0.002	0.002
	(0.74)	(1.90)	(0.99)	(2.44)	(0.30)	(0.15)
(2) Employing ex ante rental prices for computer share and high-tech share						
Difference between white-collar and blue-collar share	-0.044	-0.066	-0.042	-0.105	-0.005	-0.005
	(1.44)	(1.87)	(1.69)	(3.14)	(0.93)	(0.39)

Notes: All dependent variables are computed from the regressions, including quadratic terms of outsourcing (narrow) and outsourcing (difference). Numbers in parentheses are the absolute values of t statistics.

This study also employs data from 1972 to 1979 to estimate the first-stage regression with interaction terms. In Table 14, it can be seen that there is a *complimentary* relationship between blue-collar workers and outsourcing (difference) and a *substitutional* relationship between white-collar workers and outsourcing (difference) in affecting productivity. The results of Tables 12 and 13 show that the labor intensity of the outsourcing industry determines not only the effects of outsourcing on product prices, but also the way structural variables progress industry productivity. R&D factors have the expected positive sign when they are interacted with white-collar workers, but the coefficients are not significant. Turning to the second-stage regression, the only significant result is outsourcing (difference) in Table 15. The positive coefficient on blue-collar workers and negative one on white-collar workers makes the relative wage of white-collar to blue-collar decrease.

3.4 Concluding Remarks

The argument of whether outsourcing causes wage deterioration of unskilled labor has been supported by the evidence proposed by Feenstra and Hanson (1996) and Feenstra and Hanson (1999). However, an unsolved puzzle of outsourcing is why the effects of outsourcing on wage inequality in most empirical papers found in the 1980s can not be seen in the 1970s. Two additional questions arise from this puzzle. First, did all skilled labor’s wages become worse because of outsourcing? Second, is the falling relative wage of skilled labor to unskilled labor caused by increasing wages of unskilled labor or decreasing wages of skilled labor?

By borrowing the framework of international fragmentation from Jones and Kierzkowski (2001) and Jones (2005), this study finds that the change in the skilled/unskilled labor ratio of the outsourcing industry is a possible explanation for the outsourcing puzzle in the 1970s. If the outsourcing industry is relatively skilled-labor-intensive compared to the non-outsourcing industry, the relative wage of skilled labor increases, but if the outsourcing industry is relatively unskilled-labor-intensive, the relative wage of skilled labor decreases.

This study tests the theoretical explanation empirically. To answer the additional questions of the outsourcing puzzle, this paper adopts the idea of quality ladders and product cycles and considers laborers who conduct innovation or R&D to be a different kind of labor force than other skilled laborers. Therefore, there are three kinds of labor in this study - R&D workers, white-collar workers, and blue-collar workers. By employing the NBER Productivity Database and March CPS data to construct a new data set with three kinds of labor and regression estimation to check the influence of structural variables, including outsourcing on workers' wages, I find that R&D workers always benefit from outsourcing. The relative wage of white-collar workers was increasing because of outsourcing in the 1980s, but decreasing in the 1970s. The falling relative wage of white-collar workers in the 1970s was caused by the decreasing wages of white-collar workers.

This paper focuses on the wages of workers and not their welfare. However, wages just are part of the influence of outsourcing on labor. The welfare issues will be pursued in next chapter.

CHAPTER IV
BEYOND THE WAGE INEQUALITY, THE IMPACT OF OUTSOURCING ON THE U.S. LABOR MARKET

4.1 Introduction

Beyond wage inequality, there are other important issues related to outsourcing that have been ignored by researches. The stability of laborers' jobs, for example, could be affected by outsourcing as well. If outsourcing decreases the demand for unskilled labor, the consequence after reducing wages is layoff. As for workers, low wage means less income but layoff means a loss of income and a search for new employment. Unemployment is not only a personal problem but has social consequences. Thus, the effects of outsourcing are more complicated if we also take job stability into consideration.

Also, the effects on job stability from outsourcing lead to the changes in the hiring of new workers. Workers with different background may face different changes in the demand for their labor. Outsourcing enterprises' preferences for employees play an important role. According to Feenstra and Hanson (1999) and Hsu (2006), outsourcing decreased the wages of unskilled labor in the 1980s. Therefore, after outsourcing, employers can choose to retain original unskilled workers with lower pay or lay off current workers and hire new ones with lower pay. Their decisions also influence other employers who do not outsource. First, since outsourcing firms decrease their demand for unskilled labor, non-outsourcing firms can pay less to hire unskilled workers with the same quality or higher. As for unskilled jobs, which require physical strength, age is an important factor to be considered when hiring. Besides, the role of union is also important. Union usually controls by the labor with more tenure or seniority. When outsourcing firms need to lay off workers, laborers who have less tenure have higher probability to be laid off.

Second, the wages of skilled labor are increased by outsourcing. Skilled workers may not be attracted to employers who do not decide to outsource. As for skilled workers, normally a worker's wage increases with seniority since experience is more important than physical strength for these jobs. Outsourcing industries become more attractive to skilled workers who have higher seniority because of the increasing wage in outsourcing industries. Thus, the average age of skilled labor in outsourcing industries may be higher than the one of the industries that do not outsource. Also, education level is an important determinant of wages for skilled workers. In sum, outsourcing may influence the average age and years of completed education of workers in both outsourcing and non-outsourcing industries.

Outsourcing can also affect women's labor force participation. Usually, women spend more time on domestic activities than men do, and these activities are their opportunity costs of working for a paid job. If outsourcing increases the wages, it increases the probability for a woman to get a salary which is higher than her reservation price for joining the labor market. Skilled workers or non-production workers are those groups favored by outsourcing in the 1980s. I expect a positive effect on women's participation in outsourcing industries.

Thus, this study focuses on the employment impacts from outsourcing. I discuss not only the total number of employment, but also the job stability and inflows and outflows between different groups of labor. Following Ureta (1992) and Diebold et al (1997), I employ *Current Population Survey* (CPS) data to evaluate the job retention rates to understand the effects of outsourcing on job stability of workers during the 1980s. Also, the discussion above tells us that outsourcing can affect laborers' inflows and outflow across industries by age, education year and gender. Examining the changes of workers' demographic characteristic across manufacturing industries to see whether the changes can be explained by outsourcing can help us to see the movements between different groups of labor.

After examining the changes of employment, this paper shows some possible cases for the movements of labor due to increasing outsourcing. Thus, for understanding the directions and features of laborers' inflows and outflows, this paper needs to examine the effects of outsourcing on average age, education, the gender-ratio, and tenure years for all kinds of workers. The data on outsourcing are crucial to this study. Feenstra and Hanson (1996) use the ratio of estimated imports of intermediate inputs in the total purchase of non-energy material to proxy outsourcing. This study follows their estimation methods. Also, Hsu (2006) finds that the influence from outsourcing on the skilled labor who conducts R&D is different from the skilled labor who works for manufacturing production. Following Hsu's study, this paper separates skilled labor into white-collar workers who work in manufacturing, and R&D workers who conduct innovation of new products.

4.2 The Questions

In the labor market, outsourcing affects labor by shifting labor demand not only from a source country to a host country, but also from the industries whose outsourcing fractions are comparatively higher to the industries whose outsourcing fractions are comparatively lower. I name the first group of industries high outsourcing industries and the second group of industries low outsourcing industries. The influence of outsourcing on changes in labor demand can be known by testing wage changes. Feenstra and Hanson (1999) employ two stage regressions to estimate the change in laborers' wages due to the changes in the outsourcing fraction. They find the wages of production workers were decreased by outsourcing and the wages of non-production workers were increased in the 1980s. Hsu (2006) improves Feenstra and Hanson's workers by using working-hour data and splitting skilled labor into two categories. His results show that outsourcing decreased the wages of blue-collar workers and increased the wages of white-collar workers in the 1980s.

Thus, previous literature shows us what the change of wage will be, but the change of wage can provide us little information when laborers are mobile across industries. We also need some information about the change of employment. That is the impact on inflows and outflows of employment in manufacturing industries from outsourcing. Intuitively, the outflows in high outsourcing industries are unskilled workers who have high wages relative to their unskilled counterparts in the developing countries. Under the assumption of full employment, the outflows of employment in those high outsourcing industries also means an inflow of workers into the low outsourcing industries. On the other hand, outsourcing can be thought of as a technology improvement, which pushes industry toward skilled labor intensive production. Thus, the inflows of high outsourcing industries could be skilled labor, which also are the outflows of employment in those low outsourcing industries.

Since the preferences of employers of those outsourcing industries are unknown, the inflows and outflows described above may not happen if the employers in high outsourcing industries prefer their original workers. Thus, the outflows of unskilled labor in high outsourcing industries might not be seen and inflows of unskilled labor in low outsourcing industries are young workers who just join labor market. The inflows of skilled labor in high outsourcing industries might also disappear if the employers do not like the labor the other places. This can be tested empirically.

In the unreported results of Feenstra and Hanson (1996), they find that during the periods 1972-1979 and 1979-1990 outsourcing is positively correlated with the change in the relative employment of skilled labor. These results are consistent with most theoretical thinking that outsourcing industries, after outsourcing their basic part of production, which is mainly done by unskilled labor, concentrate on their advanced part of production, which needs more skilled workers. However, the unreported results only answer half of the questions above. The facts behind their results could be that compared to low outsourcing industries, high outsourcing industries hired more skilled workers, or they did not hire more skilled labor but laid off lots of unskilled workers.

Thus, I decompose the unreported results of relative employment of skilled labor in Feenstra and Hanson (1996) and report them in table 16. The significant negative relationship between employment-change of unskilled workers and the changes of outsourcing is expected. Outsourcing requires high outsourcing industries to hire less unskilled labor than low outsourcing industries. The insignificantly negative correlation between outsourcing and employment of skilled labor, however, is surprising. Although high outsourcing industries have higher relative employment of skilled labor, they did not hire more skilled labor than low outsourcing industries did. The reason that high outsourcing industries have higher relative employment of skilled labor is that they hire much fewer unskilled workers than low outsourcing industries.

After describing the change in the amount of employment, the information on inflows and outflows of employment across industries is still scant. The negative results in table 16 could be caused by a large outflow of employment. For outsourcing, employers might lay off workers due to decreasing labor demand. In this case, the job retention rates of high outsourcing industries are lower than those of low outsourcing industries. On the other hand, the negative results could be caused by a low inflow of employment. After knowing the change of retention rates, comparing the average tenure years can help us determine which case it is. If high outsourcing industries hire more workers than the other industries and their retention rates are lower than others, their average tenure should be lower than low outsourcing industries. Outflow of employment cause the negative coefficient in table 16. Otherwise, if high outsourcing industries have higher average tenure and higher retention rates, it means that high outsourcing industries retain their original workers but do not hire new workers. The low inflow of employment is the main factor causing high outsourcing industries to lose more workers than low outsourcing industries in the 1980s.

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Table 16. The Change of Employment in the 1980s

	Relative Empoyment of Skilled Labor	The Changes of Unskilled Workers	The Changes of Skilled Workers
outsourcing	0.891	-1.290	-0.397
	(3.04)	(2.83)	(0.79)
output	0.098	0.479	0.528
	(3.83)	(2.73)	(3.06)
constant	0.056	-0.222	-0.092
	(4.06)	(11.02)	(4.06)
R^2	0.193	0.449	0.442
N	445	445	445

Note: Numbers in parentheses are the absolute values of t statistics. All regressions are weighted by the industry share in total manufacturing employment and standard errors are robust to heteroskedasticity.

In addition to laborers' tenure, other questions like "Which group of unskilled workers had been laid off and which group of skilled labor had been hired because of outsourcing?" are also interesting. CPS data, however, can not tell us whether the workers leave or had been hired by their present employer because of outsourcing. Nevertheless, we can use average age, years of completed education and gender-ratios of industries to see the inflows and outflows. Since outsourcing firms are willing to pay more for skilled labor and pay less for unskilled labor, skilled laborers with high quality may want to flow into outsourcing industries and unskilled labor with high quality may want to flow out of outsourcing industries. Years of completed education can be thought of as a signal of laborers' quality for skilled labor. Examining the average years of completed education among manufacturing industries by running a regression with outsourcing as an explanatory variable can tell us whether the inflow and outflow of skilled labor happened. A positive relationship between the change of average years of education and outsourcing of skilled labor is expected.

Besides laborers' years of education, age is another important signal for quality. Especially for skilled labor, seniority and experience are usually an essential requirement. The change of average ages of industries can tell us whether employers hire young workers. A positive relationship is expected in a regression of average age of skilled labor with outsourcing. Young workers have more physical strength than old workers. Most occupations for unskilled labor require physical strength. If employers evaluate unskilled labor's quality by their physical strength, a negative relationship between the change of average age and the change of outsourcing can be seen when we estimate the effects of outsourcing on unskilled labor. Besides, Young workers might have more years of education than old workers do. Another expected negative effect of outsourcing is on the change of years of education of unskilled labor.

Women are usually the ones who sacrifice their opportunity to work by staying at home. Thus, the expenditure of doing housework and taking care of children becomes a part of the reservation price for women to join labor force. If the expenditure is high or the working wage is low, some women might leave the labor force. On the contrary, if the expenditure is low and wage is higher than the expenditure, those women can hire someone to do their housework and join the labor market. If outsourcing increases the wages, it also increases the probability for a woman to get a salary which is higher than her reservation price for joining the labor market. Thus, it might increase the labor supply. In figure 12, suppose normally everyone has the same basic reservation price when considering whether joining the labor market, which is w_0. When the wage is over w_0, men and women who do not need to do housework join the labor market. If the wage is over w_0', those women who need to stay at home to do housework can join the labor market and the total labor supply curve moves to the right. Thus, if an increase in outsourcing can increase the demand of labor, it is possible that the women's labor force participation can be increased. In the figure 10, the equilibrium quantity of labor moves from l_1 to l_2 and the wage moves from w_1 to w_2 because of the increasing outsourcing. The regressions of gender-ratio are used to examine this effect of outsourcing. I expect a significant negative relationship between the change of gender-ratio and the change of outsourcing. This means that women's participation is increasing in outsourcing industries in the 1980s.

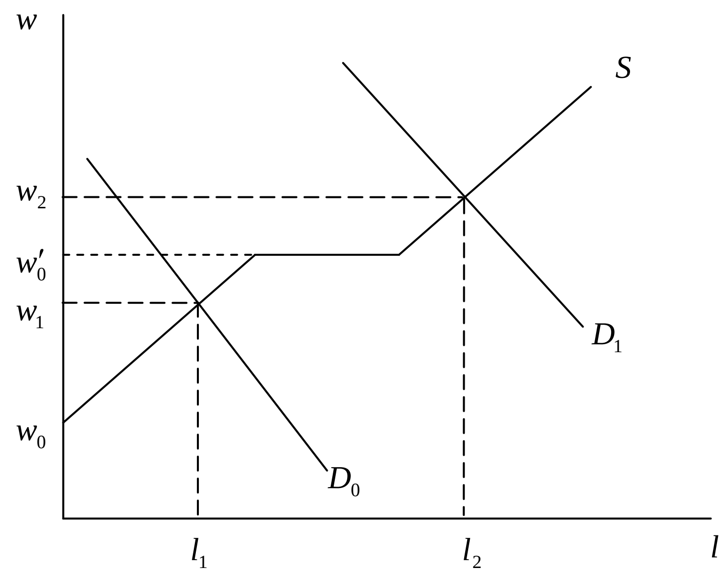

Figure 12. Labor market

4.3 Data

Following Ureta (1992) and Diebold, et al. (1997), this paper uses 1983, 1987, and 1991 CPS tenure supplements included in January CPS. The job tenure question on the CPS is "How long has …been working continuously for his present employer (or self-employed)?" A respondent's answer is his or her tenure. January CPS data also have information regarding age, years of education completed, and sex of respondents. A gender-ratio stands for the male-female ratio of an industry.

Since Hsu (2006) finds that it is necessary to separate skilled labor into white-collar and R&D workers when we investigate the impact of outsourcing on labor, this study separates skilled labor following Hsu's paper. Hsu (2006) also mention about the problem when we separate skilled labor into white-collar and R&D workers basing on CPS occupation classification, which is that even if a respondent's occupation in CPS data tells us that he or she should be classified as R&D worker, he or she is not necessarily doing R&D. By using two definitions of R&D workers, which are narrow and broad definition of R&D workers, this problem can be improved.

The first is a narrow definition of R&D workers, includes those occupations in which a high proportion of workers are doing R&D. In the 1980 CPS classification of occupations, they are computer scientists (64-65), mathematical scientists (68), and natural scientists (69-82). The second group is a broad definition of R&D workers that include both narrow definition of R&D workers and occupations in which a lower proportion of workers are doing R&D. In the 1980 CPS classification, they are scientists (64-65, 68, 69-83), engineers (44-62), economists (166), and designers (185). I also consider educational qualification. Respondents who are R&D workers must have finished at least high school. The rest of skilled workers are white-collar workers. The regression results under a decomposition rule of the narrow definition of R&D workers can be thought of as lower-bound results and under the broad definition of R&D workers can be thought of as upper-bound results. The broad definition of R&D may cause estimation problems if a considerable fraction of engineers, economists, and designers are not doing R&D jobs. The narrow definition of R&D may cause underestimation if in fact most engineers, economists, and designers are R&D workers. Thus, comparing results from both specifications can give us a better answer to the questions.

Table 17 summarizes the data of average age, gender-ratio, average education years, average tenure years, outsourcing and real output across manufacturing industries in these three years. The average age of American workers in manufacturing industries was about forty in the 1980s. The average age of skilled workers was a little higher than that of their less skilled counterpart, but the differentials are small. According to the numbers of gender-ratio category, blue-collar jobs are mainly held by men. Most working women are white-collar workers. Comparing the gender-ratios of each year, it can be seen that the gender-ratios of blue-collar workers barely change, but the gender-ratios of white-collar workers decrease year by year. This means that relative to men, more women join the white-collar labor market. Blue-collar jobs, however, requiring more physical strength which limit women’s participation, have barely changed their gender-ratios.

R&D workers have the most years of completed education. Also, white-collar workers need more educational training than blue-collar workers. Generally speaking, regardless of skill level, laborers' average years of completed education increased year by year, and average tenure did not change much from 1983 to 1991 for both unskilled and skilled labor. Skilled laborers did not have more continuous years of service with their present employers than less skilled laborers did.

According to Feenstra and Hanson (1996), outsourcing fractions are measured as the share of imported intermediate inputs in the total purchase of non-energy materials. To estimate imported intermediate inputs requires data of material purchases from *Census of Manufactures* and import data from *NBER International Trade Data*. An estimated imported intermediate for a given industry is that the value of input purchase from each supplier industry times the ratio of imports to total consumption, which is imports plus shipments, in the supplier industry, summed over all supplier industries.[34] They measure outsourcing as the share of imported intermediate input in the total purchase of non-energy material. Since there is no data that could tell us the imported intermediate input, they use alternative estimated imported data. The formula is,

(51) $$Outsourcing_j = \frac{EIM_j}{total\ non\text{-}energy\ material\ purchases}$$

where EIM_i is estimated imported intermediate input for manufacture j. EIM_i computed as

(52) $$EIM_i = \sum_{j=1 \& j \neq i}^{m} IIM_{ij} * SM_j$$

[34] Author gratefully thanks Feenstra and Hanson for providing the data and help.

Table 17. Summary Statistics

Year		Blue-Collar				Skilled				White-Collar (Broad Definition of R&D)			
		Ave.	Max.	Min.	S.D.	Ave.	Max.	Min.	S.D.	Ave.	Max.	Min.	S.D.
1983	Age	39.37	54 (381)	28.64 (190)	1.91	40.64	49.33 (140)	28.5 (201)	2.96	40.93	63 (261)	28.5 (201)	3.23
	Gender-Ratio	0.73	1 (201)	0.09 (151)	0.21	0.64	1 (381)	0 (361)	0.10	0.59	1 (381; 201)	0 (261; 231)	0.10
	Education Years	11.31	13.14 (181)	9.56 (222)	0.76	13.68	15.14 (181)	11.58 (111)	0.67	13.40	15 (381)	11.58 (111)	0.58
	Tenure Years	10.04	16.56 (270)	5.45 (190)	2.31	10.59	21.5 (261)	2 (361)	2.52	10.61	36 (261)	2 (361)	2.70
1987	Age	40.05	46.57 (281)	33.6 (381)	1.78	40.97	46.05 (251)	34.71 (171)	1.93	40.93	47.22 (251)	34.76 (`171)	2.07
	Gender-Ratio	0.74	1	0.12 (151)	0.23	0.62	1 (201)	0 (141)	0.11	0.58	1 (201)	0 (141)	0.10
	Education Years	11.41	13.16 (380)	8.67 (252)	0.70	13.91	16.10 (181)	11.86 (230)	0.70	13.69	15.90 (181)	11.86 (230)	0.61
	Tenure Years	10.42	15.62 (310)	5.8 (381)	2.17	10.84	18 (141)	6.60 (281)	2.31	10.67	18 (141)	4.33 (112)	2.37
1991	Age	39.79	48.14 (140)	29.86 (201)	1.99	40.76	48.58 (162)	30 (361)	2.35	41.14	49.65 (162)	32.33 (361)	2.54
	Gender-Ratio	0.73	1	0 (381)	0.18	0.61	1	0 (261)	0.11	0.56	1	0 (261)	0.11
	Education Years	11.63	13.11 (321)	9.71 (220)	0.71	13.96	16 (220)	12.75 (261)	0.64	13.70	16 (220)	12.29 (272)	0.55
	Tenure Years	10.25	16.68 (340)	5.23 (201)	2.15	10.15	16.82 (272)	3.40 (141)	2.31	10.10	15.86 (272)	3.40 (141)	2.36

Notes: Numbers of Ave. are the average numbers of total manufacturing industries. Numbers of Max. and Min. are the highest and lowest average statistics of all manufacturing industries. Numbers in parentheses are the corresponding 1980 CPS industrial classification codes. If there are more than two industries have the same average age, education, and gender-ratios, the industrial code is omitted.

Table 17. Summary Statistics (Continued)

		White-Collar (Narrow Definition of R&D)				R&D (Broad Definition of R&D)				R&D (Narrow Definition of R&D)			
Year		Ave.	Max.	Min.	S.D.	Ave.	Max.	Min.	S.D.	Ave.	Max.	Min.	S.D.
1983	Age	40.71	49.33 (140)	28.5 (201)	2.92	40.05	57 (110)	23.5 (121)	6.15	38.24	58.5 (210)	22 (121; 180)	10.11
	Gender-Ratio	0.63	1 (381; 201)	0 (361)	0.10	0.84	1	0	0.28	0.73	1	0	o.34
	Education Years	13.62	15.05 (251)	11.58 (111)	0.65	15.19	18 (190)	12 (281)	1.08	15.68	18	12	1.26
	Tenure Years	10.63	21.5 (261)	2 (361)	2.46	10.98	27 (380)	1 (121)	5.15	9.41	32 (270)	1 (310)	7.70
1987	Age	40.93	47 (251)	34.71 (171)	1.94	40.04	52.25 (250)	24 (281)	5.03	40.95	62 (120)	26 (130)	7.16
	Gender-Ratio	0.62	1 (201)	0 (141)	0.11	0.87	1	0 (381)	0.19	0.85	1 (120)	0 (191)	0.28
	Education Years	13.85	15.91 (181)	11.86 (230)	0.67	15.22	17.5 (251)	12 (381)	0.86	15.53	18 (200; 251	12	1.41
	Tenure Years	10.78	18 (141)	4.33 (112)	2.33	11.18	26.5 (112)	1 (281)	4.61	11.32	26.5 (112)	1 (281)	6.04
1991	Age	40.91	48.58 (162)	30 (361)	2.36	39.61	59 (142)	23 (361)	6.01	36.81	50 (292)	23 (101)	4.83
	Gender-Ratio	0.60	1	0 (261)	0.11	0.85	1	0 (191; 291)	0.18	0.74	1	0	0.22
	Education Years	13.90	16 (220)	12.75 (261)	0.61	15.46	18 (121)	12 (231)	0.82	15.81	18 (121; 300)	13 (280)	1.02
	Tenure Years	10.21	16.82 (272)	3.40 (141)	2.33	10.09	30 (142)	1 (251; 281)	4.9	8.8	23 (191)	2 (121; 372)	4.93

Notes: Numbers of Ave. are the average numbers of total manufacturing industries. Numbers of Max. and Min. are the highest and lowest average statistics of all manufacturing industries. Numbers in parentheses are the corresponding 1980 CPS industrial classification codes. If there are more than two industries have the same average age, education, and gender-ratios, the industrial code is omitted.

Table 17. Summary Statistics (Continued)

	Outsourcing					Output (millions of dollars)			
	Ave.	Max.	Min.	S.D.		Ave.	Max.	Min.	S.D.
1982	0.089	0.457	0	0.069	1982	28171	124058	1318	25075
		(381)	(141; 230)				(351)	(381)	
1987	0.116	0.533	0	0.086	1987	34387	205923	1221	33775
		(381)	(230)				(351)	(381)	
1992	0.126	0.57	0	0.094	1991	35117	188046	1268	34574
		(381)	(230)				(351)	(381)	

Notes: Numbers in output are real value of shipment. The based year is 1987. Numbers of Ave. are the average numbers of total manufacturing industries. Numbers of Max. and Min. are the highest and lowest average statistics of all manufacturing industries. Numbers in parentheses are the corresponding 1980 CPS industrial classification codes.

where IIM_{ij} is the purchased flow from manufacture j to i. SM_j is the import share of manufacture j which is

(53) $$SM_j = \frac{imp_j}{imp_j + shp_j}$$

where imp_j is the total imports of manufacture j and shp_j is the total shipment cost of manufacture j.

The data of real output come from the *NBER Productivity Database* [Bartelsman and Gray, 1996]. Using the N*BER Productivity Database* deflator, this study deflates the value of industry shipments. It can be seen that industry, “watch, clocks, and clockwork operated devices,” whose code is 381, has lowest real output and highest outsourcing fraction in all these three years. It can be realized that most of the production of this industry had been shipped to other countries.

One other important aspect of this table is that the differentials across manufacturing industries are considerable for all variables. In this study, I use outsourcing as an explanatory variable to see how much changes across sections can be explained by outsourcing. However, data sources of outsourcing are different from the ones of age, education, and tenure. To capture the features and backgrounds of laborers in the 1980s, CPS data are employed, whose tenure supplements are only available in

1983, 1987, and 1991. Outsourcing fractions, which estimated by imported intermediate purchase, are only available in the years 1982, 1987, and 1992. Since the information of labor in this study derives from January CPS data, there is no question about the year 1983 and 1987. The problems of using data of CPS 1991 and *Census of Manufactures* 1992, however, are unavoidable.

The other important issue to consider when combing information from different datasets is industrial codes. Since *NBER Productivity* Database comes from the Annual Survey Manufactures (ASM), which is coded by 1972 or 1987 Standard Industrial Classification (SIC), it is necessary to convert them into 1980 CPS Industrial Classification (CIC). This can be done by using the converting bridge between 1972 SIC and 1980 CIC provided by the Bureau of the Census. To convert SIC to CIC, some industries classifications in the 1980 CIC have to be merged. Those are census code 122 (merging with 121), 211 (merging with 210), 232 (merging with 241), 301 (merging with 300), 322 (merging with 321), 332 (merging with 331), 350 (merging with 342), 362 (merging with 370), 382 (merging with 381), 390 (merging with 391), and 392 (merging with 391). The total number of manufacturing industries is 72.

Therefore, we have two sources that tell us the employment share of each industry in total manufacturing. One is from CPS data and the other is the ASM. For checking the consistency, this paper computes those shares in each industry in 1983, 1987, and 1991 and draws them together. Figures 13, 14, and 15 are each industry's 1983, 1987, and 1991 employment share in total manufacturing employment, respectively. These two data sources are comparable. The industries with higher employment shares are "Apparel and Accessories, except knit" "Printing, Publishing, & Allied Industries, except Newspapers," "Machinery, except Electrical," "Electrical Machinery, Equipment, and Supplies, n.e.c.," and "Aircraft and Parts." Thus, using the industrial information in CPS data is as accurate as ASM.

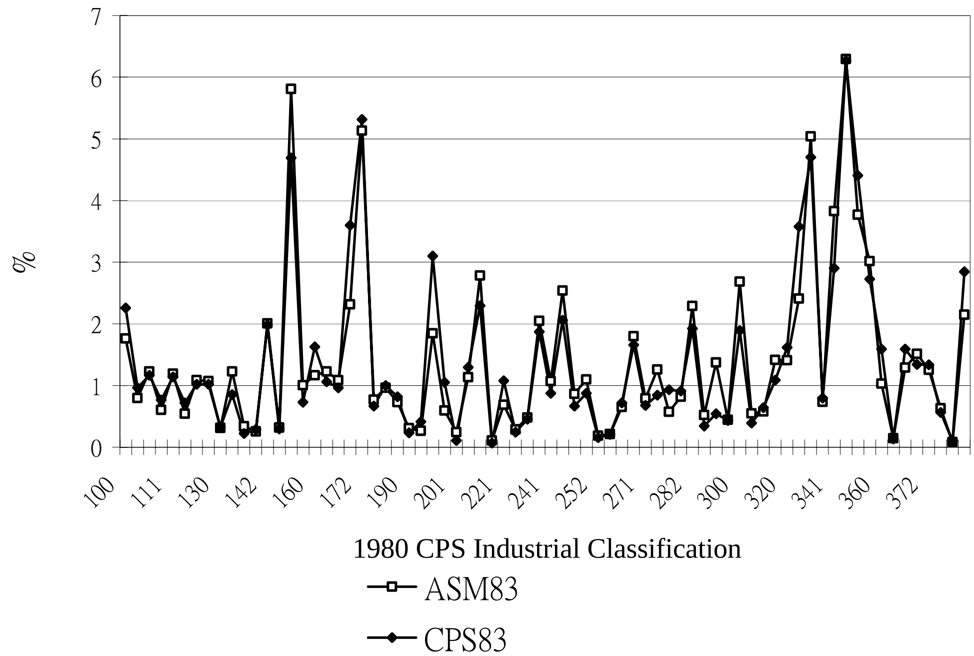

Figure 13. 1983 Industry's Employment Share in Total Manufacturing Employment

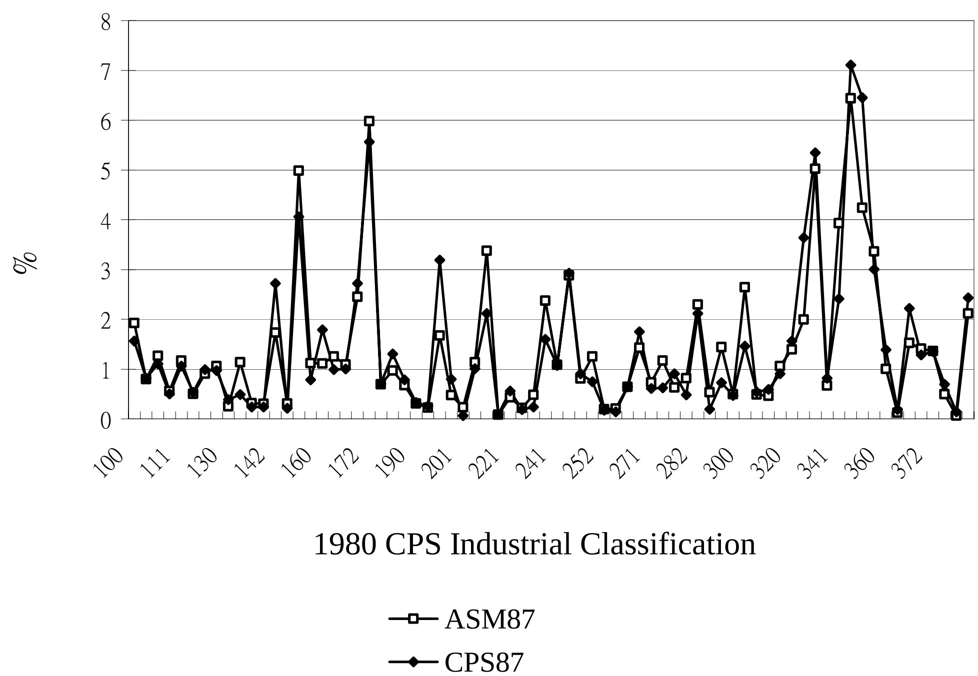

Figure 14. 1987 Industry's Employment Share in Total Manufacturing Employment

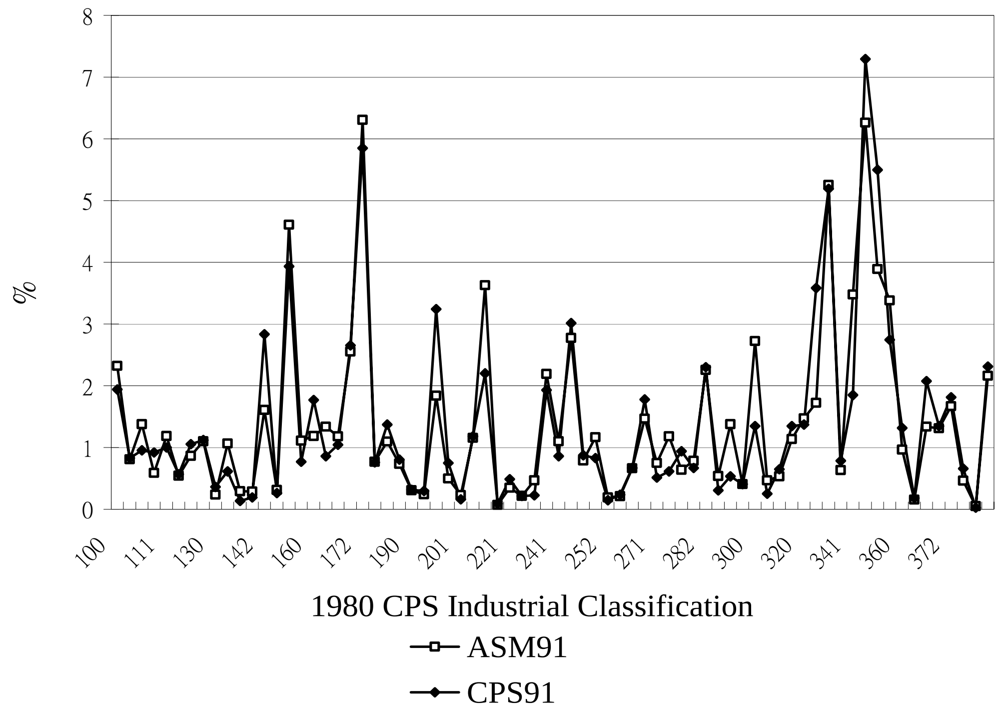

Figure 15. 1991 Industry's Employment Share in Total Manufacturing Employment

4.4 Empirical Results

In this section, I examine the impact of outsourcing on average age, gender-ratios, and education workers in each industry. Then, I examine the influence of outsourcing on job retention rates. There are two periods, 1983-1987 and 1987-1991, studied. After pooling these two periods together, the number of observations increases to 144. There are two types of regressions employed when this study discusses each kind of labor in each topic. The first one is cross-section and time-series model with random effects. The other is ordinary regression including a time dummy. All regressions in this paper are weighted by average industry share of all manufacturing employment in the beginning and ending year. Since information about R&D workers can not be found in some manufacturing industries, their age, gender-ratios, and education-years regressions are ignored. The retention rate can still be computed by using CPS data. The reasons and procedure are discussed below.

4.4.1 Age

According to table 18, generally speaking, an increase in industries' outsourcing increases the average age of both skilled and unskilled labor. The results are expected for skilled labor. Outsourcing increased the wage of skilled labor which increases the hiring of skilled worker with more seniority and experience. The average age increased with time. Since the demand for unskilled labor was decreasing, the increasing average age in unskilled labor suggests that either the outsourcing enterprises retained the original old workers and laid off young worker or they hire new old workers with lower pay. Also, increasing output hinders the age accumulation. The possible reason is the new coming workers. Increasing output also means increasing labor demand. If the new hire are young workers, the average age will decrease.

Table 18. Changes in Workers' Average Age

	Blue-Collar		Skilled		White-Collar (Broad Definition in R&D)		White-Collar (Narrow Definition in R&D)	
ΔSo	12.739	16.870	15.848	15.830	10.642	10.041	16.019	15.920
	(2.31)	(2.69)	(3.45)	(3.42)	(1.97)	(1.85)	(3.52)	(3.47)
$\Delta \ln(y)$	-3.892	-5.123	-4.103	-3.952	-2.563	-2.292	-3.732	-3.465
	(4.67)	(4.54)	(5.22)	(4.73)	(2.73)	(2.34)	(4.81)	(4.19)
D		0.961		-0.198		-0.671		-0.479
		(1.21)		(-0.34)		(-0.97)		(0.82)
Constant	-1.180	-1.609	0.386	0.461	0.401	0.716	0.401	0.601
	(2.38)	(2.91)	(1.23)	(1.13)	(1.12)	(1.48)	(1.28)	(1.49)
N	144	144	144	144	144	144	144	144

Notes: $\Delta \ln(y)$ is the change in log real output. ΔSo is the change in outsourcing. D is the time dummy. When time dummy equals to one, it means the time period in 1983-1987. Regressions without time dummy are estimated by using cross-section and time-series model with random effects. Numbers in parentheses are the absolute values t statistics. All dependent and independent variables are weighted by average industry share of all manufacturing employment in the beginning and ending year.

As for the inflows and outflows between high and low outsourcing industries, according to the results in table 18, the outflows of employment from high to low outsourcing industries could be young unskilled labor and the inflows between high and low outsourcing industries could be old skilled labor. It explains that employers evaluate unskilled labor by their ages, which are proxies of physical strength and evaluate skilled labor by their seniorities, which usually increased with ages. Thus, the remaining question for the results in table 3 is whether the original workers were replaced by those new workers. This question is analyzed below by the regression results of job tenure.

4.4.2 Gender-Ratios

As for the impact of outsourcing on Gender-Ratios of outsourcing industries, in table 19, the only significant influence can be found in white-collar workers. Expectedly, more women joined the labor market because of the increasing wages of white-collar workers. Notice that the significant coefficients become weak if engineers, economists, and designers are included in white-collar labor. This result is not unexpected because engineers are the major occupation composing the difference between the broad definition and the narrow definition of R&D workers, and few women choose these occupations as a career.

Table 19. Changes in Workers' Gender-Ratios

	Blue-Collar		Skilled		White-Collar (Broad Definition in R&D)		White-Collar (Narrow Definition in R&D)	
ΔSo	0.094	0.089	-0.114	-0.102	-0.480	-0.476	-0.223	-0.213
	(0.63)	(0.59)	(0.57)	(0.51)	(2.15)	(2.10)	(1.07)	(1.01)
Δ ln(y)	-0.012	-0.010	-0.037	-0.043	0.000	-0.002	-0.026	-0.030
	(0.47)	(-0.37)	(1.08)	(1.19)	(0.01)	(0.04)	(0.70)	(0.79)
D		-0.006		0.014		0.005		0.011
		(0.29)		(0.53)		(0.17)		0.42
Constant	0.001	0.004	-0.005	-0.012	-0.005	-0.008	-0.006	-0.011
	(0.13)	(0.29)	(0.41)	(0.66)	(0.37)	(0.39)	(0.44)	(0.61)
N	144	144	144	144	144	144	144	144

Notes: Δ ln(y) is the change in log real output. ΔSo is the change in outsourcing. D is the time dummy. When time dummy equals to one, it means the time period in 1983-1987. Regressions without time dummy are estimated by using cross-section and time-series model with random effects. Numbers in parentheses are the absolute values t statistics. All dependent and independent variables are weighted by average industry share of all manufacturing employment in the beginning and ending year.

4.4.3 Years of Completed Education

According to table 20, the average year of completed education of blue collar workers was decreased by outsourcing in the 1980s. The facts behind the results could be that unskilled workers with higher education left high outsourcing industries or the unskilled labor with more years of completed education would like to work in low outsourcing industries. If young people have a higher education level than old people do, those results are also consistent with the increasing average ages in table 3. The other thinking is that the quality of workers can help us to realize whether the outsourcing enterprise hire better workers. Table 20 shows that outsourcing also could increase white-collar workers' average years of completed education of outsourcing firms if the narrow definition of R&D workers is employed. After increasing the relative wage of white-collar workers, high outsourcing industries hire more educated skilled labor compared to low outsourcing industries.

Table 20. Changes in Workers' Average Years of Completed Education

	Blue-Collar		Skilled		White-Collar (Broad Definition in R&D)		White-Collar (Narrow Definition in R&D)	
ΔSo	-5.196	-24.970	1.376	1.575	1.261	1.548	1.572	1.776
	(3.07)	(7.44)	(1.36)	(1.56)	(1.16)	(1.44)	(1.60)	(1.81)
Δ ln(y)	0.147	-0.500	0.245	0.153	0.207	0.077	0.234	0.140
	(0.67)	(0.83)	(1.39)	(0.84)	(1.10)	(0.40)	(1.37)	(0.79)
D		0.885		0.226		0.321		0.231
		(2.08)		(1.76)		(2.36)		(1.86)
Constant	-2.861	-2.492	0.151	0.046	0.159	0.008	0.144	0.036
	(8.88)	(8.42)	(2.26)	(0.51)	(2.22)	(0.09)	(2.22)	(0.42)
N	144	144	144	144	144	144	144	144

Notes: Δ ln(y) is the change in log real output. ΔSo is the change in outsourcing. D is the time dummy. When time dummy equals to one, it means the time period in 1983-1987. Regressions without time dummy are estimated by using cross-section and time-series model with random effects. Numbers in parentheses are the absolute values t statistics. All dependent and independent variables are weighted by average industry share of all manufacturing employment in the beginning and ending year.

Thus, according to the results in table 18 and 20, the inflows of high outsourcing industries were some skilled laborers with more years of age and completed education and the outflows from them were older unskilled labor with fewer years of completed education. Also, according to table 1, high outsourcing industries did not hire more skilled workers than low outsourcing industries. Therefore, the outflows of skilled labor from high outsourcing industries to low outsourcing industries were considerable. Some skilled labor with fewer years of education could be laid off by high outsourcing industries and were hired by low outsourcing industries. After knowing the regression estimates of job retention rate, one realizes that the outflows of skilled labor from high to low outsourcing industries were the original workers or new hires.

4.4.4 Job Stability

I use a 4 years historical job retention rate to measure the job stability of manufacturing workers. The reason that I do not use a cross-sectional retention rate is because of the focus of this paper, the change of outsourcing. I want to see the impact of the change of outsourcing on the job retention rates and the change can only be seen though historical comparison. The way I compute retention rate follows Ureta (1992) and Diebold, et al. (1997). The 4-year retention rate is calculated as a ratio of the numbers of workers with at least four years tenure in the ending year in the total number of workers to the beginning year. Formally,

(54) $$\hat{R}_j^i = \frac{N_j^i(t+4)}{N_j^i(t)}$$

where R_j^i is estimated 4-year retention rate for i kind of workers in j industry. $N_j^i(t)$ is number of employment of i kind of workers in j industry of t year CPS tenure supplement. $N_j^i(t+4)$ is number of employment of i kind of workers in j industry of $t+4$ year CPS tenure supplement. These retention rates need to be adjusted before comparing them across years.

For adjusting the estimated retention rates, I decompose the estimated retention rates into the part that I can adjust and the part can not be adjusted. The decomposed estimated job retention rate is

(55) $$\hat{R}_j^i = \frac{M(t+4)\times p(t+4)\times st_j(t+4)\times sl_j^i(t+4)\times sv_j^i(t+4)\times q_j^i(t+4)}{M(t)\times p(t)\times st_j(t)\times sl_j^i(t)\times q_j^i(t)}$$

where $M(t+4)$ is the total number of employment in manufacturing industries of t year CPS tenure supplement; $st_j(t)$ is the share of total employment of j industry in t year ; $sl_j^i(t)$ is the share of the i kind of workers in j industry in t year; $sv_j^i(t+4)$ is the 4 years survival rate of the i kind of workers in j industry in t+4 year. The 4 years survival rate is the ratio of the workers with at least 4 years tenure in total number of employment in t+4 year in total number of employment in t year. $p(t)$ is the probability of being chosen as a respondent in year t; $q_j^i(t)$ is the biased probability of being chosen as a respondent i kind of workers in j industry in t year CPS tenure supplement.

Since CPS chooses respondent randomly and their procedure is similar in each year, I assume $p(t)$ are the same across years. $q_j^i(t)$ can vary across years and it make the draw seem not random. To obtain a comparison basing on the same sample sizes, I adjust the estimated retention rate by multiplying an inverse ratio of total number of employment in manufacturing industries of t year CPS tenure supplement in total number of employment in manufacturing industries of t+4 year CPS tenure supplement. Thus the adjusted 4-year retention rate is

(56) $$\hat{R}_j^i = \frac{st_j(t+4)\times sl_j^i(t+4)\times sv_j^i(t+4)\times q_j^i(t+4)}{st_j(t)\times sl_j^i(t)\times q_j^i(t)}$$

Output and outsourcing can have effects on both $st_j(t+4)\times sl_j^i(t+4)$ and $sv_j^i(t+4)$. I expect to see a positive effect of output on both of them. The impacts from outsourcing on survival rate of each kind of workers may be different.

As for R&D workers, their retention rates are difficult to determine in the following two cases. First, no R&D workers can be found in the beginning year, but there are some R&D laborers in the ending year. Second, there are no R&D workers in both beginning year and ending year in some industries. In the first case, one of the factor that cause this problem is a large $M(t+4)$ and a very small $M(t)$, but I still need a number in retention rate before the adjustment of different sample size. To get an acceptable number, I need to guess the number of R&D workers in the *t* year CPS tenure supplement. Assuming the reason why I can not find R&D workers in this industry is that there is a high $q(t+4)$ and a very low $q(t)$ which means that they are unlucky to be found. However, if there were more R&D workers in the beginning year, which is $N_j^{R\&D}(t)$ bigger than $N_j^{R\&D}(t+4)$, they still should be easier to chosen to be respondents. The denominator should be bigger than the numerator. Therefore, the reasonable assumption is that the number of R&D workers in the beginning year was the same as the one in the ending year. This study treats the industries in the second case as having a zero retention rate because the R&D workers in these industries might be minor or could be temporary.

Table 21 illustrates that outsourcing is not harmful to the job stability of the different kinds of workers. The positive significant coefficients of blue-collar workers tell us that the most likely reason for higher age and lower education is because the outsourcing firms retained the original workers and did not recruit new young workers. For increasing output, employers need to increase labor demand which leads to increased job stability among both unskilled and skilled laborers. It also can be seen after comparing the coefficients that R&D workers benefit the most, and white-collar workers and blue-collar the least from outsourcing. These results are consistent with the finding of Hsu (2006) and Feenstra and Hanson (1996).

Table 21. Changes in Laborers' Retention Rates : 1983-1991

	Blue-Collar Workers		Skilled Workers		White-Collar Workers (Broad Definition)		White-Collar Workers (Narrow Definition)		R&D Workers (Broad Definition)		R&D Workers (Narrow Definition)	
ΔSo	2.105	8.722	6.333	7.149	4.781	9.643	4.164	10.061	9.966	11.989	12.194	18.534
	(2.16)	(5.60)	(1.39)	(3.20)	(3.41)	(5.77)	(2.99)	(5.87)	(2.99)	(3.54)	(4.06)	(5.77)
Δ ln(y)	0.479	0.794	0.242	0.320	0.605	0.872	0.524	0.811	0.856	0.797	0.907	1.415
	(3.68)	(2.83)	(2.74)	(1.80)	(2.74)	(2.89)	(2.66)	(2.63)	(1.56)	(1.56)	(1.98)	(2.45)
D		-0.383		-0.198		-0.393		-0.360		0.133		-0.429
		(1.96)		(1.63)		(1.87)		(1.67)		(0.31)		(1.06)
Constant	1.233	1.142	3.853	2.311	3.853	1.244	1.314	1.240	1.288	1.159	0.772	0.682
	(8.69)	(8.38)	(4.06)	(2.68)	(4.06)	(8.50)	(8.67)	(8.26)	(5.30)	(3.91)	(2.93)	(2.43)
N	144	144	144	144	144	144	144	144	144	144	144	144

Notes: Δ ln(y) is the change in log real output. ΔSo is the change in outsourcing. D is the time dummy. When time dummy equals to one, it means the time period in 1983-1987.Dependent variables are workers' 4 years retention rates during 1983-1987 and 1987-1991. All dependent and independent variables are weighted by average industry share of all manufacturing employment in the beginning and ending year. Regressions without time dummy are estimated by using cross-section and time-series model with random effects. Numbers in parentheses are the absolute values t statistics.

4.4.5 Average Tenure

Table 22 shows the results of regressions of average tenure. Although outsourcing increases the average tenure, those effects are not statistically significant. Real output also has an insignificant positive coefficient. These results do not mean that there is no effect of outsourcing and real output on job tenure. The positive effect could be weakened when summarizing all workers' tenure together. Checking the change of retention rate can clarify the effects.

Basing on the results in table 21 and 22, the insignificant coefficients also illustrate that the inflows and outflows of employment were very frequent in both high and low outsourcing industries. Although outsourcing causes some inflows and outflows of employment across industries and, so far the results in table 18, 19, and 20 support this idea, those flows might be just one direction.[35]

Table 22. Changes in Workers' Average Tenure Years

	Blue-Collar		Skilled		White-Collar (Broad Definition in R&D)		White-Collar (Narrow Definition in R&D)	
ΔSo	4.784	5.219	5.044	5.096	1.178	1.026	4.617	4.432
	(1.54)	(1.67)	(1.35)	(1.36)	(0.29)	(0.25)	(1.22)	(1.16)
$\Delta \ln(y)$	0.280	0.081	-0.531	-0.555	0.863	0.932	-0.225	-0.140
	(0.52)	(0.14)	(0.82)	(0.82)	(1.23)	(1.27)	(0.34)	(0.20)
D		0.005		0.001		-0.002		-0.002
		(1.25)		(0.12)		(0.33)		-0.43
Constant	0.001	-0.002	-0.001	-0.001	-0.001	0.000	-0.001	0.000
	(0.32)	(0.6)	(0.45)	(0.42)	(0.45)	(0.11)	(0.43)	(0.03)
N	144	144	144	144	144	144	144	144

Notes: $\Delta \ln(y)$ is the change in log real output. ΔSo is the change in outsourcing. D is the time dummy. When time dummy equals to one, it means the time period in 1983-1987. Regressions without time dummy are estimated by using cross-section and time-series model with random effects. Numbers in parentheses are the absolute values t statistics. All dependent and independent variables are weighted by average industry share of all manufacturing employment in the beginning and ending year.

The results in table 22, however, tell us that those flows went in two directions.

[35] Here I only consider the case under full employment. If unemployment is also considered, it is difficult to use the results in table 7 to show the direction of flow of employment.

The reason is that if just high outsourcing industries outflow or inflow employment, high outsourcing industries should have significant higher or lower average tenure than low outsourcing industries. The insignificant results in table 22 indicate two directions flows of employment between high and low outsourcing industries in the 1980s.

4.5 Concluding Remarks

Although the debate of whether outsourcing contributes to wage inequality between skilled and unskilled labor in the U.S. during the 1980s had been settled by previous theoretical and empirical studies. There are other issues which are also important but have been ignored. Laborers' job tenure could be affected by outsourcing. Also, the influences of outsourcing on inflow and outflow of labor between the industries that highly outsource their production and industries that do not focus on outsourcing is important. Workers with different demographic characteristics like average age, years of completed education, and gender may face different changes in their labor demand.

In this study, following Ureta (1992) and Diebold, et al. (1997), I employ Current Population Survey (CPS) data to discuss the impact of outsourcing on the changes of workers' demographic characteristics and job retention rates in the American manufacturing industries during the 1980s. Estimating outsourcing follows Feenstra and Hanson (1996) by employing the ratio of estimated imports of intermediate inputs in the total purchase of non-energy material. Also, this paper separates skilled labor into white-collar workers who work in manufacturing, and R&D workers who conduct innovation of new products by two definitions of R&D workers.

This study finds that outsourcing decreases blue-collar laborers' average years of completed education; increased the hiring of women in white-collar jobs, and increased job stability of both unskilled and skilled laborers. Thus, outsourcing does not take away unskilled laborers' jobs but hinders new hiring of young unskilled workers. This study can be seen as a welfare check of the impact of outsourcing on laborers.

As for the inflows and outflows between high and low outsourcing industries, the results of average years of tenure also illustrate that the inflows and outflows of employment were very frequent in both high and low outsourcing industries. The employment flows between high and low outsourcing were two directions in the 1980s. On the one hand, the inflows of employment in high outsourcing industries were some skilled laborers with more years of age and completed education. The outflows of employment in high outsourcing industries were unskilled labor with more years of age and less years of completed education, and some skilled labor with fewer years of education. On the other hand, those inflows and outflows of employment in high outsourcing industries were also the outflows and inflows of employment in low outsourcing industries.

CHAPTER V
CONCLUSIONS

The argument of whether outsourcing causes wage deterioration for unskilled labor has been much supported by the new evidence proposed by Feenstra and Hanson (1996;1999). In their papers, outsourcing can explain 30.9% of the increase in the non-production wage share and 15% of the increase in the relative wage of non-production workers from 1979 to 1990. The empirical results of 1972-1979, however, are completely different from those for 1979-1990 and seem to contradict the concepts of the outsourcing theory.

In my dissertation, first, a dynamic product cycle model with three kinds of labor inputs, scientists, white-collar workers, and blue-collar workers, is constructed. It is shown that only scientists unambiguously benefit from outsourcing. Other skilled laborers are hurt by outsourcing. After relaxing the assumption of homogenous producers, if outsourcing industries, compared to non-outsourcing industries, are absolutely white-collar-intensive, an increase in the outsourcing fraction will raise the relative wage of white-collar workers. If outsourcing industries, compared to non-outsourcing industries are absolutely blue-collar-intensive, an increase in the outsourcing fraction will decrease the relative wage of white-collar workers.

The wage level of white-collar laborers can be increased by outsourcing if the total effect of the skilled effect and the scale effect dominates the substitution effect, and the cost reduction caused by outsourcing is sufficient. The wage level of blue-collar workers may rise after an increase in outsourcing if outsourcing industries, compared to non-outsourcing industries are absolutely blue-collar-intensive.

Second, by borrowing the framework of international fragmentation from Jones and Kierzkowski (2001) and Jones (2005), Chapter III finds that the change in the skilled/unskilled labor ratio of the outsourcing industry is a possible explanation for the outsourcing puzzle in the 1970s. If the outsourcing industry is relatively skilled-labor-intensive compared to the non-outsourcing industry, the relative wage of skilled labor increases, but if the outsourcing industry is relatively unskilled-labor-intensive, the relative wage of skilled labor decreases.

By employing the NBER Productivity Database and March CPS data to construct a new data set with three kinds of labor and regression estimation to check the influence of structural variables, including outsourcing on workers' wages, I find that R&D workers always benefit from outsourcing. The relative wage of white-collar workers was increasing because of outsourcing in the 1980s, but decreasing in the 1970s. The falling relative wage of white-collar workers in the 1970s was caused by the decreasing wages of white-collar workers.

Although the debate of whether outsourcing contributes to wage inequality between skilled and unskilled labor in the U.S. during the 1980s had been settled by previous theoretical and empirical studies. There are other issues which are also important but have been ignored. Laborers' job tenure could be affected by outsourcing. Also, the influences of outsourcing on inflow and outflow of labor between the industries that highly outsource their production and industries that do not focus on outsourcing is important. Workers with different demographic characteristics like average age, years of completed education, and gender may face different changes in their labor demand.

In the chapter IV of my dissertation, following Ureta (1992) and Diebold, et al. (1997), I employ Current Population Survey (CPS) data to discuss the impact of outsourcing on the changes of workers' demographic characteristics and job retention rates in the American manufacturing industries during the 1980s. Estimating outsourcing follows Feenstra and Hanson (1996) by employing the ratio of estimated imports of intermediate inputs in the total purchase of non-energy material. Also, this paper separates skilled labor into white-collar workers who work in manufacturing, and R&D workers who conduct innovation of new products by two definitions of R&D workers.

I find that outsourcing decreases blue-collar laborers' average years of completed education; increased the hiring of women in white-collar jobs, and increased job stability of both unskilled and skilled laborers. Thus, outsourcing does not take away unskilled laborers' jobs but hinders new hiring of young unskilled workers. This study can be seen as a welfare check of the impact of outsourcing on laborers.

As for the inflows and outflows between high and low outsourcing industries, the results of average years of tenure also illustrate that the inflows and outflows of employment were very frequent in both high and low outsourcing industries. The employment flows between high and low outsourcing were two directions in the 1980s. On the one hand, the inflows of employment in high outsourcing industries were some skilled laborers with more years of age and completed education. The outflows of employment in high outsourcing industries were unskilled labor with more years of age and less years of completed education, and some skilled labor with fewer years of education. On the other hand, those inflows and outflows of employment in high outsourcing industries were also the outflows and inflows of employment in low outsourcing industries.

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APPENDIX A

A.1. $\partial E(w^N)/\partial w^N$ & $\partial E(w^N)/\partial \alpha$

$$E(w^N;\alpha)=\frac{L_N^W a_1^{NB}-L_N^B a_1^{NW}}{\delta n_2\left(a_2^{NW}a_1^{NB}-a_2^{NB}a_1^{NW}\right)}.$$

$$\frac{\partial E}{\partial w^N}\times\left(\frac{n_2}{\lambda}\right)=\frac{\left(a_2^{NW}a_1^{NB}-a_2^{NB}a_1^{NW}\right)\left(L_N^W a_1^{'NB}-L_N^B a_1^{'NW}\right)}{\left(a_2^{NW}a_1^{NB}-a_2^{NB}a_1^{NW}\right)^2}-$$

$$\frac{\left(L_N^W a_1^{NB}-L_N^B a_1^{NW}\right)\left(a_2^{'NW}a_1^{NB}+a_2^{NW}a_1^{'NB}-a_2^{'NB}a_1^{NW}-a_2^{NB}a_1^{'NW}\right)}{\left(a_2^{NW}a_1^{NB}-a_2^{NB}a_1^{NW}\right)^2}.$$

By assuming $a_1^{'NW}=a_2^{'NW}$ and $a_1^{'NB}=a_2^{'NB}$, it becomes

$$=\frac{L_N^B\left(a_2^{NW}-a_1^{NW}\right)\left(a^{'NB}a_1^{NW}-a^{'NW}a_1^{NB}\right)+L_N^W\left(a_2^{NB}-a_1^{NB}\right)\left(a^{'NW}a_1^{NB}-a^{'NB}a_1^{NW}\right)}{\left(a_2^{NW}a_1^{NB}-a_2^{NB}a_1^{NW}\right)^2}$$

$$=\frac{\left(a^{'NW}a_1^{NB}-a^{'NB}a_1^{NW}\right)\left[L_N^W\left(a_2^{NB}-a_1^{NB}\right)-L_N^B\left(a_2^{NW}-a_1^{NW}\right)\right]}{\left(a_2^{NW}a_1^{NB}-a_2^{NB}a_1^{NW}\right)^2}.$$

Thus,

if $a_2^{NB}>a_1^{NB}$ and, $a_2^{NW}<a_1^{NW}$ then $\frac{\partial E}{\partial w^N}<0$

if $a_2^{NB}<a_1^{NB}$ and $a_2^{NW}>a_1^{NW}$ then $\frac{\partial E}{\partial w^N}>0$

$$\frac{\partial E}{\partial \alpha}\times\left(\frac{n_2}{\lambda}\right)=\frac{\left(a_2^{NW}a_1^{NB}-a_2^{NB}a_1^{NW}\right)\left(L_N^W a_1^{'NB}-L_N^B a_1^{'NW}\right)}{\left(a_2^{NW}a_1^{NB}-a_2^{NB}a_1^{NW}\right)^2}-\frac{\left(L_N^W a_1^{NB}-L_N^B a_1^{NW}\right)\left(a_2^{NW}a_1^{'NB}-a_2^{NB}a_1^{'NW}\right)}{\left(a_2^{NW}a_1^{NB}-a_2^{NB}a_1^{NW}\right)^2}$$

$$=\frac{\left(L_N^W a_2^{NB}-L_N^B a_2^{NW}\right)\left(a_1^{'NW}a_1^{NB}-a_1^{'NB}a_1^{NW}\right)}{\left(a_2^{NW}a_1^{NB}-a_2^{NB}a_1^{NW}\right)^2}.$$

Therefore, $\frac{\partial E}{\partial \alpha}$ depends on whether $\left(L_N^W a_2^{NB}-L_N^B a_2^{NW}\right)$ is positive or not.

A.2. $\partial\kappa/\partial w^N$ & $\partial\kappa/\partial\alpha$

$\kappa = a_2^{NW}L_N^B - a_2^{NB}L_N^W / a_1^{NB}L_N^W - a_1^{NW}L_N^B$

$$\frac{\partial\kappa}{\partial w^N}=\frac{\left(a_1^{NB}L_N^W-a_1^{NW}L_N^B\right)\left(a_2^{'NW}L_N^B-a_2^{'NB}L_N^W\right)-\left(a_2^{NW}L_N^B-a_2^{NB}L_N^W\right)\left(a_1^{'NB}L_N^W-a_1^{'NW}L_N^B\right)}{\left(a_1^{NB}L_N^W-a_1^{NW}L_N^B\right)^2}$$

Since I assume $a_1^{'NW}=a_2^{'NW}$ and $a_1^{'NB}=a_2^{'NB}$, $\frac{\partial\kappa}{\partial w^N}$ becomes

$$=\frac{\left(\left(a_2^{NB}-a_1^{NB}\right)L_N^W+\left(a_1^{NW}-a_2^{NW}\right)L_N^B\right)\left(a^{'NB}L_N^W-a^{'NW}L_N^B\right)}{\left(a_1^{NB}L_N^W-a_1^{NW}L_N^B\right)^2}.$$

Thus,

if $a_2^{NB} > a_1^{NB}$ and, $a_2^{NW} < a_1^{NW}$ then $\frac{\partial\kappa}{\partial w^N} > 0$ and $\frac{\partial r_1}{\partial w^N} > 0$

if $a_2^{NB} < a_1^{NB}$ and $a_2^{NW} > a_1^{NW}$ then $\frac{\partial\kappa}{\partial w^N} < 0$ and $\frac{\partial r_1}{\partial w^N} < 0$

$$\frac{\partial k}{\partial\alpha}=\frac{\left(L_N^B a_2^{NW}-L_N^W a_2^{NB}\right)\left(a_1^{'NW}L_N^B-a_1^{'NB}L_N^W\right)}{\left(a_1^{NB}L_N^W-a_1^{NW}L_N^B\right)^2}.$$

Therefore, $\frac{\partial k}{\partial\alpha}$ depends on whether $\left(L_N^B a_2^{NW}-L_N^W a_2^{NB}\right)$ is positive or negative.

E is positive, and by equation (41), *k* is positive. If $a_2^{NB} < a_1^{NB}$ and $a_2^{NW} > a_1^{NW}$, the denominator of *E* is positive, which means the numerator of *E* has to be positive. That is, $\left(a_1^{NB}L_N^W - a_1^{NW}L_N^B\right)$ is positive. Since the numerator of *E* is also the denominator of *k*,

$\left(L_N^B a_2^{NW} - L_N^W a_2^{NB}\right)$ has to be positive. On the contrary, if $a_2^{NB} > a_1^{NB}$ and $a_2^{NW} < a_1^{NW}$, $\left(L_N^B a_2^{NW} - L_N^W a_2^{NB}\right)$ is negative. In sum, if $a_2^{NB} > a_1^{NB}$ and, $a_2^{NW} < a_1^{NW}$, then $\frac{\partial E}{\partial w^N} < 0$, $\frac{\partial \kappa}{\partial w^N} > 0$, $\frac{\partial r_1}{\partial w^N} > 0$, $\frac{\partial k}{\partial \alpha} < 0$, and $\frac{\partial E}{\partial \alpha} > 0$. If $a_2^{NB} < a_1^{NB}$ and $a_2^{NW} > a_1^{NW}$, then $\frac{\partial E}{\partial w^N} > 0$, $\frac{\partial \kappa}{\partial w^N} < 0$, $\frac{\partial r_1}{\partial w^N} < 0$, $\frac{\partial k}{\partial \alpha} > 0$, and $\frac{\partial E}{\partial \alpha} < 0$.

A.3. $\partial \kappa / \partial w^N + \partial \kappa / \partial \alpha$

Suppose $\frac{\partial a^{NW}}{\partial \alpha} = -\frac{\partial a^{NW}}{\partial w^N}$ and $\frac{\partial a^{NB}}{\partial \alpha} = -\frac{\partial a^{NB}}{\partial w^N}$

$\frac{\partial k}{\partial w^N} + \frac{\partial k}{\partial \alpha} = \frac{\left(L_N^B a_1^{NW} - L_N^W a_1^{NB}\right)\left(a'^{NW} L_N^B - a'^{NB} L_N^W\right)}{\left(a_1^{NB} L_N^W - a_1^{NW} L_N^B\right)^2}$, which is positive if $a_2^{NB} > a_1^{NB}$ and, $a_2^{NW} < a_1^{NW}$.

APPENDIX B

(SW and SB)

$$L_S^W = a_S^W \left[\alpha n^O \delta + n^S\right] E$$

$$= a_S^W \frac{\phi\ (1-n_2)(\alpha\ r_1 \delta + \tau)}{R_1} E$$

where $R_1 = [\phi\mu + r_1(\phi + \mu)]$ & $E(w^N) = \dfrac{L_N^W a_1^{NB} - L_N^B a_1^{NW}}{\delta n_2 \left(a_2^{NW} a_1^{NB} - a_2^{NB} a_1^{NW}\right)}$.

Let $\eta = \dfrac{(\alpha r_1 \delta + \mu)}{R_1} E$

$$\partial\eta / \partial w^N = \frac{R_1\left[\alpha\delta E \dfrac{\partial r_1}{\partial w^N} + (\alpha r_1 \delta + \mu)\dfrac{\partial E}{\partial w^N}\right] - (\phi + \mu)(\alpha\ r_1 \delta + \mu) E \dfrac{\partial r_1}{\partial w^N}}{R_1^{\ 2}}$$

$$= \frac{R_1(\alpha\ r_1 \delta + \mu)\dfrac{\partial E}{\partial w^N} - [(\phi + \mu) - \phi\,\alpha\,\delta\ ]\mu\ E \dfrac{\partial r_1}{\partial w^N}}{R_1^{\ 2}}.$$

Since $\phi\,\alpha\,\delta$ is a small number, the result tells us that $\partial\eta / \partial w^N$ depends on both $\dfrac{\partial E}{\partial w^N}$ and $\dfrac{\partial r_1}{\partial w^N}$.

APPENDIX C

(H1 and H2)

Both w_N^W and w^H are positive and greater than zero. From equation (46), one can get $w_N^W = \left(\frac{E^*}{(\gamma^* + \rho)a_2^r} - w^H \right) \frac{(\gamma^* + \rho)a_2^r}{E^* \delta AC_2^{N*}}$, which gives us a condition is as follows: $\frac{w^H (\gamma^* + \rho)a_2^r}{E^*} < 1$. Plugging w_N^W into equation (45) yields

$$w^H = \frac{E^* \omega}{(\rho + r_1^* + \phi)a_1^r} - \frac{(r_1^* + \tau + \rho)AC_1^{N*} + \phi AC_1^{O*}}{(r_1^* + \tau + \rho)(\rho + r_1^* + \phi)a_1^r} \times \frac{(\gamma^* + \rho)a_2^r}{AC_2^{N*}} \left(\frac{E^*}{(\gamma^* + \rho)a_2^r} - w^H \right) > 0,$$

$$\frac{w^H (\gamma^* + \rho)a_2^r}{E^*} = \frac{\frac{(\gamma^* + \rho)a_2^r \omega}{(\rho + r_1^* + \phi)a_1^r} - \frac{\delta\left[(r_1^* + \tau + \rho)AC_1^{N*} + \phi AC_1^{O*}\right]}{AC_2^{N*}} \times \frac{(\gamma^* + \rho)a_2^r}{(r_1^* + \tau + \rho)(\rho + r_1^* + \phi)a_1^r}}{1 - \frac{(r_1^* + \tau + \rho)AC_1^{N*} + \phi AC_1^{O*}}{AC_2^{N*}} \times \frac{(\gamma^* + \rho)a_2^r}{(r_1^* + \tau + \rho)(\rho + r_1^* + \phi)a_1^r}}$$

$$= \frac{I_1/I_2 - S_1/S_2}{1 - S_1/S_2},$$

where I_1 and I_2 are the intersections of H1 and H2 and S_1 and S_2 are the absolute values of slopes of H1 and H2. For satisfying the condition that w_N^W and w^H are both positive, the following condition need to hold, $0 < \frac{w^H (\gamma^* + \rho)a_2^r}{E^*} < 1$. Therefore, when $S_1/S_2 > 1$, then $S_1/S_2 > I_1/I_2 > 1$, which means that both the slope and the intercept of H1 are larger than H2's. When $S_1/S_2 < 1$, then $S_1/S_2 < I_1/I_2 < 1$, which means that both the slope and the intercept of H1 are smaller than H2's.

APPENDIX D

(Comparative Statics of Increasing α on w^H and w_N^W)

H1 and H2 can be restated as:

H1: $w^H + w_N^W\ S_1 - I_1 = 0$

H2: $w^H + w_N^W\ S_2 - I_2 = 0$,

where S_1 is the slope of H1. S_2 is the slope of H2. I_1 is the intersection of H1. I_2 is the intersection of H2. Total differentiating H1 & H2 with w^H, w_N^W, α, w^N gets:

$$dH1:\quad dw^H + S_1 dw_N^W + w_N^W\left(\frac{\partial S_1}{\partial \alpha}d\alpha + \frac{\partial S_1}{\partial w^N}dw^N\right) - \left(\frac{\partial I_1}{\partial \alpha}d\alpha + \frac{\partial I_1}{\partial w^N}dw^N\right) = 0$$

$$dH2:\quad dw^H + S_2 dw_N^W + w_N^W\left(\frac{\partial S_2}{\partial \alpha}d\alpha + \frac{\partial S_2}{\partial w^N}dw^N\right) - \left(\frac{\partial I_2}{\partial \alpha}d\alpha + \frac{\partial I_2}{\partial w^N}dw^N\right) = 0$$

Using Jacobian matrix to express the equations above is:

$$\begin{bmatrix} H_1^{wH} & H_1^{wW} \\ H_2^{wH} & H_2^{wW} \end{bmatrix}\begin{bmatrix} dw^H \\ dw_N^W \end{bmatrix} = \begin{bmatrix} I_1^{\alpha} - w_N^W S_1^{\alpha} & I_1^{wN} - w_N^W S_1^{wN} \\ I_2^{\alpha} - w_N^W S_2^{\alpha} & I_1^{wN} - w_N^W S_1^{wN} \end{bmatrix}\begin{bmatrix} d\alpha \\ dw^N \end{bmatrix},$$

where

$$H_1^{wH} = \frac{\partial H_1}{\partial w^H} = 1,$$

$$H_2^{wH} = \frac{\partial H_2}{\partial w^H} = 1,$$

$$H_1^{wW} = \frac{\partial H1}{\partial w_N^W} = S_1 = \frac{E\ \delta\left[(r_1 + \tau + \rho)AC_1^N + \phi AC_1^O\right]}{(r_1 + \tau + \rho)(\rho + r_1 + \phi)a_1^r}\, w_N^W$$

$$= \frac{E\delta AC_1}{(\rho + r_1 + \phi)a_1^r}, \text{ where } AC_1 = AC_1(w^N, r_1; \alpha, \phi, \tau) \text{ and } \frac{\partial AC_1}{\partial r_1} > 0, \frac{\partial AC_1}{\partial \alpha} < 0,$$ [36]

$$H_2^{wW} = \frac{\partial H2}{\partial w_N^W} = S_2 = \frac{E \ \delta(AC_2^N)}{(\gamma + \rho)a_2^r},$$

$$S_1^\alpha = \frac{\partial S_1}{\partial \alpha} = \delta \frac{(\rho + r_1 + \phi)a_1^r \left(\frac{\partial E}{\partial \alpha} AC_1 + E \frac{\partial AC_1}{\partial \alpha} \right) - EAC_1 a_1^r \frac{\partial r_1}{\partial \alpha}}{(\rho + r_1 + \phi)^2 a_1^{r\,2}},$$

$$S_2^\alpha = \frac{\partial S_2}{\partial \alpha} = \delta AC_2^N \frac{(\rho + r_2)a_2^r \frac{\partial E}{\partial \alpha} - Ea_2^r \frac{\partial r_2}{\partial r_1} \frac{\partial r_1}{\partial \alpha}}{(\rho + r_2)^2 a_2^{r\,2}},$$

$$S_1^{wN} = \frac{\partial S_1}{\partial w^N} = \delta AC_1 \frac{(\rho + r_1 + \phi)a_1^r \frac{\partial E}{\partial w^N} - Ea_1^r \frac{\partial r_1}{\partial w^N}}{(\rho + r_1 + \phi)^2 a_1^{r\,2}},$$

$$S_2^{wN} = \frac{\partial S_2}{\partial w^N} = \delta AC_2^N \frac{(\rho + r_2)a_2^r \frac{\partial E}{\partial w^N} - Ea_2^r \frac{\partial r_2}{\partial r_1} \frac{\partial r_1}{\partial w^N}}{(\rho + r_2)^2 a_2^{r\,2}},$$

$$I_1^\alpha = \frac{\partial I_1}{\partial \alpha} = \frac{(\rho + r_1 + \phi)a_1^r \frac{\partial E}{\partial \alpha} - Ea_1^r \frac{\partial r_1}{\partial \alpha}}{(\rho + r_1 + \phi)^2 a_1^{r\,2}},$$ [37]

$$I_2^\alpha = \frac{\partial I_2}{\partial \alpha} = \frac{(\rho + r_2)a_2^r \frac{\partial E}{\partial \alpha} - Ea_2^r \frac{\partial r_2}{\partial r_1} \frac{\partial r_1}{\partial \alpha}}{(\rho + r_2)^2 a_2^{r\,2}},$$

[36]The effect of an increase in w^N on AC_j^N is uncertain since hiring more workers whose wages become cheaper could still not decrease their unit cost. Therefore, for simplification, I assume there is no effect of w^N on AC_j in both Northern and Outsourcing Firms.

[37] Since ω doesn't affect our analysis, I assume its value to be a constant and ignore it.

$$I_1^{wN} = \frac{\partial I_1}{\partial w^N} = \frac{\left(\rho + r_1 + \phi\right) a_1^r \frac{\partial E}{\partial w^N} - E a_1^r \frac{\partial r_1}{\partial w^N}}{\left(\rho + r_1^* + \phi\right)^2 a_1^{r\,2}},$$

$$I_2^{wN} = \frac{\partial I_2}{\partial w^N} = \frac{\left(\rho + r_2\right) a_2^r \frac{\partial E}{\partial w^N} - E a_2^r \frac{\partial r_2}{\partial r_1} \frac{\partial r_1}{\partial w^N}}{\left(\rho + r_2\right)^2 a_2^{r\,2}}.$$

Since $S_1 > S_2$, $\Delta = H_1^{wH} H_2^{wW} - H_2^{wH} H_1^{wW} < 0$.

By employing cramer's rule, it can be known:

$$\frac{dw^H}{d\alpha} = \frac{S_2\left(I_1^{\alpha} - w_N^W S_1^{\alpha}\right) - S_1\left(I_2^{\alpha} - w_N^W S_2^{\alpha}\right)}{\Delta}$$

$$\frac{dw_N^W}{d\alpha} = \frac{\left(I_2^{\alpha} - w_N^W S_2^{\alpha}\right) - \left(I_1^{\alpha} - w_N^W S_1^{\alpha}\right)}{\Delta}$$

$$\frac{dw^H}{dw^N} = \frac{S_2\left(I_1^{wN} - w_N^W S_1^{wN}\right) - S_1\left(I_2^{wN} - w_N^W S_2^{wN}\right)}{\Delta}$$

$$\frac{dw_N^W}{dw^N} = \frac{\left(I_2^{wN} - w_N^W S_2^{wN}\right) - \left(I_1^{wN} - w_N^W S_1^{wN}\right)}{\Delta}.$$

Total effect on w^H is equal to the sum of $\frac{dw^H}{d\alpha}$ and $\frac{dw^H}{dw^N}$, which is

$$\frac{dw^H}{d\alpha} + \frac{dw^H}{dw^N} = \frac{S_1\left[\left(I_2^{\alpha} + I_2^{wN}\right) - w_N^W\left(S_2^{\alpha} + S_2^{wN}\right)\right] - S_2\left[\left(I_1^{\alpha} + I_1^{wN}\right) - w_N^W\left(S_1^{\alpha} + S_1^{wN}\right)\right]}{-\Delta},$$

and total effect on w_N^W is equal to the sum of $\frac{dw_N^W}{d\alpha}$ and $\frac{dw_N^W}{dw^N}$, which is

$$\frac{dw_N^W}{d\alpha} + \frac{dw_N^W}{dw^N} = \frac{\left(I_1^{\alpha} + I_1^{wN}\right) - w_N^W\left(S_1^{\alpha} + S_1^{wN}\right) - \left[\left(I_2^{\alpha} + I_2^{wN}\right) - w_N^W\left(S_2^{\alpha} + S_2^{wN}\right)\right]}{-\Delta}.$$

where $\left(I_1^{\alpha} + I_1^{wN}\right)$- $w_N^W \left(S_1^{\alpha} + S_1^{wN}\right)$=

$$\frac{\left(1 - w_N^W \delta AC_1\right)\left[\left(\rho + r_1 + \phi\right)\left(\frac{\partial E}{\partial \alpha} + \frac{\partial E}{\partial w^N}\right) - E\left(\frac{\partial r_1}{\partial \alpha} + \frac{\partial r_1}{\partial w^N}\right)\right]}{\left(\rho + r_1 + \phi\right)^2 a_1^r} - \frac{w_N^W \delta E \frac{\partial AC_1}{\partial \alpha}}{\left(\rho + r_1 + \phi\right) a_1^r},$$

and $\left(I_2^{\alpha} + I_2^{wN}\right)$- $w_N^W \left(S_2^{\alpha} + S_2^{wN}\right)$=

$$\frac{\left(1 - w_N^W \delta AC_2^N\right)\left[\left(\rho + r_2\right)\left(\frac{\partial E}{\partial \alpha} + \frac{\partial E}{\partial w^N}\right) - E\left(\frac{\partial r_2}{\partial r_1}\frac{\partial r_1}{\partial \alpha} + \frac{\partial r_1}{\partial w^N}\right)\right]}{\left(\rho + r_2\right)^2 a_2^r}.$$

By assuming AC_1 = AC_2^N = AC for clear analysis, $\left(I_1^{\alpha} + I_1^{wN}\right)$- $w_N^W \left(S_1^{\alpha} + S_1^{wN}\right)$-$\left(I_2^{\alpha} + I_2^{wN}\right)$+ $w_N^W \left(S_2^{\alpha} + S_2^{wN}\right)$ is

$$\frac{\left(\frac{\partial E}{\partial \alpha} + \frac{\partial E}{\partial w^N}\right)\left(\rho + r_1 + \phi\right)\left(\rho + r_2\right)\left(1 - w_N^W \delta AC\right)\left[\left(\rho + r_2\right)a_2^r - \left(\rho + r_1 + \phi\right)a_1^r\right]}{\left(\rho + r_1 + \phi\right)^2\left(\rho + r_2\right)^2 a_1^r a_2^r} + \frac{-w_N^W \delta E \frac{\partial AC_1}{\partial \alpha}}{\left(\rho + r_1 + \phi\right)^2\left(\rho + r_2\right)^2 a_1^r a_2^r}$$

$$- \frac{E\frac{\partial r_1}{\partial \alpha}\left(1 - w_N^W \delta AC\right)\left[\left(\rho + r_2\right)^2 a_2^r - \left(\rho + r_1 + \phi\right)^2 \frac{\partial r_2}{\partial r_1} a_1^r\right]}{\left(\rho + r_1 + \phi\right)^2\left(\rho + r_2\right)^2 a_1^r a_2^r} - \frac{E\frac{\partial r_1}{\partial w^N}\left(1 - w_N^W \delta AC\right)\left[\left(\rho + r_2\right)^2 a_2^r - \left(\rho + r_1 + \phi\right)^2 a_1^r\right]}{\left(\rho + r_1 + \phi\right)^2\left(\rho + r_2\right)^2 a_1^r a_2^r}.$$

Since H1 has longer intersection than H2, $\left(\rho + r_2\right)a_2^r - \left(\rho + r_1 + \phi\right)a_1^r$ is always larger than zero. So, a positive w_N^W requires: 1. $\left(\frac{\partial E}{\partial \alpha} + \frac{\partial E}{\partial w^N}\right)$ is positive and larger enough, and 2. The unit cost of the Outsourcing Firm has been reduced enough by increasing the outsourcing fraction so that makes the equation above become positive. I refer to this requirement as condition w_N^W.

By the same method, $S_1\left[\left(I_2^{\alpha} + I_2^{wN}\right) - w_N^W\left(S_2^{\alpha} + S_2^{wN}\right)\right] - S_2\left[\left(I_1^{\alpha} + I_1^{wN}\right) - w_N^W\left(S_1^{\alpha} + S_1^{wN}\right)\right]$ can be calculated as

$$\frac{\left(\frac{\partial E}{\partial \alpha}+\frac{\partial E}{\partial w^N}\right)(\rho+r_1+\phi)(\rho+r_2)(1-w_N^W\delta AC)\left[S_1(\rho+r_1+\phi)a_1^r-S_2(\rho+r_2)a_2^r\right]}{(\rho+r_1+\phi)^2(\rho+r_2)^2a_1^ra_2^r}$$

$$-\frac{-w_N^W\delta E\frac{\partial AC}{\partial \alpha}}{(\rho+r_1+\phi)^2(\rho+r_2)^2a_1^ra_2^r}$$

$$-\frac{E\frac{\partial r_1}{\partial \alpha}(1-w_N^W\delta AC)\left[S_1(\rho+r_1+\phi)^2\frac{\partial r_2}{\partial r_1}a_1^r-S_2(\rho+r_2)^2a_2^r\right]}{(\rho+r_1+\phi)^2(\rho+r_2)^2a_1^ra_2^r}$$

$$-\frac{E\frac{\partial r_1}{\partial w^N}(1-w_N^W\delta AC)\left[S_1(\rho+r_1+\phi)^2a_1^r-S_2(\rho+r_2)^2a_2^r\right]}{(\rho+r_1+\phi)^2(\rho+r_2)^2a_1^ra_2^r}.$$

By equations (45) and (46), it can be seen that $S_1(\rho+r_1+\phi)a_1^r-S_2(\rho+r_2)a_2^r$ equals to zero. The value of $\left(\frac{\partial E}{\partial \alpha}+\frac{\partial E}{\partial w^N}\right)$ cannot affect the result of $\frac{dw^H}{d\alpha}+\frac{dw^H}{dw^N}$.

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