

Outsourcing, Innovation, and Wage Inequality in the United States: What Happened to the Outsourcing Effect on Wage Inequality in the 1970s?

(Job Market Paper II)

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Abstract

A puzzle of outsourcing is why the effects of outsourcing on wage inequality found in most empirical papers on the 1980s can not be seen when investigating the 1970s. Two additional questions of this puzzle are: did wages for all skilled labor decrease because of outsourcing? Second, is the falling relative wage of skilled labor to unskilled labor caused by an increasing wage of unskilled labor or a decreasing wage of skilled labor? To understand the puzzle, this paper simplifies Jones' (2005) theoretical model and employs it to analysis this issue. I find that there are two possible reasons for this phenomenon. One is the skilled/unskilled labor endowment change and the other is a change in skilled/unskilled labor intensity of the outsourcing industry. The empirical results suggest that the change in labor intensity of the outsourcing industry is the most probable case. To answer the two additional questions of the outsourcing puzzle, this paper adopts the idea of quality ladders and product cycles and considers laborers who conduct innovation 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. 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.

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I. Introduction

Although greatly debated, the issue of whether outsourcing contributes to wage inequality between skilled and unskilled labor in industrialized countries remains unsolved. Literatures, like Lawrence and Slaughter (1993) and Slaughter (1995), find no evidence that outsourcing can explain the change in wages, but Feenstra and Hanson (1996) argue this finding was due to the narrow measure of outsourcing that they used. They improve this shortcoming by employing a new measure of outsourcing and find that outsourcing can account for 30.9% of the change of non-production wage share and 15% of the increase in the relative wage of non-production workers during the period 1979-1990.

Feenstra and Hanson (1996), however, found an unexpected finding that outsourcing had a statistically insignificant negative impact on non-production workers' wage share in 1972-1979. In the 1980s, on the other hand, the coefficient of outsourcing was statistically significant and positive. According to Table 1 in Feenstra and Hanson (1996), outsourcing grew rapidly in both the 1970s and 1980s. Therefore, the growth rate of outsourcing is not the reason for this unexpected finding. Most theoretical papers' prediction, which is wage inequality increasing with an increasing in outsourcing, failed in the 1970s. The empirical results in the 1970s are puzzling to economists.

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 paper.

Further, if outsourcing does decrease the relative wage of skilled labor, this paper investigates 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, this paper considers 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.

II. Theoretical Framework

In this paper, 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 1, 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.

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 1, 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 paper 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 2. 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 2.

The α cone in Figure 2 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.¹ 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 2 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.

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

¹ 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.

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 paper 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.

III. Empirical Evidence

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 3, 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.

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.² 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.³ 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 1 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 1992.⁴ 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 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.

² 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.

³ Please see Feenstra and Hanson (1996) regarding the formula for computing outsourcing.

⁴ Both weighted fractions and ratios are weighted by industries' share of total manufacturing shipments.

According to Table 1, 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 1, 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 1 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 2 illustrates the same thing as Table 1 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 1; 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.

Although Figure 2 and Tables 1 and 2 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, this paper addresses these two questions through regression estimation.

3.2 Regression Estimation

As discussed in the theoretical section, 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.

3.2.1 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.⁵ 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 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.⁶ 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

⁵ 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.

⁶ 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.

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, Bond, 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. This paper chooses 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.⁷ The benefit of choosing 1980 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

⁷ 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 342), 362 (merging with 370), 382 (merging with 381), 390 (merging with 391), and 392 (merging with 391).

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).⁸ 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.⁹ 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.

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

⁸ Medical scientists (83) are been excluded for consistence purpose with 1970 classification.

⁹ 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.

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 2 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,¹⁰ 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.¹¹ 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 3, it can be seen that the adjustment can narrow the discrepancy.¹²

White-collar workers' share of the wage bill in Figure 2 and white-collar workers' share of total employment in Figure 3 illustrate the difference in white-collar workers' wages between the 1970s and 1980s. In Figure 2, it can be seen that the wage share of white-collar workers was non-increasing in 1970s. Figure 3 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.

Table 3 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

¹⁰ 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.

¹¹ The correlation coefficient of weighted shares in the wage bill from these two sources is 0.970.

¹² The correlation coefficient of weighted shares in employment from these two sources is 0.967.

have high-technology skills and are usually well-educated should get the highest pay among other kinds of workers. The numbers in Table 3 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.

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 grows 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).

3.2.2 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 3.1. 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).¹³ 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.¹⁴

Starting with the same period as Feenstra and Hanson (1999), Table 4-1 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. 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.

¹³ 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.

¹⁴ 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.

In Table 4-2, 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 5, 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.

3.2.3.1 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:

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

where P_{it}^{VA-NRD} and P_{it}^Y are value-added price without considering R&D workers and output price in industry $i=1, \dots, N$. S_{it}^{ME} denotes the cost-share of intermediate input, which also includes energy, in industry $i=1, \dots, N$. 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:

$$S_{it}^{RD} = \alpha' \Delta Z_{it} + RD_{it}, \quad (2)$$

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:¹⁵

$$\Delta \ln P_{it}^{VA} + ETFP_{it} = \beta' \Delta Z_{it} + \gamma' S_{it}^{RD} + \varepsilon_{it}. \quad (3)$$

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

$$\Delta \ln P_{it}^{VA} + ETFP_{it} = \phi' \Delta Z_{it} + \gamma' RD_{it} + \varepsilon_{it}, \quad (4)$$

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.¹⁶ 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).

To proceed in second-stage regression, there is an estimation issue addressed by Feenstra and Hanson (1999) that needs to be 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)

¹⁵ 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).

¹⁶ 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.

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.¹⁷ 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).

3.2.3.2 Regression Results

This paper 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 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 6-1, 6-2, 7-1, and 7-2 are first-stage regressions in 1979-1990. Regressions in Table 6 use employment data and those in Table 7 use working-hour data. Tables 8-1 to 8-4 are second-stage regressions in 1979-1990. Then, Tables 9-1 and 9-2 are first-stage regressions in 1972-1979. Finally, Tables 10-1 and 10-2 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

¹⁷ The author gratefully thanks Dumont et al. for providing help.

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 6. Regression 6a.1 and 6a.2 are replications and get almost the same results as Feenstra and Hanson (1999).¹⁸ 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. 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 6-2, 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 7-1 and Table 6-1, 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 6-2, Table 7.2 illustrates that outsourcing becomes insignificant and so do computers, while R&D factors are significant in most specifications.

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

¹⁸ 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.

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 8-1. 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 8-2. 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 8-3 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 8-4 reports the results of R&D factors.

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.¹⁹ 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 9a.1 and 9a.2 in Table 9-1 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 3.2.3. The results in Table 9-1 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 9-2, 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.²⁰ The quadratic term of outsourcing (difference) is also positive and 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 9-1 and 9-2, 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 10-1 reports these results. The coefficient, as expected, on non-production

¹⁹ 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.

²⁰ 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.

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 10-2, 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 10-1, they have no significant effects on workers' wages.

3.2.3.3 Including Interaction Terms

Another setting of two-stage regression in Feenstra and Hanson (1999) is including interaction terms in the first-stage regression.²¹ The coefficients on the interaction terms can help us know the magnitude of non-neutral technological change.²² 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 11 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 12, 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

²¹ This specification can be derived explicitly from a translog production function. Please refer to Feenstra and Hanson (1999) for details.

²² 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.

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.

This study also employs data from 1972 to 1979 to estimate the first-stage regression with interaction terms. In Table 13, 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 11 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 14. 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.

IV. Conclusion

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 future research.

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Table 1. 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

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.

Table 2. 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

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.

Table 3. Summary Statistics

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

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.

Table 4-1. Changes in R&D Workers' Wages: 1979-1990

	Dependent variables: average wage-changes per capita					
	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

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.

Table 4-2. 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 (1.33)	0.853 (0.64)	4.626 (2.07)	0.420 (1.43)	0.583 (0.40)	4.782 (2.16)
Outsourcing (difference)	-0.326 (1.67)	0.378 (0.24)	-0.149 (0.04)	-0.307 (1.65)	-0.372 (0.20)	0.451 (0.11)
Capital services (ex post rental prices):						
Computer share	-0.195 (0.56)	-5.640 (1.59)	-3.650 (0.84)			
High-tech share (difference)	0.639 (1.30)	-0.594 (0.19)	7.299 (0.84)			
Capital services (ex ante rental prices):						
Computer share				-0.214 (0.45)	-4.506 (0.57)	10.969 (1.24)
High-tech share (difference)				1.648 (7.46)	2.866 (0.79)	13.414 (2.00)
$\Delta \ln(y)$	0.051 (1.76)	0.343 (1.40)	-0.014 (0.02)	0.042 (1.78)	0.253 (1.00)	-0.389 (0.49)
$\Delta \ln(k / y)$	-0.004 (0.08)	0.372 (0.82)	-0.198 (0.22)	-0.009 (0.17)	0.224 (0.54)	-0.686 (0.69)
Constant	0.046 (20.84)	0.044 (1.76)	0.062 (1.01)	0.044 (26.74)	0.033 (1.26)	0.043 (0.72)
R^2	0.088	0.015	0.039	0.127	0.007	0.058
N	445	445	445	445	445	445

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. 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.

Table 5. Changes in the R&D Workers' Wage: 1972-1979

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

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.

Table 6-1. First-Stage Regression with Narrow Definition of R&D Workers: 1979-1990

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

Dependent variables starting with 6a are computed from all primary factors, including R&D workers, but dependent variables starting with 6n 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 6-2. First-Stage Regression with Broad Definition of R&D Workers: 1979-1990

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

Dependent variables starting with 6b 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 7-1. 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							
	7h.1	7nh.1	7nh.2	7nh.3	7h.2	7nh.4	7nh.5	7nh.6
Independent variables:								
Outsourcing (narrow)	0.051 (1.80)	0.056 (1.91)	0.055 (1.92)	0.063 (2.22)	0.062 (2.04)	0.066 (2.19)	0.065 (2.15)	0.076 (2.53)
Outsourcing (difference)	0.063 (1.35)	0.053 (1.42)	0.053 (1.48)	0.085 (1.67)	0.087 (2.06)	0.075 (2.22)	0.074 (2.29)	0.112 (2.35)
[Outsourcing] ² (narrow)				2.348 (2.31)				2.331 (2.15)
[Outsourcing] ² (difference)				-1.248 (0.46)				-1.182 (0.41)
Capital services (ex post rental prices):								
Computer share	0.111 (1.91)	0.108 (1.96)	0.108 (1.97)	0.151 (2.34)				
High-tech share (difference)	0.064 (0.83)	0.051 (0.66)	0.050 (0.64)	0.051 (0.63)				
R&D payment share			0.377 (2.14)	0.594 (2.20)				
Capital services (ex ante rental prices):								
Computer share					0.107 (1.04)	0.120 (1.27)	0.119 (1.28)	0.192 (1.84)
High-tech share (difference)					-0.058 (0.73)	-0.081 (1.07)	-0.085 (1.15)	-0.096 (1.20)
R&D payment share							0.459 (3.24)	0.651 (2.74)
Constant	0.042 (126.39)	0.041 (87.69)	0.041 (88.86)	0.042 (81.29)	0.042 (118.39)	0.042 (89.21)	0.042 (89.87)	0.042 (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

Dependent variables starting with 7h are computed by all primary factors, including R&D workers, but dependent variables starting with 7nh 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 7-2. 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					
	7bh.1	7bh.2	7bh.3	7bh.4	7bh.5	7bh.6
Independent variables:						
Outsourcing (narrow)	0.036 (1.34)	0.035 (1.38)	0.032 (1.44)	0.044 (1.67)	0.043 (1.70)	0.041 (1.84)
Outsourcing (difference)	0.047 (1.18)	0.047 (1.26)	0.074 (1.65)	0.066 (1.81)	0.065 (1.89)	0.092 (2.15)
[Outsourcing] ² (narrow)			1.309 (1.45)			1.266 (1.41)
[Outsourcing] ² (difference)			-2.682 (1.13)			-2.735 (1.11)
Capital services (ex post rental prices):						
Computer share	0.092 (1.67)	0.091 (1.73)	0.091 (1.73)			
High-tech share (difference)	0.047 (0.58)	0.046 (0.55)	0.043 (0.52)			
R&D factors		0.192 (4.08)	0.188 (4.58)			
Capital services (ex ante rental prices):						
Computer share				0.109 (1.08)	0.108 (1.11)	0.104 (1.08)
High-tech share (difference)				-0.089 (1.16)	-0.092 (1.22)	-0.092 (1.23)
R&D factors					0.215 (4.59)	0.210 (5.68)
Constant	0.041 (87.21)	0.041 (88.46)	0.041 (88.84)	0.042 (91.07)	0.042 (92.16)	0.042 (91.93)
R ²	0.176	0.194	0.203	0.163	0.185	0.194
N	445	445	445	445	445	445

Dependent variables starting with 7bh 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

Table 8-1. Second-Stage Regression: Estimated Factor-Price Changes Using Working-Hour Data in 1979-1990

Dependent variables in first-stage regressions:	7h	7h	7h	7h
(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 (0.80)	0.016 (1.15)	-0.003 (0.34)	0.022 (0.82)
Non-production labor share	0.078 (1.74)	0.050 (1.29)	0.165 (1.88)	0.006 (0.58)
Difference between production and non-production share	0.085 (1.70)	0.034 (1.12)	0.168 (1.86)	-0.016 (0.72)
(2) Employing ex ante rental prices for computer share and high-tech share				
Difference between production and non-production share	0.104 (1.89)	0.047 (1.43)	0.080 (1.03)	-0.005 (0.49)

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 8-2. Second-Stage Regression: Estimated Factor-Price Changes Due to Outsourcing in 1979-1990

Dependent variables in first-stage regressions:	6n	6n	6b	6b	6nh	6nh	6bh	6bh
(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 (0.68)	0.026 (1.18)	0.008 (0.91)	0.024 (1.30)	-0.007 (0.67)	0.026 (1.40)	0.007 (0.92)	0.023 (1.43)
White-collar labor share	0.129 (2.21)	0.049 (1.33)	0.041 (1.32)	0.052 (1.19)	0.102 (2.06)	0.032 (0.98)	0.037 (1.34)	0.038 (0.94)
Difference between white-collar and blue-collar share	0.138 (2.12)	0.024 (0.56)	0.033 (1.11)	0.029 (0.65)	0.109 (1.99)	0.006 (0.17)	0.030 (1.13)	0.015 (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 (2.29)	0.040 (0.83)	0.041 (1.26)	0.049 (1.03)	0.125 (2.16)	0.017 (0.42)	0.036 (1.26)	0.030 (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 8-3. Second-Stage Regression: Estimated Factor-Price Changes Due to Computers
in 1979-1990

Dependent variables in first-stage regressions:	6n	6b	7nh	7bh
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 (0.54)	0.002 (0.16)	-0.005 (0.53)	0.001 (0.16)
White-collar labor share	0.230 (2.29)	0.204 (1.99)	0.162 (1.93)	0.150 (1.70)
Difference between white-collar and blue-collar share	0.237 (2.25)	0.202 (1.96)	0.167 (1.91)	0.148 (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 (1.79)	0.155 (1.50)	0.090 (1.22)	0.095 (1.07)

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 8-4. Second-Stage Regression: Estimated Factor-Price Changes Due to R&D Factors in 1979-1990

Dependent variables in first-stage regressions:	6n	6b	7nh	7bh
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 (1.67)	-0.026 (2.74)	-0.011 (1.62)	-0.019 (2.67)
White-collar labor share	0.051 (2.00)	0.099 (3.79)	0.032 (1.92)	0.071 (3.60)
Difference between white-collar and blue-collar share	0.067 (1.98)	0.125 (3.74)	0.043 (1.90)	0.090 (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 (2.18)	0.058 (2.18)	0.041 (2.37)	0.087 (3.68)

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 9-1. First-Stage Regression with Broad Definition of R&D Workers: 1972-1979

	Dependent variable: change In value-added prices plus effective TFP							
	9a.1	9n.1	9n.2	9n.3	9a.2	9n.4	9n.5	9n.6
Independent variables:								
Outsourcing (narrow)	-0.003 (0.76)	0.001 (0.32)	0.001 (0.35)	-0.001 (0.34)	-0.007 (0.99)	-0.003 (0.52)	-0.003 (0.59)	-0.006 (0.87)
Outsourcing (difference)	-0.013 (1.55)	-0.007 (1.53)	-0.007 (1.56)	-0.018 (1.59)	-0.011 (1.49)	-0.005 (1.37)	-0.005 (1.42)	-0.017 (1.68)
[Outsourcing] ² (narrow)				0.013 (0.21)				0.055 (0.54)
[Outsourcing] ² (difference)				0.208 (1.50)				0.228 (1.53)
Capital services (ex post rental prices):								
Computer share	-0.008 (0.85)	-0.009 (0.88)	-0.009 (0.85)	-0.008 (0.81)				
High-tech share (difference)	-0.013 (2.05)	-0.015 (2.29)	-0.016 (2.30)	-0.016 (2.29)				
R&D factors			0.016 (1.07)	0.021 (0.50)				
Capital services (ex ante rental prices):								
Computer share					0.005 (0.29)	0.005 (0.38)	0.005 (0.40)	0.008 (0.58)
High-tech share (difference)					-0.006 (0.54)	-0.010 (1.27)	-0.011 (1.34)	-0.012 (1.51)
R&D factors							0.023 (1.39)	0.049 (1.42)
Constant	0.072 (773.31)	0.072 (371.97)	0.072 (372.29)	0.072 (361.05)	0.072 (764.52)	0.072 (371.16)	0.072 (370.87)	0.072 (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

Dependent variables starting with 9a are computed from all primary factors, including R&D workers but dependent variables starting with 9n 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 9-2 First-Stage Regression with Narrow Definition of R&D Workers: 1972-1979

	Dependent variable: change in value-added prices plus effective TFP					
	9b.1	9b.2	9b.3	9b.4	9b.5	9b.6
Independent variables:						
Outsourcing (narrow)	0.000 (0.09)	0.000 (0.11)	-0.004 (0.93)	-0.004 (0.62)	-0.004 (0.72)	-0.008 (1.12)
Outsourcing (difference)	-0.009 (1.70)	-0.009 (1.75)	-0.023 (1.97)	-0.008 (1.57)	-0.008 (1.64)	-0.023 (2.11)
[Outsourcing] ² (narrow)			0.036 (0.56)			0.074 (0.71)
[Outsourcing] ² (difference)			0.280 (1.88)			0.298 (1.88)
Capital services (ex post rental prices):						
Computer share	-0.007 (0.62)	-0.007 (0.60)	-0.005 (0.50)			
High-tech share (difference)	-0.013 (1.80)	-0.013 (1.83)	-0.014 (1.88)			
R&D factors		0.026 (1.49)	0.024 (1.34)			
Capital services (ex ante rental prices):						
Computer share				0.009 (0.64)	0.009 (0.68)	0.012 (0.91)
High-tech share (difference)				-0.007 (0.84)	-0.007 (0.92)	-0.009 (1.24)
R&D factors					0.032 (1.71)	0.030 (1.61)
Constant	0.072 (349.75)	0.072 (350.37)	0.072 (339.55)	0.072 (350.77)	0.072 (351.29)	0.072 (338.32)
R ²	0.054	0.057	0.069	0.041	0.046	0.060
N	445	445	445	445	445	445

Dependant variables starting with 9b 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 10-1 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 (0.41)	0.001 (0.69)	-0.001 (0.29)	0.004 (0.54)
Non-production labor share	-0.009 (0.97)	-0.023 (1.45)	0.000 (0.28)	0.002 (0.53)
Difference between production and non-production share	-0.009 (0.96)	-0.024 (1.43)	0.001 (0.29)	-0.001 (0.48)
(2) Employing ex post rental prices for computer share and high-tech share				
Difference between production and non-production share	-0.005 (0.75)	-0.028 (1.49)	-0.002 (0.57)	-0.011 (1.62)

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 10-2 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 (0.42)	0.002 (0.98)	0.000 (0.37)	0.001 (0.50)
White-collar labor share	-0.007 (0.86)	-0.028 (1.68)	-0.008 (1.07)	-0.040 (2.10)
Difference between white-collar and blue-collar share	-0.008 (0.86)	-0.030 (1.67)	-0.007 (1.03)	-0.041 (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 (0.35)	-0.032 (1.57)	-0.003 (0.88)	-0.043 (1.90)

All dependent variables are computed from the regressions, including quadratic terms of outsourcing (narrow) and outsourcing (difference). 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.

Table11. 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		11n.1	11n.2	11b.1	11b.2
Independent variables:		Interacted with the average log quantities of:			
Outsourcing (narrow)		0.480 (3.33)	0.711 (3.20)	0.312 (2.26)	0.658 (3.03)
	Blue-collar labor	0.013 (0.25)	0.014 (0.22)	0.042 (0.92)	0.011 (0.20)
	White-collar Labor	0.099 (3.31)	0.114 (3.09)	0.036 (1.06)	0.084 (2.44)
	Capital	-0.093 (2.52)	-0.127 (2.68)	-0.069 (2.06)	-0.110 (2.60)
[Outsourcing] ² (narrow)			-18.043 (1.02)		-33.145 (2.11)
Outsourcing (difference)		-0.332 (1.54)	-0.453 (2.00)	-0.253 (1.15)	-0.388 (1.66)
	Blue-collar labor	0.173 (3.31)	0.199 (1.87)	0.209 (3.84)	0.234 (2.62)
	White-collar Labor	-0.094 (2.19)	-0.109 (1.37)	-0.093 (1.95)	-0.122 (2.01)
	Capital	-0.013 (0.40)	0.001 (0.03)	-0.048 (1.35)	-0.029 (0.91)
[Outsourcing] ² (difference)			46.756 (1.85)		35.433 (1.69)
R&D factors		-4.503 (1.54)	-4.510 (1.57)	-2.532 (2.21)	-2.419 (1.85)
	Blue-collar labor	-0.824 (2.32)	-0.738 (1.87)	-0.443 (2.36)	-0.437 (2.17)
	White-collar Labor	0.304 (1.22)	0.249 (1.16)	-0.177 (1.67)	-0.188 (1.55)
	Capital	0.894 (1.68)	0.859 (1.62)	0.634 (2.71)	0.618 (2.28)
Constant		0.042 (106.64)	0.042 (113.53)	0.042 (101.93)	0.042 (106.21)
R^2		0.632	0.649	0.605	0.622
N		445	445	445	445

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 12. Estimated Factor-Price Changes: 1979-1990

Dependent variables in first-stage regressions:	11n	11n	11b	11b	11n	11b
(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 (2.09)	0.168 (3.30)	-0.016 (0.50)	0.173 (3.44)	0.015 (0.91)	0.001 (0.06)
White-collar labor share	0.446 (3.82)	-0.085 (1.71)	0.194 (1.97)	-0.144 (2.00)	0.038 (1.70)	0.080 (2.56)
Difference between white-collar and blue-collar share	0.544 (3.41)	-0.253 (2.74)	0.210 (1.68)	-0.318 (2.82)	0.023 (0.70)	0.079 (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 (3.81)	-0.059 (1.24)	0.301 (2.52)	-0.104 (1.69)	0.032 (1.37)	0.059 (1.94)

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.

Table13. 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		13n.1	13n.2	13b.1	13b.2
Independent variables:		Interacted with the average log quantities of:			
Outsourcing (narrow)		0.005 (0.11)	0.159 (1.60)	0.023 (0.43)	0.171 (1.85)
Blue-collar labor		0.009 (1.04)	0.003 (0.48)	0.004 (0.61)	0.003 (0.43)
White-collar Labor		-0.010 (0.96)	0.009 (1.02)	-0.006 (0.61)	0.010 (0.99)
Capital		-0.002 (0.28)	-0.023 (1.61)	-0.004 (0.46)	-0.026 (1.81)
[Outsourcing] ² (narrow)			-7.783 (1.79)		-9.121 (2.02)
Outsourcing (difference)		0.062 (1.17)	0.185 (1.26)	0.055 (1.06)	0.166 (1.07)
Blue-collar labor		0.018 (1.83)	0.044 (2.00)	0.027 (2.25)	0.057 (2.47)
White-collar Labor		-0.011 (1.35)	-0.026 (2.23)	-0.021 (1.99)	-0.044 (3.31)
Capital		-0.016 (1.53)	-0.043 (1.49)	-0.018 (1.62)	-0.044 (1.44)
[Outsourcing] ² (difference)			-3.514 (1.36)		-4.401 (1.43)
R&D factors		0.434 (1.34)	0.380 (1.24)	0.293 (1.26)	0.160 (0.90)
Blue-collar labor		-0.110 (1.32)	-0.091 (1.22)	0.015 (0.26)	0.016 (0.27)
White-collar Labor		0.066 (1.03)	0.060 (0.91)	0.027 (0.68)	0.002 (0.06)
Capital		-0.015 (0.36)	-0.016 (0.33)	-0.053 (1.12)	-0.029 (0.78)
Constant		0.072 (495.44)	0.072 (456.58)	0.072 (476.75)	0.072 (435.63)
R^2		0.218	0.249	0.260	0.295
N		445	445	445	445

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 14. Estimated Factor-Price Changes: 1972-1979

Dependent variables in first-stage regressions:	13n	13n	13b	13b	13n	13b
(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 (0.74)	0.019 (1.97)	0.002 (0.59)	0.025 (2.54)	0.000 (0.03)	-0.002 (0.64)
White-collar labor share	-0.007 (0.66)	-0.051 (1.79)	-0.013 (0.99)	-0.077 (2.28)	-0.002 (0.48)	0.000 (0.02)
Difference between white-collar and blue-collar share	-0.010 (0.74)	-0.070 (1.90)	-0.016 (0.99)	-0.102 (2.44)	-0.002 (0.30)	0.002 (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 (1.44)	-0.066 (1.87)	-0.042 (1.69)	-0.105 (3.14)	-0.005 (0.93)	-0.005 (0.39)

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.

Figure 3. Skilled/unskilled labor ratio in U.S. manufacturing industries: 1970-1990

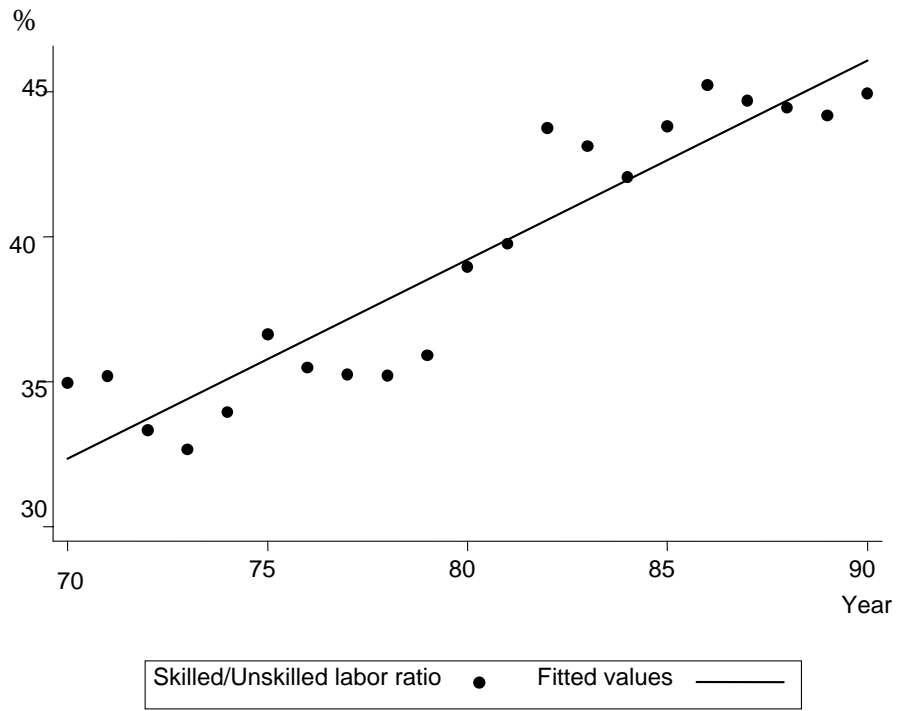
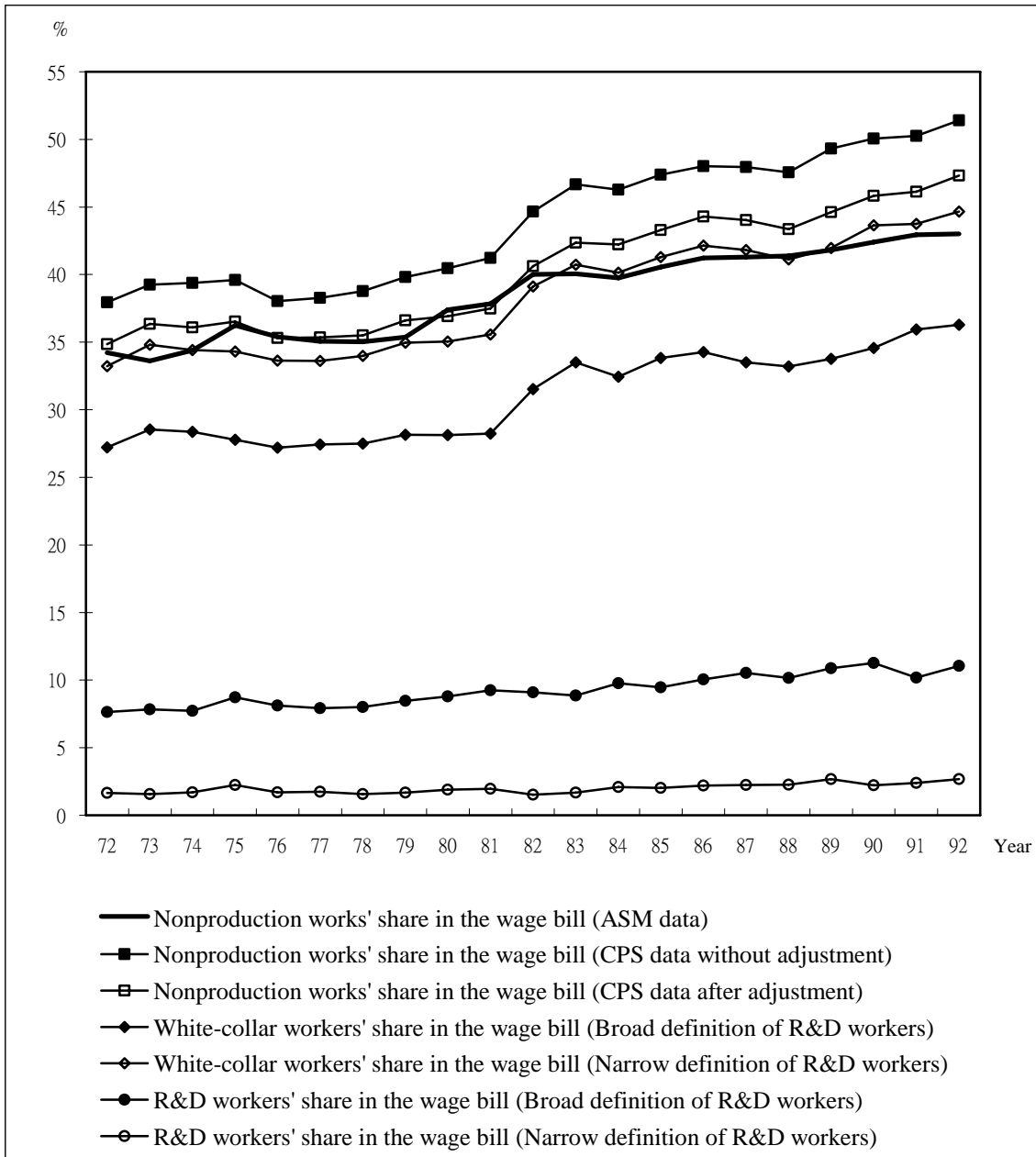
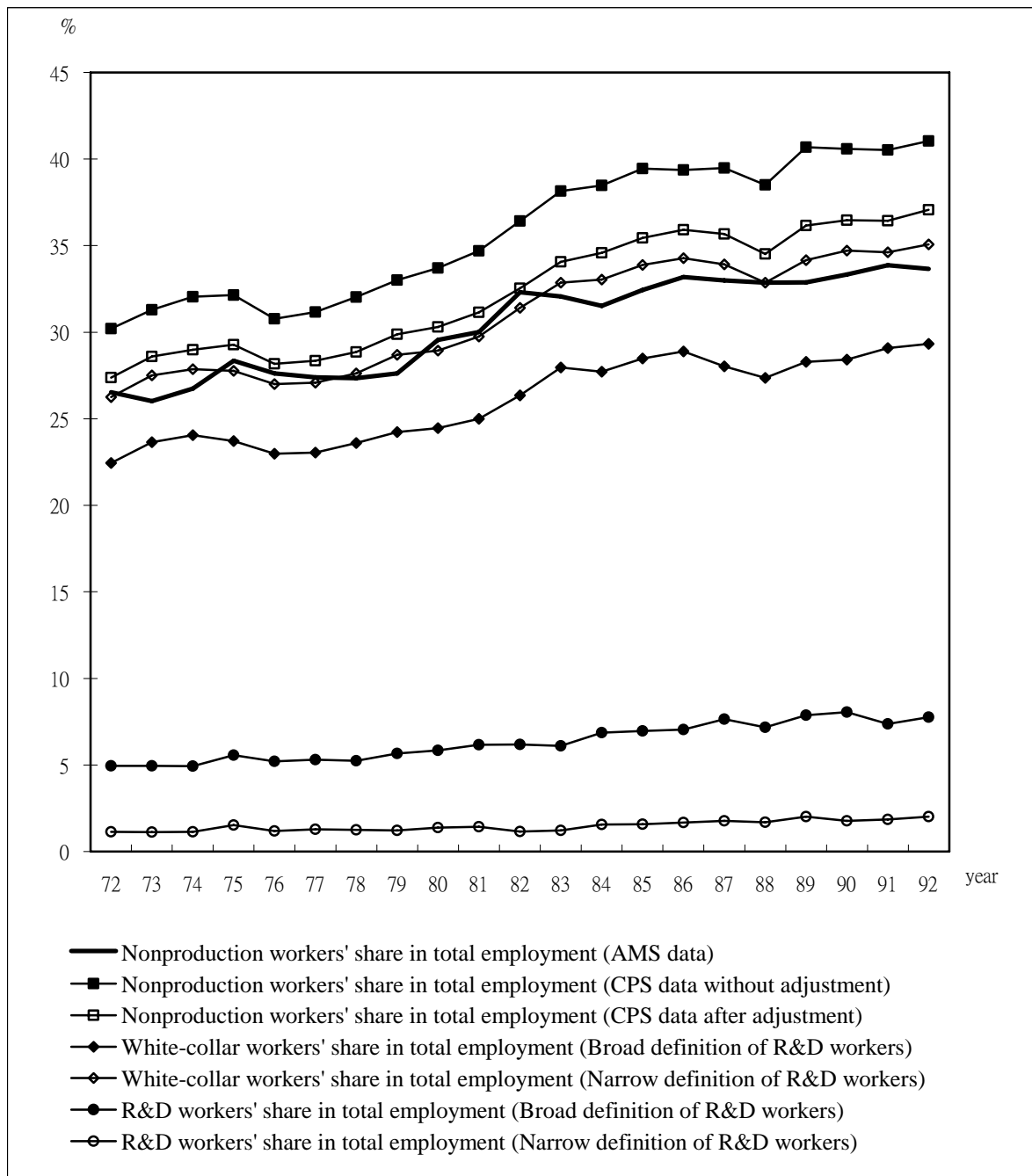


Figure 4. Non-production Workers' Share in the Wage Bill



All shares are weighted by industries' share of total manufacturing shipments.

Figure 5. Non-production Workers' Share in Total Employment



All shares are weighted by industries' share of total manufacturing shipments.