CESifo
HEER Helsinki Center of Economic Research
RUESG

Workshop on

International Outsourcing

What Explains the Widening Wage Gap? Outsourcing vs. Technology?

Claudia Canals

1-2 June 2007
University of Helsinki, Economicum Building

What Explains the Widening Wage Gap? Outsourcing vs. Technology*

Claudia Canals†

First Draft: September 2005

This Draft: August 2006

Abstract

The relative rise of wages for high-skilled workers over the last three decades has been the subject of intense academic and popular scrutiny. This paper develops a new methodology for decomposing wage changes into three sources: outsourcing, biased technological change, and total biased technological change. We find that for the 1980-1999 period the change in outsourcing accounts for between 28 and 36 percent of the observed wage change, and biased technological change for another 15-19 percent in the US. Jointly these two forces (total biased technological change) explain 58 percent of the wage change. In sum, we find that outsourcing and biased technological change can account for a large share of the observed divergence in the skilled wage premium.

Keywords: outsourcing, technology, wage gap, translog.
JEL classification: F11, F14, F20, J31.

*I am grateful to David E. Weinstein for invaluable guidance and constant encouragement. I would also like to thank Roc Armenter, Rajeev Cherukupalli, Mitali Das, Donald R. Davis, Ronald E. Findlay, Marc Gratacos, Judit Montoriol, Arvind Panagariya, Bernard Salanie, Matthew Slaughter, Daniel Trefler, Eric Verhoogen, Josep M. Vilarrubia, and seminar participants at Columbia University for very helpful comments and suggestions. Financial support from Columbia University, and Banco de España are acknowledged and greatly appreciated. All remaining errors are my own. The views expressed in this paper are those of the author only and should not be attributed to "La Caixa" (Caixa d'Estalvis i Pensions de Barcelona)

†"la Caixa" Economic Studies. Av Diagonal 629, torre I 08028 Barcelona, Spain. email:ccanals@lacaixa.es Webpage: http://www.claudiacanals.com

1 Introduction

Between 1980 and 1999 there was a sharp decline in the wages of low-skilled workers relative to high-skilled workers. During this time period the relative wage of high-skilled workers rose from 1.33 to 1.68. Many authors have sought to explain this phenomenon by appealing to changes in international relative prices, improvements in technology, changes in education level, a rise in immigration, as well as, a rise in the level of outsourcing, among others.[1] A failing of much of the prior literature is that it has tended to consider the effects one at a time.[2] Thus, it is often difficult to know the extent to which outsourcing is correlated with other technological changes that might be driving wage movements. This paper represents the first attempt to structurally estimate a general equilibrium model of the US economy that integrates two of the most prominent explanations: outsourcing, and biased technological change. This structure enables us to estimate a number of *counterfactual* exercises of interest. For example, we can answer what the impact of US wages would have been if only outsourcing had changed.

The answers suggest that wages over the last decades were buffeted by substantial shocks due to outsourcing shifts, and biased technological change. We find that between 1980 and 1999, outsourcing accounts for 28-36 percent of the observed wage change, and biased technological change for another 15-19 percent. Jointly these two forces explain 58 percent of the wage change. These numbers are intuitive, precisely measured, and suggest that both globalization and technological change were important determinants of the relative decline in wages for unskilled workers in the US. As a parallel result we find that outsourcing is a substitute for unskilled labor and a complement for skilled labor.[3]

In terms of definitions, we should mention that outsourcing has been specified or understood in very different ways. Some have used it mistakenly as a synonym for foreign direct investment or even imports. Bhagwati et al. [2004] define it as "the services trade at arm's length that does not require geographical proximity of the buyer and the seller." We use Feenstra and Hanson [1999]'s approach and define outsourcing as imported intermediate inputs. Our definition is augmented by the method used by Hummels et al. [2001] to account for domestic intermediate inputs using imported intermediate inputs. This has also been called international outsourcing

[1] Borjas [2003], for instance, suggests that an increase in immigration of competing workers, reduces wages by 3 to 4 percent. Other explanations have been deregulation movements, deunionization in the eighties, capital deepening, etc.

[2] Blum [2004] is an exception since he analyzes the effect of trade (understood as change in international prices), changes in the sectoral composition, technological changes, and outsourcing, all in a Ricardo Vinier set up. However, he cannot distinguish between the effect of the last two sources in explaining the increase in the wage inequality, which will be accomplished in this paper.

[3] See Canals [2006] for a further analysis in the labor demand substitution topic.

or offshoring.

The approach we take is an accounting decomposition that is in some sense analogous to growth decomposition in the productivity literature. We consider an economy where each good is produced using five production factors: unskilled labor, skilled labor, domestic intermediate inputs, imported intermediate inputs (or outsourcing), and capital.[4,5] In order to obtain estimates of the shocks affecting the economy, we first make use of a translog cost function approximation for each sector to capture estimates of biased technological change, shifts in outsourcing, and total biased technological change.[6] We then use these estimates and the zero profit condition to back out the implied wage changes from the general equilibrium framework.

Before diving into the workings of the model, we should clarify our definitions of shifts in outsourcing, biased technological change, and total biased technological change. Shifts in outsourcing are defined as changes in the demand for imported intermediates inputs as a result of technological improvements (i.e. after controlling for factor price changes). Hence, this can be understood as an outsourcing biased technological change.[7] We refer to biased technological change as those technological improvements affecting the relative quantity of labor and capital needed to produce one unit of final good.[8] Finally, total biased technological changes are all the previous changes considered at the same time. Notice that, there might be some correlation between the different technological changes, such that the effect on the wage gap of the total biased technological change does not correspond to the exact sum of the other two.

Recall that the questions (or counterfactuals exercises) we study are of the following type: if only a change in technology affecting/facilitating outsourcing (or biased technological change, or total biased technological change) would have occurred, what would have been the implied US wage gap? As a starting point to our exercise, we note the following facts about the evolution of the main variables of interest to our study. First, the wage gap between skilled and unskilled workers has increased by 46.55% between 1980 and 1999. Figure 2 illustrates this point by displaying the evolution of the skilled-unskilled wage ratio over time. Second, there has been a positive trend in the level of the oustourcing share which went from 5.19% in 1973, to 6.52% in 1986 and 9.22% in 1999.[9] Obviously, the co-movement of these two variables does not imply

[4]Domestic intermediate inputs are intermediate goods and services purchased inside the country.

[5]Hence, outsourcing is a production factor and not an structural or exogenous variable like in Feenstra and Hanson [1999].

[6]A translog cost function is simply a second order Taylor polynomial approximation of the logarithmical costs. We use both definitions indistinctively.

[7]Here is an example of a technological change facilitating outsourcing: improvements in information technology may make easier for car manufacturers to offshore designer services in India (controlling for the cost of these services).

[8]See Findlay and Jones [1999] for factor bias definitions.

[9]Outsourcing share is the share of imported intermediate inputs over total intermediate inputs (domestic plus

direct causality from one to the other. Finally, as can be seen in Table 4, there has been an increase in the usage of skilled workers relative to unskilled workers in the US economy over the last thirty years. In particular, by 1973 32% of the labor force was skilled, and by 1999 this was 52%. This could be the result of technology affecting the relative demand for skilled and unskilled workers and thus the wage gap. Given the inter-relatedness of these variables, a further exploration is required, and that is accomplished by the empirical decomposition that follows.

In order to decompose the change in factor prices or wages into the different sources we apply a two-step methodology based on Haskel and Slaughter [2002].[10] In particular, we derive a way of measuring technological change (*first step*) and a theory that links wages to technological change (*second step*). We then link the changes in technology from the *first step* with the change in wages from the *second step*. More precisely, consider an economy where each final good is produced using the five production factors previously mentioned: unskilled labor, skilled labor, domestic intermediate inputs, outsourcing, and capital. In the *first step*, related to Berman et al. [1994] and Feenstra and Hanson [1996]'s methodology, we use a second order Taylor polynomial to approximate each industry's cost function. Then we logarithmically differentiate this polynomial cost function with respect to factor prices and employ Shepard's lemma to obtain a system of cost-share equations. Using this set of equations we capture the changes in technology associated with changes in the usage of outsourcing (outsourcing biased technological change), and changes in the usage of labor and capital necessary to produce one unit of final good (biased technological change).

In our *second step* we assume that all industries are in perfect competitive markets, and so the zero-profit condition must hold. Following Baldwin and Hilton [1984], Leamer [1997], and Feenstra and Hanson [1999], among others, we apply a well-known methodology which consists on differentiating the zero-profit condition over time. With this, we find a price equation that relates the change in factor usage or technology change[11] with the change in product prices and the change in factor prices. Finally, using the change in outsourcing usage from the *first step*, and the price equation from the *second step*, we obtain the change in factor prices necessary to reestablish the market equilibrium due to the change in technology shifting the level of outsourcing. With an analogous methodology, we can isolate the change in the wage gap necessary to accommodate any biased technological change, or any total biased technological change.

The applied methodology is a distinctive characteristic of our empirical analysis, since it has

imported).

[10]However, as explained later there are some differences in both methodologies, mainly due to the fact that Haskel and Slaughter [2002] do not use intermediate inputs as a production factor.

[11]Also known as total factor productivity (TFP)

not been used before to tackle the effect of outsourcing on the wage gap. But there are two other novelties in our paper that merit mention. First, we include services on top of manufactures in our analysis. This is particularly relevant given the large and increasing size of services. In particular, services account for two-thirds of the total US economy by 1999, and one third of total imported intermediate inputs is made by service sectors. The second feature is related to the classification of unskilled and skilled workers. Theoretically, education is the appropriate way to classify both types of labor, but empirically that has not been the case, since data on the level of education is not always available. In particular, most of the empirical work identifies unskilled workers as production workers, and skilled as non-production workers, thus introducing a possible bias. As we use both manufactures and services, we cannot perform this identification, since such a classification does not exist for services. Nevertheless, we are able to match the years of education to the data set we have, which is the theoretical way to do it. We identify unskilled labor as those workers with a high school degree or less, and skilled workers are those workers with some years of college or more.

The results when applying the *first and second steps* indicate that for the 1980-1999 period, the wage gap induced by outsourcing equals 13.1%. As the actual wage gap for the period is 46.55%, we can say that outsourcing explains 28% of the actual wage gap. Biased technological changes and total technological changes account for a total of 15% and 58% of the actual gap, respectively.[12]

The reminder of this paper is organized as follows. Subsection 1.1 contains a literature review where we connect and relate our paper to previous research. The econometric methodology is given in Section 2. Section 3 presents an overview of the construction of the data set, and then outlines the evolution over time of some of the variables of interest. Section 4 examines the main results of the paper and, finally, Section 5 concludes.

1.1 Literature Review

Our approach differs and builds on prior work in several ways. Berman et al. [1994] study a related question, and we use part of their methodology to construct our *first step* in the two-step methodology we apply.[13] They analyze if the shifts in demand away from unskilled workers and towards skilled workers during the eighties is due to trade, and in particular, due to imported intermediate inputs (outsourcing). Using a translog function (second order Taylor polynomial)

[12]These numbers slightly change depending on the construction of the price for intermediate inputs. Hence, we write sometimes between 28 and 36 percent, instead of only 28 percent.

[13]A similar approach has been used by others like Feenstra and Hanson [1996], Autor et al. [1998], among others.

to approximate each industry cost function, they regress the annual change in the nonproduction workers' wage share over a set of controls, like the change in capital-shipments ratio and computer share.[14] We use their idea of approximate the cost function using a Taylor's second order polynomial in our methodology. They conclude that outsourcing accounts for between 15% to 24% of the shift in the demand towards nonproduction workers. However, as Feenstra [2003] points out, the results of Berman et al. [1994] specification are not very robust. Moreover, they only use skilled and unskilled labor as the moving production factors, and take capital as fixed. Thus, because of their short run approach, they ignore the substitution and complementarities between capital and labor.

We take part of the methodology used by Leamer [1997] to build up the *second step* in our methodology. His goal is to empirically test the Stolper-Samuelson effect, that is, the relationship between factor and commodity prices. Leamer derives a price equation that relates changes in technology or techniques with commodity and factor prices. We use this same derivation as part of our methodology. He finds that during the seventies and the eighties, a change in good or commodity price had an effect in factor prices. However, such a relationship is not found for the sixties. Feenstra [2003] shows that this methodology alone does not have predictive power when it is well formulated, and so the results obtained from it are not valid.

Feenstra and Hanson have done some of the best work to date on the impact of outsourcing and technology on the wage gap. The work most closely related to the present paper is Feenstra and Hanson [1999] where the authors investigate the effect of outsourcing and computers (as a way of measuring technological level) on the wage gap. While the question we answer is similar, there are two major departures of our study from their work. First, we apply a different methodology. Feenstra and Hanson [1999] assume that changes in commodity prices and technology (or TFP) can be explained by some structural variables, namely change in outsourcing and changes in computer usage. They regress change in good or commodity prices and TFP against a measure of change in outsourcing and the change in computer usage. Consider, however, a situation where a big country suddenly opens its markets. This could lead to a change in both, the U.S. level of outsourcing and international prices. So, there is a common factor moving commodity prices (their dependent variable), and outsourcing (their independent variable) at the same time, which could be biasing the results.[15] We consciously address this problem in our set up since when we measure the shift in outsourcing we control for both, shifts in factor prices and changes in output prices. In fact, our definition for shift in outsourcing is a change in the use of imported

[14] They proxy skilled workers with non-production workers.

[15] Another example that could be biasing their results would be a change in the preferences.

intermediate inputs controlling for factor and final good price changes. The second important difference from Feenstra and Hanson [1999] comes from the inclusion of services in our sample, with services having been excluded in their study. Hence, we obtain that the effect of outsourcing on the wage gap is twice as large as the one in their paper, 15 versus 28 percent.

Our two-step methodology is based on Haskel and Slaughter [2002]. They, like us, merge two approaches. The first one is based on the cost minimization of each industry and the usage of a translog function to approximate each industry cost, used by Berman et al. [1994], among others. The second one is based on the zero profit condition, used by Leamer [1997]. However, Haskel and Slaughter [2002] do not use intermediate inputs, or capital as production factors, disregarding possible complementarity and substitutability between these production factors and labor. Moreover, in line with previous work, they only use manufacturing sectors to derive the effect on the wage gap. Hence, they conclude that biased technical change accounts for more than a 100% of the actual wage gap, and that other forces bring the skill wage premium down.

While most of the previous empirical literature has focused on manufactures, there have been other studies that have included services on top of manufacturing.[16] For instance, Amiti and Wei [2006] study the evolution of outsourcing differentiating between manufactures and services. However, they do not study its effect on the wage gap. Three other related studies, Harrigan [2000], Harrigan and Balaban [1999], and Blum [2004] are worth mentioning, not only for the inclusion of services but because they are the first ones to make an effort in using a general equilibrium framework. Harrigan [2000] and Harrigan and Balaban [1999] study some of the causes of the increase in the wage gap, concluding that relative factor supply and relative price changes are important causes. However, their studies do not consider either outsourcing, or biased technological changes. Blum [2004] concludes that changes in sectoral composition from manufacturing sectors to services were the most important forces in explaining the increase in the wage gap. Even though he does include outsourcing and technological changes in his methodology, he cannot disentangle the effect these are having separately.

The present paper extends this effort of a general equilibrium analysis, addressing the Feenstra and Hanson [1999] question, with an adaptation of the Haskel and Slaughter [2002] framework.

[16]See Berman et al. [1994], Leamer [1997], Feenstra and Hanson [1996], Feenstra and Hanson [1999], and Hummels et al. [2001], among others, for papers focused on manufactures.

2 Methodology

2.1 Intuition

This exercise is useful in helping understand the econometric methodology used to disentangle the technological changes and its effects in the wage gap.

Consider an economy with two goods (A and B), and two production factors, labor (L) and capital (K). Each industry has a cost function, which is a function of factor prices (ω and r), output (y), and technology, that wants to minimize.

$$C_{it} = C_{it}(\omega_{it}, r_{it}, y_{it}, t) \quad i = A, B \tag{1}$$

where t stands for time and when it appears as an argument in the cost function it represents the technological progress that changes the cost function over time. Assuming homotheticity, the above expression can be rewritten as:

$$C_{it}(\omega_{it}, r_{it}, y_{it}, t) = y_{it} \cdot C_{it} \underbrace{(\omega_{it}, r_{it}, t)}_{(+)(+)(-)} \tag{2}$$

which implies that whenever any factor price increases, so does the cost, and as time goes by, the cost goes down, due to technological progress.

We can approximate each cost function using a second-order Taylor polynomial:

$$lnC_{it} = \alpha_{0i} + \alpha_{Li} \cdot ln\omega_{it} + \alpha_{Ki} \cdot lnr_{it} + \beta_{Li} \cdot ln\omega_{it} \cdot t + \beta_{Ki} \cdot lnr_{it} \cdot t + ... \tag{3}$$

where $\alpha_{Li} + \beta_{Li} \cdot t > 0$, and $\alpha_{Ki} + \beta_{Ki} \cdot t > 0$. Moreover, because of the cost function being homogeneous of degree one in factor prices, we have that:

$$\alpha_{Li} = 1 - \alpha_{Ki} \qquad \beta_{Li} = -\beta_{Ki} \tag{4}$$

Thus, we rewrite expression (3) as:

$$lnr_{it} = \frac{-lnC_{it} + \alpha_{0i}}{-\alpha_{Ki} - \beta_{Ki}t} + \frac{\alpha_{Li} + \beta_{Li}t}{-\alpha_{Ki} - \beta_{Ki}t} \cdot ln\omega_{it} \tag{5}$$

We graph the above relationship in figure 1, where each line can be seen as a combination of r_{it} and ω_{it} where C_{it} is the same, all in logarithmic terms. The solid line corresponds to commodity A and the doted line corresponds to commodity B. Moreover, the bold lines indicate the starting year while the regular lines indicate the end year. When t increases, meaning that technology changes, and nothing else moves, the lines in figure 1 will move implying a new equilibrium in factor prices.

2.2 Econometric Model

Now, we generalize by considering an economy with a number of industries (i), each industry producing one good, and 5 production factors. In particular, the five production factors are: unskilled labor (u), skilled labor (s), domestic intermediate inputs (d), imported intermediate inputs (m), and capital (k).[17] First, each industry cost function is approximated using a second-order Taylor polynomial. Then, technological changes linked to changes in outsourcing, and to changes in capital and labor use, are isolated. Secondly, assuming all industries are in perfect competitive markets, the zero profit condition must hold. Thus, we find a price equation that relates the change in factor usage or technology with the change in product prices and the change in factor prices. Finally, using the price equation we have just described, we are able to find the change in factor prices necessary to accommodate and reestablish the zero profit condition after the changes in outsourcing, or in capital and labor usage have occurred. Particularly, we can isolate the change in the wage gap that is due to outsourcing, or to biased technological change, or to total biased technological change. In the following subsections the methodology is explained in greater detail.

2.2.1 Translog Cost Function - First Step

Each industry i has a cost that is a function of factor prices (ω_{fit}), output (y_{it}), and technology, and wants to minimize:

$$C_{it}(\omega_{fit}, y_{it}, t) = \sum_f v_{fit}(\omega_{fit}, y_{it}, t) \cdot \omega_{fit} \tag{6}$$

where v_{fit} represents the quantity of factor f necessary to produce commodity i at time t; as before, t stands for time, and when it appears as an argument in the v function it represents the technological progress that changes equation (6) over time.[18] We use the translog functional form to approximate the cost function for each industry i, since it has been useful in lots of empirical papers as a good approximation for the cost function[19] [20]. For each industry, we assume homotheticity and homogenity of a constant degree, and so we have:

[17] As stated before, we understand imported intermediate inputs as outsourcing.

[18] Jorgenson [1984] and Harrigan [2000] use this time argument to account for technology affecting the "translog" revenue function. We do similarly for the "translog" cost function.

[19] It introduces less constraints on factor substituability than CES, Cobb-Douglas, or Leontieff production functions.

[20] See Berndt and Wood [1975], and Segal [2003] as examples.

$$lnC_{it} = \alpha_{0i} + \sum_f \alpha_{fi} \cdot ln\omega_{fit} + \frac{1}{2} \sum_f \sum_{f'} \gamma_{ff'} \cdot ln\omega_{fit} \cdot ln\omega_{f'it} +$$
$$+ t \cdot \sum_f \beta_{fi} \cdot ln\omega_{fit} + \alpha_{ti} \cdot t + \frac{1}{2} \cdot \pi_{ti} \cdot t^2 + \alpha_{y_i} \cdot lny_{it} + \eta_{ty_i} \cdot t \cdot lny_{it} \tag{7}$$

For this to be well-behaved we need, homogeneity of degree one in factor prices, given y_{it}, which means:

$$\sum_f \alpha_{fi} = 1, \qquad \sum_f \beta_{fi} = 0, \qquad \sum_{f'} \gamma_{ff'} = 0 \qquad \forall f \tag{8}$$

Moreover, as the sum of the cost shares must be equal to one at each point in time, we need:

$$\sum_f \gamma_{ff'} = 0 \qquad \forall f' \tag{9}$$

Finally, some symmetry restrictions must be imposed to have symmetry in the elasticities:

$$\gamma_{ff'} = \gamma_{f'f} \qquad \forall f \neq f' \tag{10}$$

If we logarithmically differentiate (7) with respect to factor prices (ω_{fit}) and employ Shepard's lemma we get the following system of cost-share equations:

$$\theta_{uit} = \alpha_{ui} + \beta_{ui} \cdot t + \sum_{f'} \gamma_{f'u} \cdot ln\omega_{f'it} \tag{11}$$

$$\theta_{sit} = \alpha_{si} + \beta_{si} \cdot t + \sum_{f'} \gamma_{f's} \cdot ln\omega_{f'it}$$
$$\theta_{dit} = \alpha_{di} + \beta_{di} \cdot t + \sum_{f'} \gamma_{f'd} \cdot ln\omega_{f'it}$$
$$\theta_{mit} = \alpha_{mi} + \beta_{mi} \cdot t + \sum_{f'} \gamma_{f'm} \cdot ln\omega_{f'it}$$
$$\theta_{kit} = \alpha_{ki} + \beta_{ki} \cdot t + \sum_{f'} \gamma_{f'k} \cdot ln\omega_{f'it}$$

where θ_{fit} is the cost-share of factor f in industry i at time t. Notice first, that the coefficient $\gamma_{ff'}$ is assumed equal in all industries, since we have some data restrictions. However, in section 4 we have some robustness checks assuming $\gamma_{ff'}$ different if the industry belongs to manufactures or services, or if it is a capital intensive industry or a labor intensive one. Second, we have data at the industry level, thus, industry level factor prices (ω_{fit}) can be taken as fixed (see Jorgenson [1987], and Harrigan [2000] as examples.) Finally notice that, technological progress, represented by the argument t, changes the form of the cost equation in (6) over time. Thus, the time trend, t, in each cost-share equation (11) can be seen as the *reduced-form effect of technological progress* *on cost-shares* (See Harrigan [2000].) In particular, β_{fi} is the technological (biased) change of factor f occurring over time that changes the cost-share of production factor f in industry i. For example, β_{mit} can be understood as a change in information technologies or law enforcement affecting the outsourcing cost-share, or the outsourcing usage.[21] An analogous analysis can be performed by taking the effect of technology on capital and labor factors ($\beta_{ui}, \beta si, \beta ki$).

2.2.2 Price Equation - Second Step

Each industry, i, is in a perfect competitive market, thus, the zero-profit condition holds for each of them:

$$p_i = \sum_f a_{fi} \cdot \omega_{fi} \qquad \forall i \tag{12}$$

where a_{fi} are the units of factor f needed to produce one unit of output belonging to industry i. We name a_{fi}, usage element, or production technique element. Following Leamer [1997] we differentiate the zero-profit condition for each industry i and obtain:

$$\hat{p_i} = \sum_f \hat{a}_{fi} \cdot \theta_{fi} + \sum_f \theta_{fi} \cdot \hat{\omega}_{fi} \tag{13}$$

where $\hat{x} = dx/x$, θ_{fi} is the cost-share for factor f in industry i at the beginning of the period, and ω_{fi} is the f factor price in industry i. Rearranging the terms of the above equation:

$$\sum_f \hat{a}_{fi} \cdot \theta_{fi} = \hat{p_i} - \sum_f \theta_{fi} \cdot \hat{\omega}_{fi} \tag{14}$$

As Feenstra [2003] points out, when you use data and have different years, infinitesimal changes might not be a good approximation of discrete changes. Therefore, instead of using the cost-share at the beginning of the period, we should use the average of the cost-shares at the beginning of the period and at the end of the period, and so the identity in (14) can be expressed as:[22]

$$\sum_f \hat{a}_{fit} \cdot \frac{1}{2} \cdot (\theta_{fit-1} + \theta_{fit}) = \hat{p}_{it} - \sum_f \frac{1}{2} \cdot (\theta_{fit-1} + \theta_{fit}) \cdot \hat{\omega}_{fit} \tag{15}$$

where the subindex t stands for time and appears for the first time because changes are not infinitesimal. The above Price Equation relates the change in product prices, $\hat{p}_{it}$ with the change in factor prices, $\hat{\omega}_{fit}$, and the change in factor usage, given by the term in the left hand side of

[21] See Bartel et al. [2005]. Puga and Trefler [2005] show that the number of patents own by US in China, for instance, has increased a lot since 1980. One of the reasons could be the improvement in property rights and law enforcement in this country.

[22] It consists on applying the Fisher-Chain Index

the equation.[23]

One of the counterfactual exercises we are trying to answer here is, how much technology affecting outsourcing usage has changed factor prices assuming the rest has stayed the same. Or how much technological changes affecting capital and labor usage in each industry has changed factor prices, all else equal. To do such an empirical experiment, we use the *first step*, form where we can capture the evolution over time of the cost-share of each factor due to changes in technology.

2.2.3 Relate the First Step with the Second Step

Our objective consists on isolate the effect that technology shifting outsourcing (capital and labor, or all of them at the same time) has on factor prices. To do so, we only consider the time trend(s) affecting outsourcing (capital and labor, or all factors) cost share(s) in equation (11), since, as already explained, this captures the outsourcing biased technological changes (biased technological changes, or total biased technological changes.) For simplicity, let's imagine from here until the end of the Methodology Section that we are only interested in the counterfactual "if only outsourcing would have changed, what would have happened to the US wage gap?"[24] Hence, as showed in (11), we only consider the outsourcing time trend:

$$\Delta\widetilde{\theta}_{mit} = \beta_{mi} \cdot \Delta t \tag{16}$$

where tilde stands for the change in the cost-share that is only due to technological progress affecting outsourcing, in this particular case, and nothing else.

Expression (16) shows how the cost-share of outsourcing evolves over time due to technological changes facilitating outsourcing. Assuming this is the only cost-share changing would be incorrect, since we would end up with the sum of cost-shares being different from one at time t. To correct for this, an extra assumption is needed. Consider that the cost-shares for all $f \neq m$ change such that they cancel out the change in the outsourcing cost-share. In particular, the change in the cost-share of factor $f \neq m$ is "proportional" to the negative of the change in the outsourcing cost-share, being the importance of factor f at the beginning of the period the "proportionality" coefficient. This can be expressed as:

$$\Delta\widetilde{\theta}_{fit} = \frac{\theta_{fit-1}}{1-\theta_{mit-1}} \cdot (-\Delta(\widetilde{\theta}_{mit})) \qquad \forall f \neq m \tag{17}$$

[23]Note that the left hand side term in equation (15) is also known as the negative of the total factor productivity ($-TFP$).

[24]Recall that when we say outsourcing and its effect in the wage gap, we are talking about technological improvements facilitating outsourcing and its further effects on the wage gap.

where $\sum_{f \neq m} \Delta\widetilde{\theta}_{fit} = -\Delta\widetilde{\theta}_{mit}$, $\sum_{f} \Delta\widetilde{\theta}_{fit} = 0$. Hence, we capture the effect that technology has over the outsourcing cost-share. Analogously as we do with outsourcing we can proceed with capital and labor (biased technological change,) and with all factors at the same time (total biased technological change.)

In this *first step* is where there is the main divergence from Feenstra and Hanson [1999]. As it has been already stated, they"endogenize prices and productivity", by regressing TFP and commodity price changes, against the change in outsourcing, where outsourcing is an exogenous variable. Then, they use the estimation results on TFP and change in commodity prices due to outsourcing, and put them in the price equation. With this procedure they find out the effect of outsourcing in factor price changes. This partial equilibrium approach might suffer from an omitted variable problem in the"endogenizing" step already discussed. We take a "more" general equilibrium approach considering outsourcing as a factor of production and not as an exogeneous variable modifying commodity prices and TFP. Using the versatility of the translog, we capture the effect that technology is having on the usage of production factors, including outsourcing.

In order to combine the result in the translog cost function (*first step*) with the price equation (*second step*), we use the relationship between the production techniques element, a_{fit}, and the cost-shares, θ_{fit}. In particular, a_{fit}, are the units of factor f needed to produce one unit of good i at time t, and θ_{fi} is the expenditure of factor f over total expenditure in industry i at time t. As we are assuming competitive markets in all industries, total cost equals total revenue, and so:

$$\theta_{fit} = a_{fit} \cdot \frac{\omega_{fit}}{p_{it}} \tag{18}$$

As stated above, we are only interested in the effect technology has over the outsourcing cost-share, and the further effect that this has on the skilled-unskilled wage gap. Thus, in the change in outsourcing cost-share controlling by factor prices. Moreover, as in our counterfactual we are assuming that only outsourcing changes and the rest stays the same as before, we are assuming that commodity prices are not moving ($\Delta p_{it} = 0$). In this case we can write:

$$\frac{\Delta\widetilde{\theta}_{fit}}{\theta_{fit-1}} = \frac{\Delta\widetilde{a}_{fit}}{a_{fit-1}} \qquad or \qquad \widehat{\widetilde{\theta}}_{fit} = \widehat{\widetilde{a}}_{fit} \tag{19}$$

Remember that we use tilde when assuming that outsourcing biased technological case has occurred and nothing else. Substituting this into the price regression equation (15) we obtain the effect that the change in outsourcing has over the change in factor prices, specifically, the change in the skilled-unskilled wage gap. In particular:

$$\sum_f \widehat{\widetilde{a}}_{fit} \cdot \frac{1}{2} \cdot (\theta_{fit-1} + \widetilde{\theta}_{fit}) = -\sum_f \frac{1}{2} \cdot (\theta_{fit-1} + \widetilde{\theta}_{fit}) \cdot \delta_{ft} + \epsilon_{fit} \tag{20}$$

where $\widehat{\widetilde{a}}_{fit}$ is the percentage change in a_{fit} due to change in outsourcing usage driven by technology changes; $\widetilde{\theta}_{fit}$ is the cost-share of factor f at time t if only outsourcing changes, δ_{ft} is the coefficient that needs to be estimated and it gives the mean or average percentage price change of factor f due to outsourcing changing over time; and ϵ_{fit} is an error term that captures the departure of the factor price change for each industry from the mean percentage change, plus the percentage change in international prices.[25] ,[26] Finally we compare the predicted change in the wage gap, $(\delta_{st} - \delta_{ut})$, with the actual one, $(\hat{\omega}_{st} - \hat{\omega}_{ut})$. This gives the relative importance of the effect of outsourcing on wages with respect to reality.

Since $\sum_f \Delta\widetilde{\theta}_{fit} = 0$, we can rewrite equation (20), and our final estimation equation can be stated as:

$$\sum_f \frac{1}{2} \cdot \frac{(\Delta\widetilde{\theta}_{fit})^2}{\theta_{fit-1}} = -\sum_f \frac{1}{2} \cdot (2\theta_{fit-1} + \Delta\widetilde{\theta}_{fit}) \cdot \delta_{ft} + \epsilon_{fit} \tag{21}$$

We estimate the above equation using weighted OLS for the 27 industries and for the 1980-1999 period, where more weight is given to those industries with a larger value-added. Similarly, we do for the biased technological change and the total biased technological change.

3 Overview of the Data

3.1 Construction of the Data Set

We use several sources to construct all the variables needed to apply our methodology, ending up with a total of 27 industries over the period 1973-1999, 18 manufactures, and 9 services, see table 1. Unfortunately, we do not have all variables for the 26 year period, but for 16 years of this period.[27] A detailed explanation of the construction of the Data Set is in Appendix A and B. In this section, we give a broad overview of the construction of the data in order to introduce some variables used in later sections.

First, we obtain the cost share for intermediate inputs (domestic and imported.) We use the Annual Input Output tables (IO) from the Bureau of Economic Analysis [b] (BEA). From there we extract the total intermediate coefficients, b_{ij}^{tot}, that give the quantity of intermediate inputs

[25]The rest of the of the production factors change following the "proportionality" assumption

[26]Notice that we are assuming $\Delta p_{it} = 0$, since the counterfactual shows what would have been the wage gap in the US wages if the only thing changing would have been outsourcing (or biased technological change, or total biased technological change), and international prices would have moved minimally.

[27]The years where we do have data for all variables are: 1973, 1974, 1975, 1976, 1978, 1979, 1980, 1981, 1983, 1984, 1985, 1986, 1996, 1997, 1998, and 1999.

of industry i necessary to produce one dollar worth of good in industry j. Following Feenstra [1998] and the OECD Stan data set procedure, we can construct the domestic intermediate coefficients, b^d_{ij}, quantity of domestic intermediate inputs of industry i necessary to produce one dollar worth of good in industry j; and the imported intermediate coefficients, b^m_{ij}, quantity of domestic intermediate inputs of industry i necessary to produce one dollar worth of good in industry j. With these elements we construct the total expenditure for domestic and imported intermediate inputs by industry and year, and then construct the corresponding cost-shares (θ_{dit}, θ_{mit}).

Second, we construct the cost share for skilled and unskilled workers. From Bureau of Economic Analysis [a], we extract the compensation of employees and the total number of employees by industry and year. Then, from Current Population Survey (CPS) we can extract the wage by industry and level of education, as well as, the percentage of skilled and unskilled employees by industry. With all this, we compute, both, the number of skilled and unskilled workers by industry, and the wages for skilled and unskilled workers by industry (ω_{uit}, ω_{sit}). Finally, we are able to obtain the cost share for skilled and unskilled workers by industry and year (θ_{uit}, θ_{sit}).

Third, we compute the cost share of capital. We start by getting the quantity of capital and its price by industry from the 35-KLEM data set constructed by Jorgenson [1987] (ω_{kit}). This data set is explained in Jorgenson et al. [1987]. Thus, we can extract the capital cost-share (θ_{kit}).

Finally, we compute the prices for domestic and imported intermediates by industry, using the Bureau of Labor Analysis data sets (BLS). In particular, for the domestic intermediate inputs we use the Producer's Price Index Industry Data (PPI) by industry series from Bureau of Labor Analysis [b].[28] We construct a price index for each industry and using the domestic intermediate coefficients, b^d_{ij}, we input to each industry the price of domestic intermediates that is associated with the quantity of domestic intermediates that is using from all industries. A similar methodology is applied to compute the price for imported intermediates (or price of outsourcing), but in this case we use the Import Price Indexes computed by Bureau of Labor Analysis [a] and the import intermediate coefficients, b^m_{ij}.[29] We should *highlight* that we construct two alternative price index, in both the domestic and imported case, for the sectors belonging to services. In the first alternative, we assume that the price index for all services equals the average of manufactures price index, since we do not have particular information for services prices. One could argue,

[28] The PPI tracks selling prices received by domestic producers of goods and services. It is measured from the perspective of the seller.

[29] The Import Price Index tracks prices of nonmilitary goods and services traded between U.S. and the rest of the world.

that with this assumption the price index for services goes down too slowly. In order to correct for this, we construct an alternative price index, where the price for computer manufacturing affects certain types of services price index, on top of the average price of manufactures.[30]

3.2 Preliminary Results

Since outsourcing has been blamed for being one of the main factors driving up the wage gap, we start by presenting proof of the raise in the wage gap between skilled and unskilled workers, and the increase in the level of the "outsourcing share."

First, some evidence about the evolution of the wage gap in the US economy for the 1980-1999 period is presented. Skilled wages rose by 122.36% over the period, and unskilled wages increased by 75.81%. Hence, the total increase in the wage gap from 1980 to 1999 has been equal to 46.55%.[31] For comparison purposes, we compute the same for the 1979-1990 period and for manufactures only, since this is the period and the industries studied by Feenstra and Hanson [1999]. They found that wages for skilled workers (non-production workers) relative to unskilled workers (production workers) increased by an average of 0.72% per year. We obtain that the total percentage change in skilled wages equals 82.89%, and for unskilled wages this is 69.57%, so we also get an average of 0.72% per year.[32] But if we do include services in the computation we obtain that the wage for skilled labor relative to unskilled labor increases by an average of 1.31% per year, which is substantially different from the 0.72% for only manufactures. Thus, the inclusion of services is not trivial. The increase in the wage gap can be seen in figure 2, where we are graphing the skilled-unskilled wage ratio for the average skilled and unskilled worker over the time period 1973-1999. The time period for the graph is longer than 1980-1999 period to see that the increase in the wage gap does not occur until the beginning of the eighties. Analyzing the wage gap industry by industry shows that the general effect on wages is not due to a shifting in industries, since the evolution of the wage ratio for the top nine industries in the economy has an increasing tendency as well.[33]

Secondly, we construct a measure of the "outsourcing share" following the one constructed by Feenstra and Hanson [1999]. In particular, remember that b_{ij}^{tot}, taken directly from BEA, gives the quantity of total intermediate inputs of industry i needed to produce one dollar worth of good in industry j. Similarly with b_{ij}^{d} and b_{ij}^{m}, but for domestic and imported intermediate

[30] See appendix for a more detailed explanation.

[31] The percentage change in the wage gap is defined as the percentage change of skilled wages minus the percentage change of unskilled wages.

[32] From the skilled 82.89% we get a annual increase of 5.64%, and from 69.57% we obtain 4.92%. If we subtract one from another we get the average annual percentage change, which equals 0.72%.

[33] We use industry gross output to classify the top industries.

inputs, respectively.[34] Thus, we define outsourcing share of industry j at time t as:

$$os_{jt} = \sum_i \left[\frac{b_{ij}^m}{\sum_i b_{ij}^{tot}} \right] \tag{22}$$

Moreover, we apply Hummels et al. [2001]'s method to control for the fact that some domestic intermediate inputs might be using imported intermediate inputs.[35]

We compute this for each year and industry and then, we take a weighted average by year of the outsourcing share measure, where the weight is the value added of each industry, see column 1 in table 2.[36] In 1973 this average measure of outsourcing share is 5.19%, it is 6.52% in 1986, and 9.22% in 1999. This means that between 1973 and 1986 the annual average growth rate of the outsourcing share was 1.77%, while between 1986 and 1999 it was 2.70%. Similarly, we can decompose the above measure between imported intermediates of services share (outsourcing of services share - oss) and of goods share (outsourcing of goods share - osm), where the imported intermediates of services share are imported intermediate services as a share of total intermediate inputs, controlling for domestic intermediate inputs using imported intermediate services. Analogously, for the imported intermediate of goods share, see column 2 and 3 in table 2. In 1973 the outsourcing of services share was 0.38%, it increased to 0.50% in 1986, and it was 0.87% in 1999. Similarly, we have 4.81%, 6.02%, and 8.35% for the outsourcing of goods share in 1973, 1986, and 1999, respectively.[37] The most interesting feature of this decomposition is that it allows us to study the different trend of the outsourcing of goods share and of services over time. The annual average growth rate of the outsourcing of services share increases a lot in the last years in comparison to the first years studied. We have that between 1973 and 1986 the annual growth rate in the outsourcing of goods share is 1.73%, and it is 2.5% in the 1986-1999 period. For the outsourcing of services share we jump from a 2.07% to a 4.42% annual increase. That could be a possible explanation of why people started getting worried about outsourcing of services by the end of the nineties, even though, the level of the outsourcing of services share is still a lot lower than the goods one, it accelerated.

Finally, we can also decompose the outsourcing share measure in two other measures: the outsourcing by services share and the outsourcing by manufactures and agriculture share, see

[34] These are constructed making some assumptions. For more information go to the Appendix section.

[35] They use it to compute what they name Vertical Specialization

[36] When computing this measure of outsourcing share we use 29 industries, instead of the 27 above mentioned. Here we include agriculture and forestry, and mining sectors, that later in the regression results will not be included.

[37] Amiti and Wei [2006] perform this decomposition for the period 1992-2001 and find similar results as the ones we have for the period 1996-1999. However, we can compare the different behavior of outsourcing share over time, and they cannot given their limited data. Note that the results for Amiti and Wei [2006] we are comparing with, are the ones corresponding to an earlier version of this paper. See Canals [2006] for a more detailed comparison between both works.

table 3. The outsourcing by services share are imported intermediate inputs as a share of total intermediate inputs by service sectors. Similarly, with the outsourcing by manufactures and agriculture share. We observe an increase in both measures, though outsourcing by manufactures and agriculture is larger at all points in time. An interesting feature, is that the growth speed of outsourcing by services has increased in the last period (1986-1996) with respect to the previous one, which is not true for outsourcing by manufactures and agriculture. Thus, the inclusion of services in the analysis is not irrelevant.

A striking feature of these two phenomena, the wage gap and the level of the outsourcing share, is that while the wage gap seems that it starts increasing at the beginning of the eighties, but not before, that is not true for the outsourcing share measure. The outsourcing share has been increasing for the last thirty years. However, it has increased its speed in the latest period, and that is specially true for the outsourcing of and by services share.

An interesting exercise consists on plotting the percentage change in the outsourcing cost-share for each industry against the change in the wage gap for each industry in the 1980-1999 period, see figure 3. It seems that the change in the wage gap is larger for those industries with a smaller change in the outsourcing cost-share. This intuition would go in the opposite direction as those who claim that the increase in the level of outsourcing has implied an increase in the wage gap. But this plot does not imply any direct causality, and a more detailed study needs to be performed in order to disentangle if there is some truth in the effect of outsourcing over the wage gap. That is what we accomplish with the empirical decomposition.

Other variables of interest are the evolution of factor prices and the change in the cost-shares over time, since these are key variables in the translog cost step. We start by showing the evolution of the average factor prices taking 1973 as the unitary year, and deflated by the CPI, see 4. To compute the average price for skilled (unskilled) workers we use as weight the number of skilled (unskilled) workers in each industry. For the rest of the factor prices, we use each industry value added as the weight to compute an average measure per year. Notice that, for the domestic and imported intermediate factor prices the only available years are the sixteen years mentioned earlier. The evolution of the skilled and unskilled wages is similar in the first years, but as already explained, at the beginning of the eighties they grow apart. The price of capital behaves similarly to unskilled wages. Finally, we observe that both, price for domestic and imported intermediate inputs decrease over time, being the decrease faster for imported intermediate inputs. We end up by showing the evolution of the average cost-share over time, see table 5. In particular, we take a weighted average of each industry cost-share, where more weight is given to those industries with a larger value added. We observe that the unskilled cost-share decreases over time almost the same amount as the skilled cost-share increase, around 40%. Outsourcing cost-share increases by 73%. Finally, the capital and the domestic intermediate input cost-shares are quite stable across years.

4 Regression Results

In order to obtain δ_{ft}, the average factor price percentage change for factor f, and be able to compute the wage gap $(\delta_{st} - \delta_{ut})$ caused by different technological changes affecting outsourcing, and capital and labor usage, we need to run equation (21) for the final 27 industries and for the 1980-1999 period.[38] Nonetheless, before running this final equation, we need to apply the first-step. Thus, we run the cost-share system specified in equation (11), for all available years in the 1973-1999 period, together with the restrictions specified in (8), (9), and (10). Then we obtain $\Delta\widetilde{\theta}_{fit}$ as explained at the end of subsection 2.2.1. Finally we substitute it in equation (21) and run it.

Observe that, only four out of the five cost-share equations in (11) are linearly independent. Thus, to handle this singularity problem we drop an arbitrary equation and then estimate for the remaining ones.[39] However, in order to avoid variability in the estimated parameters depending on the equation dropped, we should use a ML procedure, in particular the iterated Zellner's seemingly unrelated procedure, IZEF, since it also deals with the cross-equation symmetry constraints, see Berndt [1991]. Hence, we start by running:

$$\theta_{uit} = \alpha_{ui} + \beta_{ui} \cdot t + \sum_{f'} \gamma_{f'u} \cdot ln\Big(\frac{\omega_{f'it}}{\omega_{kit}}\Big) \tag{23}$$

$$\theta_{sit} = \alpha_{si} + \beta_{si} \cdot t + \sum_{f'} \gamma_{f's} \cdot ln\Big(\frac{\omega_{f'it}}{\omega_{kit}}\Big)$$

$$\theta_{dit} = \alpha_{di} + \beta_{di} \cdot t + \sum_{f'} \gamma_{f'd} \cdot ln\Big(\frac{\omega_{f'it}}{\omega_{kit}}\Big)$$

$$\theta_{mit} = \alpha_{mi} + \beta_{mi} \cdot t + \sum_{f'} \gamma_{f'm} \cdot ln\Big(\frac{\omega_{f'it}}{\omega_{kit}}\Big)$$

together with the constraints given by (8), (9), and (10). As already pointed out, we should notice

[38]There are two reasons why we take the 1980-1999 period, first we have observed that the wage gap started increasing at the beginning of the eighties, and not before. The second reason, is that this is a pretty stable period in the U.S. economy .

[39]In our case we drop the capital factor share equation.

that since the data is at the industry level factor prices can be taken as fixed (see Jorgenson [1984]). This is not true when the data is less disaggregated. Then, prices might be correlated with the error term, and instruments are needed to run the cost-share equations. See chapter 9 of Berndt [1991] for a more detailed explanation.

After running the above system of equations, we obtain β_{ui} negative for almost all industries; β_{mi} always positive ; β_{si} mainly positive; and β_{di} and β_{ki} positive or negative depending in the industry. Thus, over time and controlling for all factor prices, the cost-share for unskilled workers goes down, while it goes up for skilled workers and imported intermediate inputs or outsourcing. This result is similar to the one obtained in the preliminary results regarding the behavior of the average cost-shares over time. The difference is that in the translog equation we are controlling for factor prices. This shows that biased technological change over time implies a larger usage of skilled labor and outsourcing, and less unskilled labor is needed. Moreover, we observe that the largest percentage change in the outsourcing cost-share due to technological changes (βmi) is in the Finance, Insurance, and Real Estate sector, followed by Communications, and Health, Educational and Social Services, and Membership Organizations.[40]

From the translog results we can compute the Allen elasticities of substitution, ($\sigma_{ff'}$), to measure the factor substitution possibilities. These show which production factors are substitutes and which are complements. The results for the Allen elasticities are in table 6, where a positive number indicates the the factors are substitutes, and a negative number means factor complementarity.[41] We start by analyzing the relationship between outsourcing and the other factors of production. We can conclude that unskilled workers and outsourcing are substitutes, σ_{um} is about 0.618; capital and outsourcing are slightly substitutes, being σ_{km} equals 0.226; while domestic intermediate inputs and outsourcing have a higher degree of substitutability, being σ_{dm} equal to 1.882; finally it seems that skilled labor is complement with outsourcing, with σ_{sm} about -1.142. Then, checking at the relationship between unskilled and skilled workers, they are complements, being σ_{us} -1.047; unskilled workers and capital are slightly substitutes, $\sigma_{uk} = -0.106$; and skilled workers and capital are complements, since σ_{sk} is 0.553.

Before starting with the second-step, we need to check that the estimated translog cost function is monotonically increasing and strictly quasi-concave in input prices, as theory requires. First, we check that all fitted shares are positive, thus monotonicity is proven. Secondly, for strict quasi-concavity we check that the matrix of substitution elasticities is negative semidefinite at

[40] We are not taking the largest β_{mi} but the largest one with respect to the outsourcing cost-share.

[41] We take 1986 and a weighted average of the fitted cost-shares for the different industries to compute the elasticities.

each observation.

Using the translog cost estimation we isolate the effect that technology has on the different production factor cost-shares, β_{fit}. In particular, we start by analyzing the effect of technology on outsourcing and its further effect in the wage gap. Secondly, we analyze the effect of biased technological change in the wage gap. Finally, we analyze the effect of total biased technological change in the gap.

The first objective is to isolate the effect of outsourcing on the wage gap (outsourcing biased technological change) for the period 1980-1999. Thus, after running the translog, we take β_{mit} and compute $\Delta\widetilde{\theta}_{mit}$ using equation (16). Then for the rest of the factors we apply the "proportionality" assumption to obtain $\Delta\widetilde{\theta}_{fit} \quad \forall f \neq m$. Remember that we cannot only assume a change in the outsourcing cost-share due to technology without making any further changes in the rest of the cost-shares, since the cost-shares always have to add up to one. So we assume that the rest of the cost-shares change "proportionally" and in the opposite direction as the change in the outsourcing cost-share, where the proportionality coefficient is their importance at the beginning of the period. Then, we obtain $\widehat{\widehat{a}}_{fit}$ from $\widehat{\widehat{\theta}}_{fit}$ as indicated in equation (19). Finally, we run equation (21). The final results for this particular experiment are in column (1) of table 7 and table 9, for the two alternative methods of computing price of domestic and imported intermediate inputs. We comment the results for the first alternative, since the ones for the second alternative are very similar. As already explained, δ_{ft} gives the mean percentage change of factor price f due to outsourcing. We observe that the effect of outsourcing on the unskilled and skilled average percentage wage change is not significant in either of them (δ_{ut}, δ_{st}). However, our interest is not in δ_{ut} and δ_{st} by themselves but in their difference being positive, which means an increase in the wage gap. Testing for $\delta_{st} - \delta_{ut}$ being positive, we can conclude that the wage gap due to outsourcing is positive and equals 0.131 $(0.049 - (-0.0082))$[42], and it is significant at a 10% significant level, see column (1) in table 8 (and column (1) in table 10 for the second alternative). Thus, outsourcing accounts for 28% (36% if second price alternative) of the actual wage gap in the 1980-1999 period, which is 46.55%.

Using the same approach as with outsourcing, we isolate the effect of the change in labor and capital (biased technological change) usage on the wage gap. Hence, we take β_{uit}, β_{sit}, and β_{kit} and compute the change of the cost-shares for these factors. We assume that the cost-shares for the rest of the factors, intermediate inputs, change proportionally. Finally we run equation (21), see column (2) in table 7 and table 9. The effect of the biased technological change on unskilled

[42] More precisely, this is the wage gap that would have occurred if only technology facilitating outsourcing would have happened, all else being equal.

wages is significant and negative, -0.139, while it is not significant for skilled wages. Again, as before, we are not interested in the effects by themselves, but in their difference, $\delta_{st} - \delta_{ut}$, see column (2) in table 8, or alternatively column (2) in table 10. Hence, we can conclude that biased technological change implies an increase in the wage gap of 0.078 $(-0.061 - (-0.139))$ percentage points (10% level of significance). Thus, it can explain 15% of the actual wage gap (or 19% at the 15% level of significance for the alternative way of intermediate input prices.)

Finally, we study the total technological change effect in the wage gap. We take all β_{fit}, compute $\widehat{\widehat{\theta}}_{fit}$ and $\widehat{\widehat{a}}_{fit}$, and run equation (21), see column (3) in tables 7 and 8 (or alternatively, 9 and 10). The difference between the average percentage wage change in skilled workers versus the average percentage wage change in unskilled workers equals 0.27 $(-0.031 - (-0.301))$ (5% level of significance). Therefore, we conclude that between 58% and 59% of the actual wage gap for the 1980-1999 period can be explained thanks to technological changes affecting all the production factors.

4.1 Robustness Checks

Some sensitivity analysis need to be performed in order to check the robustness of these results. We start by repeating the same counterfactuals than before: outsourcing, biased technological change, and total biased technological change, for two different periods, 1983-1999, and 1980-1996. Since the results are similar to the previous ones when we slightly change the time period studied, the table results is not included here.

Second, in the first step we allow for the effect of wages on the cost-shares ($\gamma_{ff'}$) to be different depending on the level of capital intensitivity of the industry. We perform a similar exercise, but allowing for two different $\gamma_{ff'}$'s, one if the industry belongs to manufacturing, and the other if it is a service. The results for both exercise for the outsourcing counterfactual are on table 11. Again, we perform the counterfactual using the first alternative on the computation on intermediate input prices, however, the results are robust if using the second alternative, as well.

Finally, even though we claim that due to the level of disaggregation of the data there should not be endogeneity problems in the first step, we have performed the same analysis using instruments. We use the average factor price of all sectors excluding sector i as instruments for factor prices for each industry i . Moreover, we use the first alternative to construct intermediate prices. The results are consistent, thus we do not include the table, since it is very similar to tables 7 and 8.

Hence, we can conclude that for the 1980-1999 period, outsourcing can explain between 28% and 36% of the 46.55% actual wage gap. Biased technological change accounts for between 15% and 19%, and total technological change accounts for 58%-59% of the increase in the gap, depending on the construction of the intermediate input prices.

5 Conclusions

The skilled-unskilled wage gap has increased by 46.55% between 1980 and 1999. Quantifying the impact of outsourcing and biased technological change on the wage gap has been a preeminent question in international and labor economics, as well as in policy studies.

In this paper we break down the effect that technology facilitating outsourcing (outsourcing biased technological change), or affecting labor and capital usage (biased technological change), or affecting all production factors (total biased technological change), has on the wage gap. Previous empirical work done by Feenstra and Hanson [1999] use a partial equilibrium model with exogenous shocks to outsourcing and to computers to explain the effects on the wage gap. Nevertheless, this approach encounters some problems because of the partial equilibrium framework adopted. We overcome this by structurally estimating a "more" general equilibrium statistical framework that integrates outsourcing, biased technological change, and total biased technological change. Particularly, for each industry, we use a translog cost approximation to capture the change in the usage of outsourcing, induced by technology changes, necessary to produce one unit of good. Similarly, with labor and capital, and with all production factors altogether. Then, using a price equation that relates change in factor usage with change in commodity prices and with change in factor prices, we compute the change in factor prices, and so the wage gap, induced by the change in outsourcing, or by biased or total biased technological change.

Besides the methodology, another novelty is the introduction of services together with manufactures. Thus, allowing us to control for services and its recent increase. In particular, services account for two thirds of the total US economy by 1999, and one third of the total imported intermediate inputs. As a parallel result we are able to study the evolution of a measure of the outsourcing share over time. Defining the outsourcing share as the value of imported intermediate inputs as a share of total intermediate inputs, and controlling by the fact that domestic intermediate inputs might be using some imported intermediate inputs, we conclude that the outsourcing share has risen. In particular, in 1973 its value is 5.19%, while it is 9.22% by 1999. We go a little bit further and decompose the outsourcing share measure in the outsourcing of goods share and the outsourcing of services share. We conclude that they behave differently. The annual growth rate of the outsourcing of services share in the last period (1986-1999) is larger than the one in the first period, 4.42% versus 2.07%. This increase in the last period speed is not as big for the outsourcing of goods share. Still, we should point out that the level of the outsourcing of services share is much lower than the outsourcing of goods share. We also calculate a measure of the outsourcing by services share and by manufactures and agriculture share. The results indicate that the outsourcing by service sectors has increased their speed in the recent years in comparison with the outsourcing by manufactures and agriculture.

Hence, applying the new methodology explained and using a new data set, we conclude that, outsourcing, as well as biased technological change and total biased technological change play an important role in explaining part of the widening in the wage gap. In particular, we quantify that outsourcing accounts for 28 percent of the actual widening in the wage gap in the 1980-1999 period, biased technological change explain 15 percent of the widening, and total biased technological change explain up to 58 percent of it.

Finally, we should mention the importance of recollecting more precise data on imported intermediate inputs and its prices. Since, due to the lack of data on these we have to make some assumptions that might be seen as too strong in some cases.

A Appendix: Construction of the Data

Here we describe the computation of all the variables needed to run the two-step procedure.

A.1 Input Output Tables - $\theta_{dit}, \theta_{mit}$

A.1.1 IO tables

From the Bureau of Economic Analysis (BEA) we extract the annual IO tables. From them, we can get three different matrices: the total intermediate matrix (B^T), the domestic intermediate matrix (B^D), and the imported intermediate matrix (B^M). The first matrix, B^T is given directly by the BEA, and an element b^T_{ij} in this matrix gives us the quantity of good belonging to industry i needed to produce total output of industry j. We follow Feenstra and Hanson (1996, 1999), and OECD STAN dataset to compute B^D and B^M. In particular, for each industry i we compute:

$$d_i = 1 - \frac{IMP_i}{ID_i + DFDi} \tag{A-1}$$

where d_i stands for the domestic portion of the use of industry i, IMP_i are the total amount of imports of industry i, ID_i total intermediate demand for industry i, and DFD_i is the total domestic demand for industry i, including imports less exports. Then, we obtain B^D and B^M such that:

$$\mathbf{B^D} = \begin{pmatrix} d_1 \cdot b^T_{11} & d_1 \cdot b^T_{12} & \cdots \\ d_2 \cdot b^T_{21} & d_2 \cdot b^T_{22} & \cdots \\ \vdots & \vdots & \ddots \end{pmatrix} \tag{A-2}$$

$$B^M = B^T - B^D \tag{A-3}$$

Once you have these three matrices you can divide each column of the matrices by the total output of that industry and you get the following matrices: B^t, B^d, and B^m, where now an element b^t_{ij}, named total intermediate coefficient, is the quantity of industry i necessary to produce one dollar worth of good in industry j. Similarly with the elements in B^d, and B^m, but for domestic intermediate inputs and imported intermediate inputs, respectively.

We should point out that to generate B^D and B^M we do not use the 27 industries finally analyzed but the larger set of industries given by the Annual IO tables. Depending on the year we have between 75 and 80 industries. Using this larger industry set we get a smaller bias in the decomposition of the matrices.

A.1.2 $\theta_{dit}, \theta_{mit}$

We need the cost share for the domestic intermediate inputs (θ_{dit}), and for the imported intermediate inputs (θ_{mit}). We take the B^D matrix at time t and sum up each column and obtain a vector, where each element indicates the total expenditure in domestic intermediates by each industry at time t. We do this for each year available. Analogously we compute the total expenditure in imported intermediates by each industry at each point in time using A^M instead. Once we have the total expenditure for domestic and imported intermediates for each industry, we divide it for the total expenditure in each industry and obtain the cost-shares for domestic intermediate inputs, θ_{dit}, and for imported intermediate inputs, θmit.

A.2 Compensation of Workers - $\omega_{uit}, \omega_{sit}$ - $\theta_{uit}, \theta_{sit}$

A.2.1 Compensation of Workers

First, using CPS March Supplement we consider only full-time employees [43] and we classify them according to their level of education: unskilled (high-school degree or less) and skilled (some years of college or more). Then, we can obtain the earnings by skilled-unskilled level and by industry (ω^{CPS}_{uit}, ω^{CPS}_{sit}), and also the percentage of skilled and unskilled workers by industry (f^{CPS}_{uit}, and f^{CPS}_{sit}). Using BEA data set we can obtain the total compensation of employees (CE^{BEA}_{it}) by industry and year, and the number of employees by industry and year (n^{BEA}_{it}). With all this we are able to compute the total number of unskilled and skilled workers by industry and year (n_{uit}, and n_{sit}) :

$$n_{uit} = f^{CPS}_{uit} \cdot n^{BEA}_{it} \qquad n_{sit} = f^{CPS}_{sit} \cdot n^{BEA}_{it}$$

We can also compute the total compensation by skill level for each industry at each point in time (CE_{uit}, and CE_{sit}):

$$CE_{uit} = n_{uit} * \omega^{CPS}_{uit} \qquad CE_{sit} = n_{sit} * \omega^{CPS}_{sit}$$

When using two data sets we need to scale them in order to make them compatible. In this case the scaling factor for the variables coming from the CPS data set is:

$$\kappa_{it} = \frac{CE^{BEA}_{it}}{CE_{it}}$$

where $CE_{it} = CE_{uit} + CE_{sit}$. Hence, we multiply the wages by this scaling factor. Now all data coming from BEA and CPS is scaled such that it matches.

[43] Since employers do not report correct earnings, and the variable reporting the number of hours worked is not well reported

A.2.2 $\omega_{uit}, \omega_{sit}$

As it is explained in the A.2.1 subsection, we obtain ω_{uit}^{CPS}, ω_{sit}^{CPS} from CPS, and then we simply need to scale it by κ_{it} to match it with the BEA data.

A.2.3 $\theta_{uit}, \theta_{sit}$

We have the total expenditure for unskilled workers and skilled workers: CE_{uit} and CE_{sit}. Thus, we simply need to divide this by total expenditure for each industry at each point in time to obtain the costs-share for unskilled and skilled workers.

A.3 Scaling BEA data into IO data

We need to have a coherent data set and to do so we need to scale the above variables constructed, coming from BEA and CPS (already scaled to BEA data), to match the rest of the data coming form the IO tables. To do so, we construct a scaling factor with the Gross Output from BEA and the one from the IO tables:

$$\tau_{it} = \frac{GO_{it}^{IO}}{GO_{it}^{BEA}}$$

where GO_{it}^{IO} is the Gross Output coming from IO tables, and similarly the one coming from BEA. With this scaling factor we scale the variables coming from BEA and CPS.

Note 1: BEA does not publish the GO industry by industry for years 1973, 1974, 1975, and 1976. Thus, for all those years we use the average τ_{it} obtained from the period 1978-1986 .

Note 2: For sectors 8, 23, and 24 we compute τ_{it} using the value added from the BEA and from the IO tables.

Note 3: finally for sectors 13, and 16 we take the value for gross output and value added from the BEA as the correct one. In other words, $\tau_{it} = 1$ for all years.

A.4 Capital - ω_{kit} - θ_{kit}

A.4.1 Capital

We use the data set developed by Dale W. Jorgenson, named 35-KLEM. The data covers 35 sectors and the 1958-1996 period. It contains the value of capital and a capital price index for each sector and year. First we match his sectors with ours according to the following criteria:

Final Sectors	Jorgenson Sectors	Final Sectors	Jorgenson Sectors	Final Sectors	Jorgenson Sectors
1	6	10	27	19	18
2	11	11	7	20	28+30+31
3	12	12	8	21	29
4	19	13	9	22	32
5	20	14	10	23	33
6	21	15	13	24	part 34
7	22	16	14	25	part 34
8	23+26	17	15	26	part 34
9	24+25	18	17	27	part 34

Then we take the value of capital and the price of capital from his data set. If we have that one of our sectors corresponds to two or more than his ones, we take the value of capital as the sum, and the price index as the weighted average of the price indexes, where the weight is the value of capital. If we have that one of our sectors corresponds to a fraction of one of his sectors, like we have for our sectors 24, 25, 26, and 27, we take the price index as the price index for his sector, and the value of capital equals a percentage of his value of capital. Where the percentage is computed considering the gross output of our sector.

Finally, notice that their data set ends in 1996, while we need data until 1999. We compute the values for 1997 to 1999, as the linear approximation considering only years 1990-1996.

A.4.2 ω_{kit}

As stated above we take the price for capital directly from the Jorgenson data set.

A.4.3 θ_{kit}

We have the value of capital for each industry at each point in time from the Jorgenon data set. This is the expenditure that each industry has on capital. Thus, we compute the cost-share of capital as the ratio between this value of capital over total expenditure.

A.5 Price for Imported Intermediate Inputs = ω_{mit}

From BLS we get U.S import price index series for a selected category of goods, available in:

ftp://ftp.bls.gov/pub/suppl/ximpim.sitimp.txt.

The first thing we do is match the goods from this series with the 27 final industries we have as showed in Appendix B. Then, for each industry we have a price index showing the evolution of the price of the goods belonging to that industry that are being bought by U.S. firms (p_{imp}) as intermediates. Finally, following Bartelsman and Gray [1996]'s procedure, we use B^m, which tells us the percentage that each industry is using from other industries and itself to produce its own output, we construct an outsourcing price index by industry and year such that:

$$\omega_{mit} = \sum b_{ij}^m \cdot p_{jmp} \quad \text{(A-4)}$$

There are two important things that need to be highlight. First, we do not have all years to compute p_{imp}. In some industries we have data from 1975 onwards and then we have take the estimates for the missing years: 1973 and 1974. All of them start no later than 1981. Second, the series given by BLS only contains goods belonging to manufacturing sectors, not services. Thus, we construct two alternative price index, p_{mit}, for the services sectors. In the first alternative, we assume that the price index for all services equals the average of manufactures price index, since we do not have particular information for services prices. In the second alternative, we consider that the the price for computer manufacturing affects certain types of services, and so on top of the average price of manufactures we include its tendency in some of the services prices. In particular take the average between the price for computer manufacturing and the average price of manufactures for Communications, Finance, Insurance and Real Estate, and Business Services and Professional Services.

A.6 Price for Domestic Intermediate Inputs = ω_{dit}

Similarly to the construction of the Price for Imported Intermediate Inputs we construct this one. The only difference is that we use PPI by industry as the first data set, and A^d as the weight matrix to compute the final price indexes. Again, we construct two alternative price indexes, and so we obtain two alternative price for domestic intermediate inputs, ω_{dit}.

A.7 Extra adjustments

There are a couple of extra adjustments that need to be done. First, we have that sectors 11 and 12 (Food and Kindred Products, and Tobacco) appear together in the BEA accounts for the years 1998 and 1999. We use the proportion each one had in 1997 and apply such proportion to the 1998 and 1999 data. Second, we do similarly, with sectors 14 and 19 (Apparel and Other textile products, and Leather and leather products.)

B Appendix: Concordance of the different Data Sets

B.1 Input Output concordance with Final industries

First of all notice that the Annual IO tables contain between 75 and 80 industries. The first step consists on convert those IO tables into tables with only 71 industries 71. This is very straightforward. Next we show the final concordance between the 71 industries and our final industries[44]:

[44] Here we include agriculture, mining and petroleum sectors.

	IO industries		IO industries
1	Livestock and livestock products	39	Farm, construction, and mining machinery
2	Other agricultural products	40	Materials handling machinery and equipment
3	Forestry and fishery products	41	Metalworking machinery and equipment
4	Agricultural, forestry, and fishery services	42	Special industry machinery and equipment
5	Metallic ores mining	43	General industrial machinery and equipment
6	Coal mining	44	Miscellaneous machinery, except electrical
7	Crude petroleum and natural gas	45	Computer and office equipment
8	Nonmetallic minerals mining	46	Service industry machinery
9	New construction	47	Electrical industrial equipment and apparatus
10	Maintenance and repair construction	48	Household appliances
11	Ordnance and accessories	49	Electric lighting and wiring equipment
12	Food and kindred products	50	Audio, video, and communication equipment
13	Tobacco products	51	Electronic components and accessories
14	Broad and narrow fabrics, yarn and thread mills	52	Miscellaneous electrical machinery and supplies
15	Miscellaneous textile goods and floor coverings	53	Motor vehicles (passenger cars andtrucks), bodies, trailers, and motor vehicles parts
16	Apparel	54	Aircraft and parts
17	Miscellaneous fabricated textile products	55	Other transportation equipment
18	Lumber and wood products	56	Scientific and controlling instruments
19	Furniture and fixtures	57	Ophthalmic and photographic equipment
20	Paper and allied products, except containers	58	Miscellaneous manufacturing
21	Paperboard containers and boxes	59	Railroads and related services, Motor freight transportation and warehousing,
22	Newspapers and periodicals, Other printing and publishing	60	Communications, except radio and TV
23	Industrial and other chemicals, Agricultural fertilizers and chemicals	61	Radio and TV broadcasting
24	Plastics and synthetic materials	62	Electric services , Gas production and distribution,Water and sanitary services
25	Drugs, Cleaning and toilet preparations	63	Wholesale trade, Retail trade
26	Paints and allied products	64	Finance, Insurance
27	Petroleum refining and related products	65	Owner-occupied dwellings, Real estate and royalties
28	Rubber and miscellaneous plastics products	66	Hotels and lodging places, Personal and repair services (except auto)
29	Footwear, leather, and leather products	67	Computer and data processing services, including own-account software, Legal, engineering, accounting, and related services, Other business and professional services, except medical, Advertising
30	Glass and glass products	68	Eating and drinking places
31	Stone and clay products	69	Automotive repair and services
32	Primary iron and steel manufacturing	70	Amusements
33	Primary nonferrous metals manufacturing	71	Health services, Educational and social services, and membership organizations
34	Metal containers		
35	Heating, plumbing, and fabricated structural metal products		
36	Screw machine products and stampings		
37	Other fabricated metal products		
38	Engines and turbines		

Final Industries	Concordance
Agriculture, Foresty and Fishery	1, 2, 3, 4
Mining	5, 6, 7, 8
Construction	9, 10
Lumber and Wood products	18
Furniture and Fixtures	19
Stone, Clay and Glass products	30, 31
Primary Metals	32, 33
Fabricated Metals	34, 35, 36, 37
Machinery except electrical	38, 39, 40, 41, 42, 43, 44, 45, 46
Electrical Machinery, equipment and supplies	47, 48, 49, 50, 51, 52, 56, 57
Motor vehicles and other transportation equipment	53, 54, 55
Misc. Manufacturing indutries	58
Food and Kindred products	12
Tobacco products	13
Textile Mill products	14
Apparel and other finished textile products	15, 16, 17
Paper and allied products	20, 21
Printing, Publishing and allied industries	22
Chemicals and allied products	23, 24, 25, 26
Petroleoum and Coal products	27
Rubber and misc. plastic products	28
Leather and leather products	29
Transportation, Utilities and Sanitary Services	59, 62
Communications	60, 61
Wholesale and Retail Trade	63, 68
Finance, Insurance and Real Estate	64, 65
Business Services and professional services	67
Personal Services	66
Entertainment and Recreation	70
Health, Educational and Social Services, and Membership Organizations	71

B.2 BEA data on employment and other concordance with Final industries

There are two types of classification for the BEA data: SIC, and NAICS. The first type goes all the way to 1997. Then for 1998 and 1999 we use NAICS.

	BEA SIC industries		BEA SIC industries
1	All industries	46	Telephone and telegraph
2	Private industries	47	Radio and television
3	Agriculture, forestry, and fishing	48	Electric, gas, and sanitary services
4	Farms	49	Wholesale trade
5	Agricultural services, forestry, and fishing	50	Retail trade
6	Mining	51	Finance, insurance, and real estate
7	Metal mining	52	Banking
8	Coal mining	53	Credit agencies other than banks
9	Oil and gas extraction	54	Security and commodity brokers
10	Nonmetallic minerals, except fuels	55	Insurance carriers
11	Construction	56	Insurance agents, brokers, and service
12	Manufacturing	57	Real estate
13	Durable goods	58	Housing
14	Lumber and wood products	59	Other real estate
15	Furniture and fixtures	60	Holding and other investment offices
16	Stone, clay, and glass products	61	Services
17	Primary metal industries	62	Hotels and other lodging places
18	Fabricated metal products	63	Personal services
19	Machinery, except electrical	64	Business services
20	Electric and electronic equipment	65	Auto repair, services, and parking
21	Motor vehicles and equipment	66	Miscellaneous repair services
22	Other transportation equipment	67	Motion pictures
23	Instruments and related products	68	Amusement and recreation services
24	Miscellaneous manufacturing industries	69	Health services
25	Nondurable goods	70	Legal services
26	Food and kindred products	71	Educational services
27	Tobacco products	72	Social services and membership organizations
28	Textile mill products	73	Social services
29	Apparel and other textile products	74	Membership organizations
30	Paper and allied products	75	Miscellaneous professional services
31	Printing and publishing	76	Private households
32	Chemicals and allied products	77	Statistical discrepancy
33	Petroleum and coal products	78	Government
34	Rubber and miscellaneous plastics products	79	Federal
35	Leather and leather products	80	General government
36	Transportation and public utilities	81	Government enterprises
37	Transportation	82	State and local
38	Railroad transportation	83	General government
39	Local and interurban passenger transit	84	Government enterprises
40	Trucking and warehousing	85	Not allocated by industry
41	Water transportation	86	Electronic equipment and instruments
42	Transportation by air	87	Depository and nondepository institutions /
43	Pipelines, except natural gas	88	Business, miscellaneous professional, and other services
44	Transportation services		
45	Communications		

	BEA NAICS industries		BEA NAICS industries
1	All industries	46	Publishing industries (includes software)
2	Private industries	47	Motion picture and sound recording industries
3	Agriculture, forestry, fishing, and hunting	48	Broadcasting and telecommunications
4	Farms	49	Information and data processing services
5	Forestry, fishing, and related activities	50	Finance, insurance, real estate, rental, and leasing
6	Mining	51	Finance and insurance
7	Oil and gas extraction	52	Federal Reserve banks, credit intermediation, and related activities
8	Mining, except oil and gas	53	Securities, commodity contracts, and investments
9	Support activities for mining	54	Insurance carriers and related activities
10	Utilities	55	Funds, trusts, and other financial vehicles
11	Construction	56	Real estate and rental and leasing
12	Manufacturing	57	Real estate
13	Durable goods	58	Rental and leasing services and lessors of intangible assets
14	Wood products	59	Professional and business services
15	Nonmetallic mineral products	60	Professional, scientific, and technical services
16	Primary metals	61	Legal services
17	Fabricated metal products	62	Computer systems design and related services
18	Machinery	63	Miscellaneous professional, scientific, and technical services
19	Computer and electronic products	64	Management of companies and enterprises
20	Electrical equipment, appliances, and components	65	Administrative and waste management services
21	Motor vehicles, bodies and trailers, and parts	66	Administrative and support services
22	Other transportation equipment	67	Waste management and remediation services
23	Furniture and related products	68	Educational services, health care, and social assistance
24	Miscellaneous manufacturing	69	Educational services
25	Nondurable goods	70	Health care and social assistance
26	Food and beverage and tobacco products	71	Ambulatory health care services
27	Textile mills and textile product mills	72	Hospitals and nursing and residential care facilities
28	Apparel and leather and allied products	73	Social assistance
29	Paper products	74	Arts, entertainment, recreation, accommodation, and food services
30	Printing and related support activities	75	Arts, entertainment, and recreation
31	Petroleum and coal products	76	Performing arts, spectator sports, museums, and related activities
32	Chemical products	77	Amusements, gambling, and recreation industries
33	Plastics and rubber products	78	Accommodation and food services
34	Wholesale trade	79	Accommodation
35	Retail trade	80	Food services and drinking places
36	Transportation and warehousing	81	Other services, except government
37	Air transportation	82	Government
38	Rail transportation	83	Federal
39	Water transportation	84	General government
40	Truck transportation	85	Government enterprises
41	Transit and ground passenger transportation	86	State and local
42	Pipeline transportation	87	General government
43	Other transportation and support activities	88	Government enterprises
44	Warehousing and storage		89 Private goods-producing industries
45	Information	90	Private services-producing industries

Final Industries	Concordance SIC	Concordance NAICS
Agriculture, Foresty and Fishery	3	3
Mining	6	6
Construction	11	11
Lumber and Wood products	14	14
Furniture and Fixtures	15	23
Stone, Clay and Glass products	16	15
Primary Metals	17	16
Fabricated Metals	18	17
Machinery except electrical	19	18,19(25%)
Electrical Machinery, equipment and supplies	20, 23	19(75%),20
Motor vehicles and other transportation equipment	21, 22	21, 22
Misc. Manufacturing indutries	24	24
Food and Kindred products	26	26
Tobacco products	27	26
Textile Mill products	28	27
Apparel and other finished textile products	29	28
Paper and allied products	30	29
Printing, Publishing and allied industries	31	30, 46
Chemicals and allied products	32	32
Petroleoum and Coal products	33	31
Rubber and misc. plastic products	34	33
Leather and leather products	35	28
Transportation, Utilities and Sanitary Services	37(36?), 48	10, 36
Communications	45	48
Wholesale and Retail Trade	49, 50	34, 35, 80
Finance, Insurance and Real Estate	51	50
Business Services and professional services	64, 70, 74	49, 59
Personal Services	62, 63, 75	79
Entertainment and Recreation	67, 68	75, 47
Health, Educational and Social Services, and Membership Organizations	69, 71, 72, 73	68

B.3 CPS data concordance with Final industries

The CPS classification for industries can be found in the MWX.TXT file on $http : //www.nber.org/mare_{w}inship/MWX.TXT$. There are three types of industry classification for the whole period. The first one goes from 1971 to 1982, the second from 1983 to 1991, and the last one from 1992 onwards.

Final Industries	71-82	83-91	92-
Agriculture, Foresty and Fishery	17, 18 19, 27,28	10/31	1, 2, 47
Mining	47,48,49,57	40/50	3
Construction	67,68,69,77	60	4
Lumber and Wood products	107,108,109	230/241	5
Furniture and Fixtures	118	242	6
Stone, Clay and Glass products	119,127,128,137,138	250/260	7
Primary Metals	139,147,148,149	270/280	8
Fabricated Metals	157,158,159,167,168,000	281/301	9, 10
Machinery except electrical	177, 178, 179, 187, 188, 189, 197, 198	310/332	11
Electrical Machinery, equipment and supplies	199, 207, 208, 209, 239, 247, 248, 249,257	340/350, '371/382	12, 16
Motor vehicles and other transportation equipment	219, 227, 228, 229, 237, 238	351/370	13, 14, 15
Misc. Manufacturing indutries	259, 398	390/392	17, 18
Food and Kindred products	268 - 298	100/122	19
Tobacco products	299	130	20
Textile Mill products	307-318	132/150	21
Apparel and other finished textile products	319, 327	151, 152	22
Paper and allied products	328-337	160/162	23
Printing, Publishing and allied industries	338, 339	171, 172	24
Chemicals and allied products	347 - 369	180/192	25
Petroleoum and Coal products	377, 378	200, 201	26
Rubber and misc. plastic products	379, 387	210/212	27
Leather and leather products	388 , 389, 397	220/222	28
Transportation, Utilities and Sanitary Services	407 - 429, 467- 479	400/432	29, 31
Communications	447 - 449	440/442	30
Wholesale and Retail Trade	507-699	500/691	32, 33, 34
Finance, Insurance and Real Estate	707-718	702/712	35, 36
Business Services and professional services	727-749, 849,869-897	721-750, 841, 872-892	38, 46
Personal Services	777-798, 769	762/791	40, 37
Entertainment and Recreation	807 - 817	800/802	41
Health, Educational and Social Services, and Membership Organizations	828-868	812-840, 850, 851, 852	42, 43, 44, 45

B.4 Import Price Index and PPI by industry from BLS concordance with Final industries

- *Import Price Index:* As already explained above the first step we do is to match the goods from this series to the final 27 industries. The import price index for each goods is available at: ftp://ftp.bls.gov/pub/suppl/ximpim.sitimp.txt . We use the SITC code that appears in such data set to obtain the final concordance

- *PPI by Industry:* We match these industries to the final ones. The code we use to perform the concordance is available in the BLS webpage: ftp://ftp.bls.gov/pub/time.series/pd/pd.industry

Final Industries	Import Price Index	PPI by Industry
Agriculture, Foresty and Fishery	0,2	Average Manuf.
Mining	333	1
Construction	None	BNEW
Lumber and Wood products	63	24
Furniture and Fixtures	81,82	25
Stone, Clay and Glass products	66	32
Primary Metals	67	33
Fabricated Metals	69	34
Machinery except electrical	72,73,74,75	35
Electrical Machinery, equipment and supplies	76,77,87,88	36
Motor vehicles and other transportation equipment	78	37
Misc. Manufacturing indutries	Average Manuf.	39
Food and Kindred products	0	20
Tobacco products	12	21
Textile Mill products	65	22
Apparel and other finished textile products	84	23
Paper and allied products	64	26
Printing, Publishing and allied industries	892	27
Chemicals and allied products	5	28
Petroleoum and Coal products	333	29
Rubber and misc. plastic products	62	30
Leather and leather products	83,85	31
Transportation, Utilities and Sanitary Services	Average Manuf.	Average Manuf.
Communications	Average Manuf.	Average Manuf.
Wholesale and Retail Trade	Average Manuf.	Average Manuf.
Finance, Insurance and Real Estate	Average Manuf.	Average Manuf.
Business Services and professional services	Average Manuf.	Average Manuf.
Personal Services	Average Manuf.	Average Manuf.
Entertainment and Recreation	Average Manuf.	Average Manuf.
Health, Educational and Social Services, and Membership Organizations	Average Manuf.	Average Manuf.

Where Average Manuf. is an average of the price index for all manufactures.

References

Mary Amiti and Shang-Jin Wei. "Service Offshoring, Productivity and Employement: Evidence from the US". *CEPR No 5475*, 2006.

Bureau Economic Analysis. "Gross Domestic Product by Industry". Online, a.

Bureau Economic Analysis. "Annual Input-Output Tables". Online, b.

David Autor, Lawrence Katz, and Alan Krueger. "Computing Inequality: Have Computers Changed the Labor Market?". *Quarterly Journal of Economics*, 113 (4):1169–1214., November 1998.

Robert E Baldwin and R S Hilton. "A Technique for Indicating Comparative Costs and Predicting Changes in trade Ratios". *Review of Economics and Statistics*, LXVI:105–110, 1984.

Ann Bartel, Saul Lach, and Nachum Sicherman. "Ousourcing and Technological Change". *NBER Working Paper 11158*, 2005.

Eric J Bartelsman and Wayne Gray. "The NBER Productivity Database". *NBER Technical Working Paper No 205*, October 1996.

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

Ernst R Berndt. *"The Practice of Econometrics: Classic and Contemporary"*. Addison Wesley, 1991.

Ernst R. Berndt and David O. Wood. "Technology, Prices, and the Derived Demand for Energy". *The Review of Economics and Statistics*, LVII(3):259–266, August 1975.

Jagdish Bhagwati, Arvind Panagariya, and T. N. Srinivasan. "The Muddles over Outsourcing". *Journal of Economic Persepectives*, Fall 2004.

Bernardo S. Blum. "Trade, Technology, and the Rise of the Service Sector: An Empirical Assessment of the Effects on US Wage Inequality. *Unpublished*, September 2004.

George Borjas. "The Labor Demand Curve is Downward Sloping: Reexamining the Impact of Immigration on the Labor Market". *Quaterly Journal of Economics*, pages 1335–1374, November 2003.

Claudia Canals. "Outsourcing and your Collar's Color. *Mimeo*, 2006.

Robert C Feenstra. *"Advanced International Trade: Theory and Evidence"*. Princeton University Press, December 2003. ISBN 0691114102.

Robert C Feenstra. "Integration of Trade and Disintegration of Production in the Global Economy". *Journal of Economic Persepctives*, pages 31–50, April 1998.

Robert C Feenstra and Gordon H Hanson. "Globalization, Outsourcing and the Wage Inequality". *American Economic Review*, 86(2):240–245, May 1996.

Robert C Feenstra and Gordon H Hanson. "The Impact of Outsourcing and High-Technology Capital on Wages: Estimates for the United States, 1979-1990". *Quaterly Journal of Economics*, 114(3):907–940, 1999.

Ronald Findlay and Ronald Jones. "Factor bias and technical progress". *Economics letters*, 68: 303–308, 1999.

James Harrigan. “International Trade and American Wages in General Equilibrium, 1967-1995”. *in Robert C. Feenstra “The Impact of International Trade on Wages”*, pages 171–193, 2000.

James Harrigan and Rita Balaban. “U.S. Wages in General Equlibrium: The Effects of Prices, Technology, and Factor Supplies, 1963-1991”. *NBER Working Paper 6981*, 1999.

Jonathan E. Haskel and Matthew J. Slaughter. “Does the Sector Bias of Skill-Biased Technological Change Explain Changing Skill Premia?”. *European Economic Review*, 46(10):1757–1783, 2002.

David Hummels, Jun Ishii, and Kei-Mu Yi. “The Nature and Growth of Vertical Specialization in World Trade”. *Journal of International Economics*, 54, 2001.

Dale W Jorgenson. 35-KLEM Data Set http://post.economics.harvard.edu/faculty/jorgenson/, 1987.

Dale W. Jorgenson. “Econometric Methods for Applied General Equilibrium Analysis”. *H. Scarf and J. Shoven (eds.), Applied General Equilibrium Analysis, Cambridge, Cambridge University Press*, 1984.

Dale W Jorgenson, Frank M Gollop, and Barbara F Fraumeni. “Productivity and U.S. Economic Growth”. *Cambridge, Harvard University Press*, 1987.

Edward E. Leamer. “In Search of Stolper-Samuleson Effects on US Wages”. *in Susan Collins ed. “Imports, Exports and the American Worker”, Brookins*, pages 141–214, 1997.

Bureau of Labor Analysis. “Import Export Price Indices”. Online, a.

Bureau of Labor Analysis. “Producers Price Index”. Online, b.

Diego Puga and Daniel Trefler. “Wake up and smell the ginseng: the rise of incremental innovation in low-wage countries”. *NBER Working Paper 11571*, August 2005.

Dan Segal. “A Multi-Product Cost Study of the U.S. Life Insurance Industry”. *Review of Quantitative Finance and Accounting*, V20(2):169–186, 2003.

Current Population Survey. “March CPS Supplement”. Online.

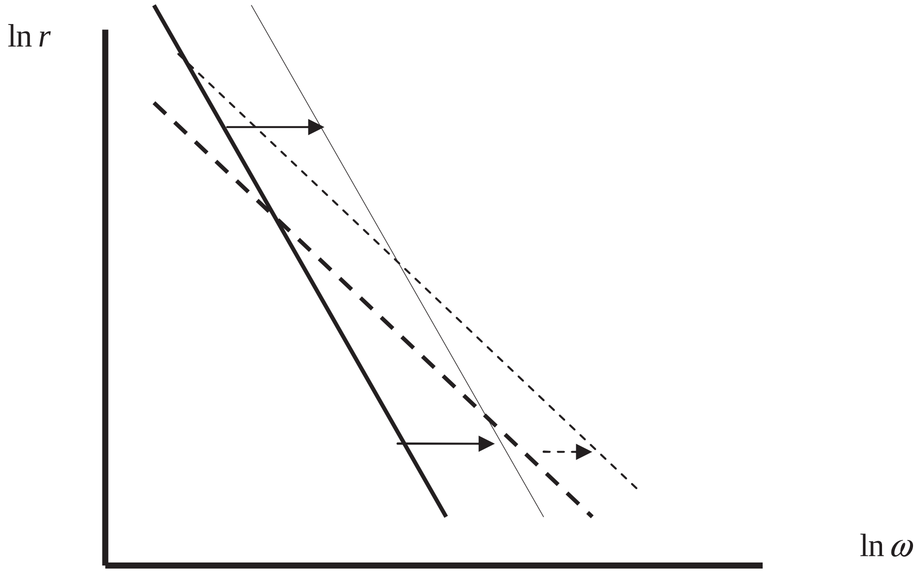

Figure 1: Intuition

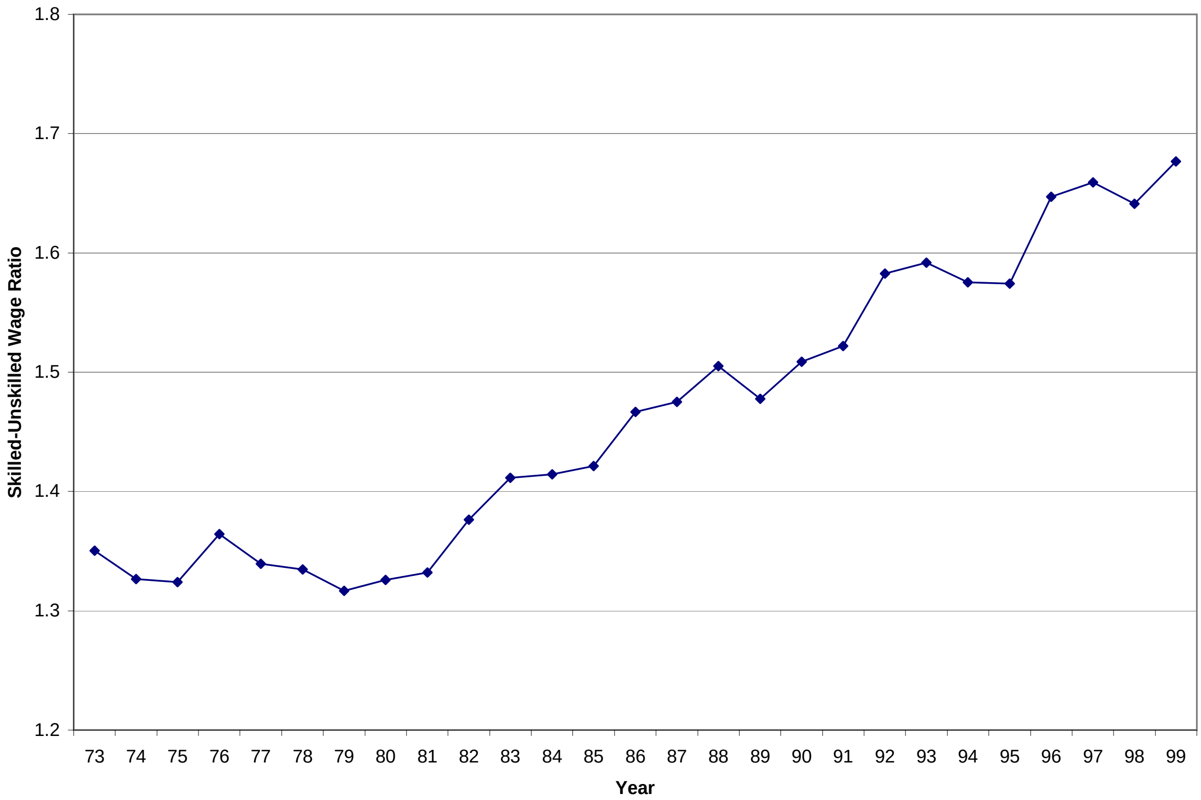

Figure 2: Skilled-Unskilled Wage Ratio. CPS source

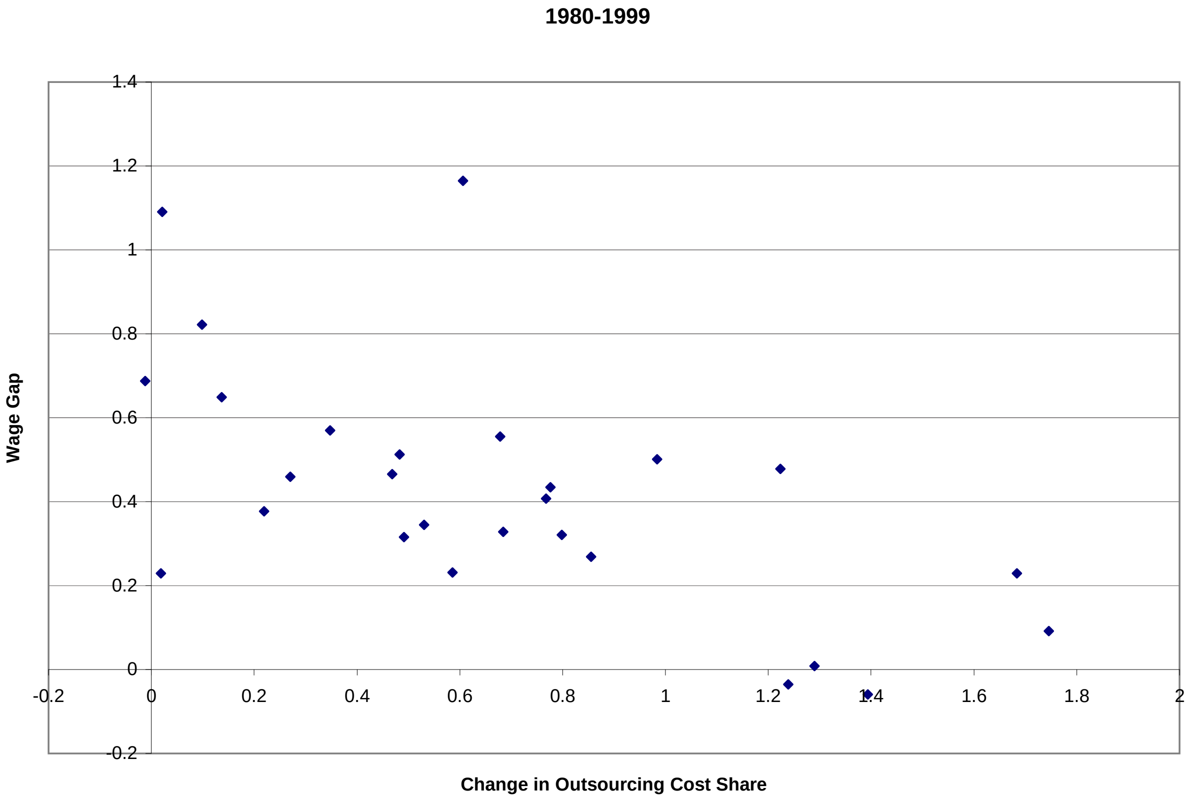

Figure 3: Wage Gap versus Change in Outsourcing Cost-Share
For the period 1980-1999 and for each industry we compute the skilled-unskilled wage gap and the percentage change in the imported intermediate (outsourcing) cost- share. It seems that the behavior goes in the opposite direction as expected, since a larger change in outsourcing is associated with a smaller wage gap.

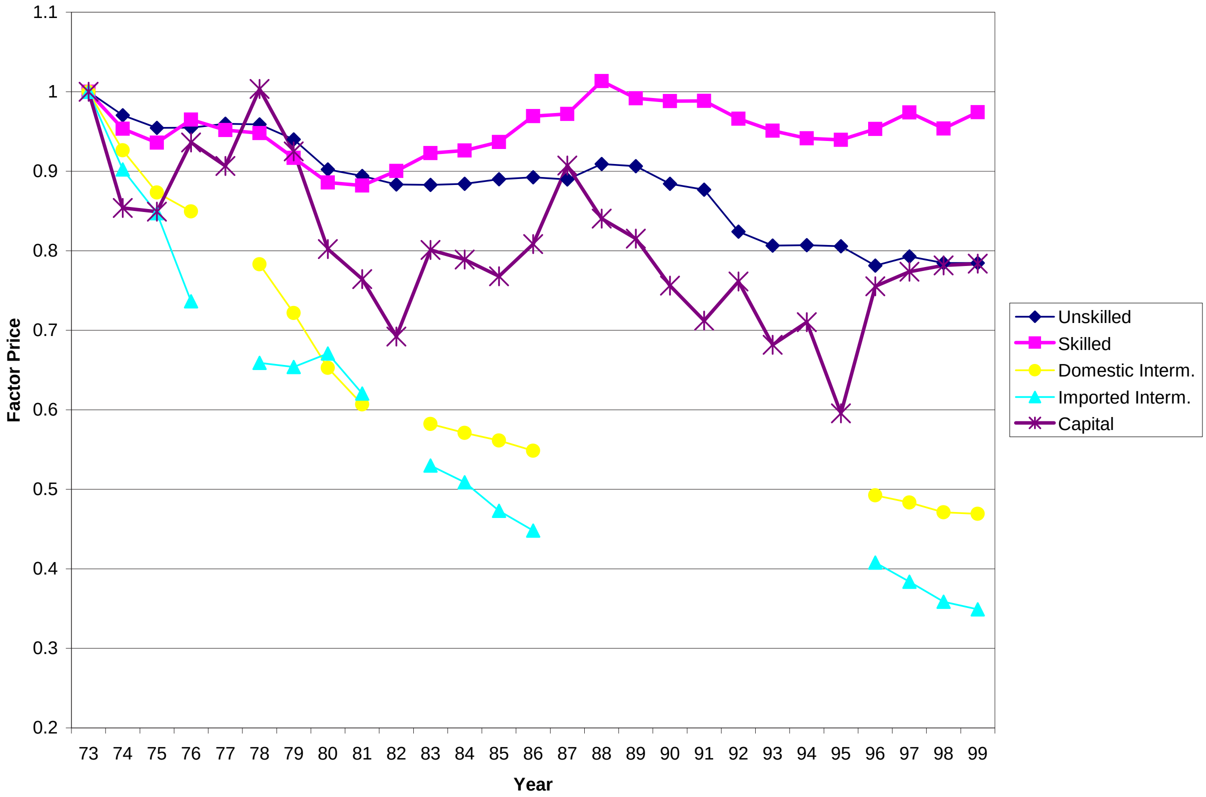

Figure 4: Factor Prices Deflated by CPI

Table 1: Final Sectors

1 Construction
2 Lumber and Wood products
3 Furniture and Fixtures
4 Stone, Clay and Glass products
5 Primary Metals
6 Fabricated Metals
7 Machinery except electrical
8 Electrical Machinery, equipment and supplies
9 Motor vehicles and other transportation equipment
10 Misc.Manufacturing industries
11 Food and Kindred products
12 Tobacco products
13 Textile Mill products
14 Apparel and other finished textile products
15 Paper and allied products
16 Printing, Publishing and allied industries
17 Chemicals and allied products
18 Rubber and misc. plastic products
19 Leather and leather products and footwear
20 Transportation, Utilities and Sanitary Services
21 Communications
22 Wholesale and Retail Trade
23 Finance, Insurance and Real Estate
24 Business Services and professional services
25 Personal Services
26 Entertainment and Recreation
27 Health, Educational and Social Services

Table 2: Evolution of Outsourcing Share

	Total Outsourcing *os*	Outsourcing of Goods *osm*	Outsourcing of Services *oss*
1973	5.19%	4.81%	0.38%
1974	5.97%	5.60%	0.37%
1975	5.86%	5.38%	0.48%
1976	5.96%	5.45%	0.51%
1978	6.63%	6.18%	0.45%
1979	6.86%	6.40%	0.47%
1980	6.78%	6.30%	0.48%
1981	6.79%	6.19%	0.60%
1983	6.67%	6.14%	0.53%
1984	6.82%	6.37%	0.44%
1985	6.47%	6.01%	0.46%
1986	6.52%	6.02%	0.50%
1996	9.27%	8.35%	0.92%
1997	9.44%	8.50%	0.94%
1998	9.36%	8.36%	1.00%
1999	9.22%	8.35%	0.87%
Annual Growth Rate	Total	of Goods	of Services
73-86	1.77%	1.73%	2.07%
86-99	2.70%	2.55%	4.42%

Source BEA: Annual Input-Output Tables
Total Outsourcing: value of imported intermediate inputs as a share of total intermediate inputs.
Outsourcing of Goods: value of imported intermediate goods as a share of total intermediate inputs.
Outsourcing of Services: value of imported intermediate services as a share of total intermediate inputs.

Table 3: Evolution of Outsourcing Share

	Outsourcing by Goods	Outsourcing by Services
1973	8.24%	3.72%
1974	9.30%	4.29%
1975	8.94%	4.31%
1976	9.23%	4.39%
1978	10.33%	4.83%
1979	10.41%	5.10%
1980	10.77%	5.01%
1981	10.80%	4.98%
1983	11.32%	4.83%
1984	11.86%	4.82%
1985	11.55%	4.64%
1986	12.07%	4.68%
1996	16.70%	7.29%
1997	17.10%	7.39%
1998	17.27%	7.30%
1999	17.34%	7.21%
Annual Growth Rate	by Goods	by Services
73-86	2.97%	1.78%
86-99	2.82%	3.37%

Source BEA: Annual Input-Output Tables
Outsourcing by Goods: value of imported intermediate inputs as a share of total intermediate inputs by good sectors
Outsourcing of Services: value of imported intermediate inputs as a share of total intermediate inputs by service sectors.

Table 4: Skilled Unskilled Workers

year	Skilled-Unskilled Workers Ratio	Percentage Unskilled Workers	Percentage Skilled Workers
73	0.46	68	32
80	0.68	59	41
86	0.88	53	47
96	1.09	48	52
99	1.10	48	52

Table 5: Evolution of the Cost-Shares

	Unskilled	Skilled	Dom. Interm.	Imp. Interm.	Capital
73	0.200	0.144	0.447	0.015	0.195
86	0.133	0.202	0.440	0.019	0.206
99	0.124	0.202	0.458	0.026	0.190

Table 6: Allen Elasticities

	u	s	d	m	k
u	-4.075	-1.047	1.544	0.618	-0.106
s		-2.558	1.044	-1.142	0.553
d			-1.159	1.882	0.670
m				-34.252	0.226
k					-2.223

u stands for unskilled, s for skilled, d for domestic intermediates, m for imported intermediates (outsourcing), and k for capital.

These are the Allen Elasticities of Substitution. The upper and lower part of the matrix presented are equal. These elasticities are estimated elasticities, since they vary across years and industries. Thus, we compute them for 1986 (middle year) and for a weighted cost-share, where more weight is given to the industries with higher gross output.
A positive number indicates the factors are **substitutes**, and a negative number means factor **complementarity**.

Table 7: Effect of Outsourcing, Biased Technological Change, and Total Technological Change in the Wage Gap in the 1980-1999 period

	Outsourcing (1)	Biased tech. change (2)	Total biased tech. change (3)
δ_u	-.082	-.139	-.301
	(.058)	(.058)**	(.091)***
δ_s	.049	-.061	-.031
	(.060)	(.044)	(.065)
δ_d	.073	.053	.149
	(.018)***	(.021)**	(.027)***
δ_m	-.880	.282	-.645
	(.136)***	(.204)	(.172)***
δ_k	-.091	-.336	-.432
	(.044)**	(.032)***	(.045)***
Obs	27	27	27
R^2	.885	.933	.948

Standard errors are reported in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels of significance.

We run the weighted regression given by equation 21 for the 1980-1999 period, where more weight is given to the sectors with a higher value added. The actual wage gap in this period is 46.55%
δ_f is the average change of factor price f for the whole period. In particular, we are interested in $(\delta_s - \delta_u)$, since it gives the estimated wage gap.

Table 8: Imputed Wage Gap for the 1980-1999 period

	Outsourcing (1)	Biased tech. change (2)	Total biased tech. change (3)
$\delta_u - \delta_s$	0.131	0.078	0.270
	(0.099)*	(0.083)*	(0.131)**

Standard errors are reported in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels of significance.
The actual wage gap for this period was close to 47%

Table 9: Effect of Outsourcing, Biased Technological Change, and Total Technological Change in the Wage Gap in the 1980-1999 period (using Price of Computers to construct the intermediate input prices)

	Outsourcing (1)	Biased tech. change (2)	Total biased tech. change (3)
δ_u	-.083	-.145	-.313
	(.060)	(.055)***	(.090)***
δ_s	.038	-.057	-.037
	(.062)	(.042)	(.065)
δ_d	.077	.052	.152
	(.018)***	(.020)**	(.027)***
δ_m	-.887	.309	-.638
	(.141)***	(.196)	(.171)***
δ_k	-.103	-.332	-.436
	(.046)**	(.031)***	(.044)***
Obs	27	27	27
R^2	.882	.938	.951

Standard errors are reported in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels of significance.

We run the weighted regression given by equation 21 for the 1980-1999 period, where more weight is given to the sectors with a higher value added. The actual wage gap in this period is 46.55%
δ_f is the average change of factor price f for the whole period. In particular, we are interested in $(\delta_s - \delta_u)$, since it gives the estimated wage gap.

Table 10: Imputed Wage Gap for the 1980-1999 period (using Price of Computers to construct the intermediate input prices)

	Outsourcing (1)	Biased tech. change (2)	Total biased tech. change (3)
$\delta_u - \delta_s$	0.172	0.088	0.276
	(0.102)[1]	(0.080)[2]	(0.237)[3]

Standard errors are reported in parentheses. [1] significant at the 12%. [2] significant at the 15%. [3] significant at the 13%. The actual wage gap for this period was close to 47%

Table 11: Effect of Outsourcing in the Wage Gap

	K-L Intensive (1)	Manufactures and Services (2)
δ_u	-.084	-.084
	(.060)	(.058)
δ_s	.055	.057
	(.062)	(.060)
δ_d	.081	.072
	(.019)***	(.018)***
δ_m	-.928	-.887
	(.138)***	(.137)***
δ_k	-.115	-.084
	(.046)**	(.045)*
Obs	27	27
R^2	.887	.887

Standard errors are reported in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels of significance.