FOUR ESSAYS ON

TRADE, GLOBALIZATION, AND WAGE INEQUALITIES

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SUMMARY

Globalization is a phenomenon of great worldwide interests. Owing to advancement in production technology and lower transportation and communication cost, fragmenting and contracting out production processes has spilled over into international arena with outsourcing of numerous material components and service activities. With a significant increase in the degree of internationalization, ‘outsourcing’ for the time being is loosely coined. It is therefore clearly difficult to understand the explicit impacts of outsourcing in the economy. In this thesis, both theoretical and empirical frameworks aiming to analyze the economic impacts of this ongoing phenomenon have been developed.

In Chapter I, the starting point is to generalize the successive monopoly model by incorporating the labor-management and inter-firm negotiations vis-à-vis the Generalized Nash Bargaining. Under downstream unionization, a firm may find vertical integration profitable if her relative bargaining power with the labor union is sufficiently high, compared with that with the upstream firm. Given the basic framework, I introduce the foreign downstream firm, who outsources key intermediate inputs from the domestic downstream firm, thereby triggering competition in the downstream market. I show that a firm may strategically exercise vertical foreclosure by merger if her relative bargaining power with both labor union and domestic upstream firm is sufficiently high.

Chapter II attempts to investigate the linkages among outsourcing activities, labor productivity, and wage inequality for skilled and unskilled labor by employing a primal approach that involves estimating a nested constant elasticity of substitution (CES) production function, using the data of six-digit North American Industry

Classification System (NAICS) US manufacturing industries from 2002 to 2005. First, I find that the skill-biased impact of general outsourcing on labor productivity is larger than that of international outsourcing. Second, the wage gap between skilled and unskilled labor, which is defined as their marginal productivity gap, can be better explained by general outsourcing than by international outsourcing. These two results imply that the wage inequality of US manufacturing industries during 2002-2005 was mainly due to the skill-biased labor productivity effect of general outsourcing rather than that of international outsourcing.

Existing studies on the impact of outsourcing activities on relative wages and the demand for skilled workers mainly focus on aggregate outsourcing activities, in which imported intermediate inputs are used as a proxy. Chapter III departs from the existing studies by focusing on various types of outsourcing and on the manufacturing sector at a lower aggregation level. The main finding is that downstream materials and service outsourcing are skill-biased whereas upstream materials outsourcing is not

With increasing emphasis on the importance of outsourcing, the 'fear of job losses' has been of public interests, not only in developed countries, but also in developing countries. In Chapter IV, I empirically investigate the impacts of material and service outsourcing on the relative demands for skilled and unskilled labor in the Thailand's manufacturing sector from 1999 to 2003 by using firm-level data. I find that material outsourcing and service outsourcing are both skill-biased. Furthermore, I extend the analysis to capture the impacts of outsourcing on labor substitution as measured by the Hicks-Allen partial elasticities of substitution.

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CHAPTER I
VERTICAL INTEGRATION, FOREIGN OUTSOURCING, AND UPSTREAM FORECLOSURE

1.1 Introduction

The first chapter is concerned with strategic incentives for vertical integration. A traditional issue has long emphasized on how the presence of market power in vertically related firms sheds light on the motives for vertical integration. It is well established that the disintegrated firms always have an incentive to be vertically integrated due to the externality resulting from double marginalization (Spengler, 1950). [1] In other words, under the successive non-competitive structure, since upstream and downstream firms are independently engaged in non-competitive pricing, the fact that they carry merely their individual profits for the pricing entails a failure to take into account the impacts of overall firm's profit. As is well known, this vertical externality (Tirole, 1988) would be dissipated by vertical integration (Greenhut and Ohta, 1979, Waterson, 1982, and Lin, 1988, among others).

I abstract from the conventional successive monopoly model in two respects. Firstly, I introduce the inter-firm negotiation of successive monopoly, i.e., the bargaining between the upstream and downstream firms. [2] In contrast with the literature which mostly focuses on the extreme case where the material price can be unilaterally set by either upstream (Zhao, 2001) or downstream (parent) firms (Chen,

[1] The literature on double marginalization under the successive monopoly structure provides another rationalization of vertical integration incentives and is therefore complementary with the literature that clarifies the role of transaction costs, asset specificity, and incomplete contracts which affect the firms' decision whether to undertake the activities in-house (vertical integration) or to afford them from outside. The studies of this bilateral relationship have been pioneered by Grossman and Hart (1986) among others.

[2] Successive monopoly in the conventional context is the extreme case of my framework. Specifically, the successive monopoly is the case where the upstream firm has perfect negotiation power over the downstream firm, thereby enabling her to charge the monopoly price. By introducing inter-firm bargaining, the transfer price of intermediate inputs is assumed to be determined via the Generalized Nash Bargaining.

et al., 2004 and Hyde and Choe, 2005 among others), the inter-firm bargaining of the transfer price between upstream and downstream firms is the norm, rather than the exception, from the viewpoint of real business practices (Vaysman, 1998). Moreover, in line with the inter-firm bargaining, I generalize the labor-management negotiation by taking into account negotiation power between the downstream firm and the labor union. Although my generalization may not qualitatively change the existing, well-known results, it may be appealing to formulate the framework in a more generalized fashion, which in turn may yield us clearer insights into the optimal organizational choices under the presence of inter-firm and labor-management negotiations.

In this chapter, I model the labor-management and inter-firm negotiations based on the Generalized Nash Bargaining. It is also worthwhile to highlight that another alternative bargaining model could be the Rubinstein's alternating-offers model. It is well established that as the offers are made in the continuous time fashion, the unique sub-game perfect equilibrium payoff pair in the Rubinstein's model converges to the Generalized Nash Bargaining solution. This may provide the justification of the Generalized Nash Bargaining solution in that its bargaining outcome generated is equivalent to the limiting bargaining outcome under Rubinstein's model (see Muthoo, 1999, pp. 65-69 for more detailed discussions). Furthermore, the relative bargaining powers in the Generalized Nash Bargaining can be interpreted as the players' discount rates in the Rubinstein's alternating-offers model.

In contrast with the conventional literature without unionization, in which it is always profitable for a disintegrated firm to be vertically integrated, and the model with downstream unionization where such vertical integration incentives may not exist, I show that, despite the presence of unionization, the vertical integration incentives may still prevail if the relative bargaining position of the downstream firm in the labor-management negotiation is relatively high, compared with that in the inter-firm bargaining. I also reveal that if the labor-management and inter-firm negotiations can be undertaken simultaneously, rather than sequentially, the vertical integration motives are declined. Furthermore, I complete the analysis of timing structures of negotiations by arguing that if the disintegrated firm can strategically choose the negotiation agendas, she will never find the labor-management bargaining prior to the inter-firm bargaining optimal. Given these results, my generalization may provide a clearer insight into the roles of the labor-management and inter-firm negotiations on the vertical integration motives.

Besides the merger incentives under the monopolized downstream market, one of the central debates has to do with the anti-competitive aspects of vertical integration. For instance, in face of competition in the downstream market, the integrated firm may foreclose her rivals' access to the supply of intermediate inputs. Hence, upstream foreclosure brings about monopoly rent in the downstream market. The notion of upstream foreclosure is defined as the extent to which a downstream firm is excluded from the access to the upstream supplier (Stefanadis, 1997). The standard foreclosure theory suggests that vertical foreclosure may characterize the equilibrium as it provides them monopoly power and raises rivals' cost (Salinger, 1988 and Ordover, et al., 1990).[3] A clear example can be seen from the merger between a broadband internet service provider, AOL, and its internet content supplier, Time Warner. The AOL Time Warner can do away with its rivals' access to internet contents and services by exercising the conduit discrimination (Rubinfeld and Singer,

[3] The crucial assumption in the standard foreclosure theory as in Salinger (1988) is that vertically integrated firms will neither buy nor sell in intermediate input markets. In the case of the upstream foreclosure and the homogenous product as in the present chapter, it implies that, with a tight relationship under vertical integration, the upstream firm can make a credible commitment to the downstream firm to supply the key inputs only internally.

2001), thereby improving its monopoly power in broadband internet industries.[4] This gives rise to the antitrust issue in the context of domestic and international competition.

To theoretically investigate how anti-competitive effects of upstream foreclosure affect incentives for vertical integration, I develop the benchmark model of the disintegrated structure by introducing downstream competition in which a foreign downstream firm outsources key intermediate inputs by purchasing them from the domestic upstream firm, thereby changing the final output market structure from monopoly to Cournot competition.[5] Hence, the upstream firm will bargain over the intermediate input price with not only the domestic downstream firm, but also the foreign outsourcer. This chapter contributes to the standard foreclosure theory by emphasizing the roles of the labor-management and inter-firm negotiations, which account for the possibilities that upstream foreclosure, though anti-competitive, is not always profitable in that, although the downstream firm's profits will certainly increase due to higher market power, the refusal to supply intermediate inputs to a foreign outsourcer will undermine the upstream firm's profits. My result reveals that the domestic firm may not have a motive to exclude a foreign downstream firm from the access to intermediate inputs if the downstream firm's relative bargaining positions with the labor union and with the upstream firm are both sufficiently low. Therefore, the upstream foreclosure may not be profitable, depending on two tradeoffs: monopoly rent gains versus upstream losses and vertical externality

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[4] Alternatively, AOL Time Warner can also exercise content discrimination in order to insulate its firm from competition by worsening or banning the contents and services of outsiders. In this sense, the content discrimination may be classified as downstream foreclosure.

[5] I assume that the final outputs are homogenous, and therefore the final output market is characterized by Cournot competition. However, it is straightforward to extend my model to account for differentiated products and therefore Bertrand competition.

elimination gains versus losses of surpluses extracted by the labor union.[6] These may explain the counterexample of AOL Time Warner, for which some firms, especially in automotive and high-tech industries, supply their intermediate materials and technologies to their rivals, thereby entailing competitive effects in the final output market. For instance, Toyota Motors supplies her engines to Chinese car manufacturers; IBM provides a Chinese computer manufacturer, Lenovo, the technologies for laptop production; and some Taiwanese computer manufacturers, such as Acer, also use the processors supplied by Apple.

The organization of this chapter can be outlined as follows. In Section 1.2, I will briefly elaborate the overview of the literature, which are relevant to my analyses. In Section 1.3, I formulate the basic model in which a monopoly is disintegrated into two vertically linked firms: non-unionized upstream and unionized downstream firms. Then, the vertically integrated structure will be considered and compared with the disintegrated structure to reveal the conditions under which the vertical integration incentives exist. Section 1.4 discusses the strategic use of bargaining agendas. In Section 1.5, the foreign outsourcer will be introduced. After solving the equilibrium with the foreign downstream rival, I obtain the conditions under which the firms will strategically exercise upstream foreclosure. Section 1.6 concludes.

1.2 Overview of the Related Literature

The motives for vertical integration have long been examined in the literature. Among others, the incentives for a disintegrated firm to merge could be explained by double marginalization, firstly introduced by Spengler (1950). As is well known, "…*the*

[6] Since my focus is on obtaining the condition under which upstream foreclosure may or may not be profitable under the presence of the labor-management and inter-firm bargaining, rather than the commitment problem (Reiffen, 1992), I assume the standard foreclosure assumption (Salinger, 1988) that the upstream firm under the integrated structure credibly commits to exclusively supplying intermediate inputs to the downstream firm.

objective of vertical integration is to avoid the double price distortion that occurs when each firm adds its own price-cost margin at each stage of production…" (Tirole, 1988, Chapter 4, p. 175). A number of literatures have subsequently examined several models of successive non-competitive industries. For instance, Greenhut and Ohta (1979), Waterson (1982), and Lin (1988) assume homogenous products and hence Cournot competition in the final output markets. Hart and Tirole (1990) consider the models characterized by differentiated products and Bertrand competition.

Zhao (2001) extends the mainstream vertical integration theory by introducing a unionized downstream industry. In the model with successive monopoly in which the wage and employment are determined via the labor-management negotiation based on the Nash bargaining, vertical integration motives may disappear as the gains from the elimination of vertical externality are extracted by the labor union. Thus, the labor union will be better-off under vertical integration in terms of both higher wage and employment, whereas the non-integrated industries will not. Nonetheless, some important aspects, including the inter-firm bargaining between upstream and downstream firms and the role of its interaction with the labor-management negotiation, have not been sufficiently emphasized. Though introducing those aspects into the model does not change the well-known results, it should yield us clearer insights into vertical integration incentives and other interesting results regarding the roles of the labor-management and inter-firm negotiations.

Apart from a vertical integration motive under the non-competitive market, I extend the model by introducing a foreign downstream firm that chooses to outsource key intermediate inputs from a domestic upstream firm and compete in the same market as the domestic downstream firm. It should be highlighted that my focus is on how the anti-competitive strategies against a foreign outsourcer, so called upstream foreclosure, change the vertical integration incentives. That is, given the presence of a foreign outsourcer, a domestic firm may or may not have an incentive to exercise upstream foreclosure by ceasing the foreign downstream firm's access to procuring the intermediate materials from the upstream firm.

Indeed, the notion of vertical foreclosure is not new. The well established results that the firms with production advantages, probably in terms of production efficiency, cost advantages, key resources, and economies of scale, can obtain higher monopoly rent by vertically foreclosing the competition from their rivals as it would increase their competitors' cost, have been shown by a number of literatures, such as Aghion and Bolton (1987), Salinger (1988), and Ordover, et al. (1990). Hart and Tirole (1990) examine the model in which both upstream and downstream foreclosures are implemented in order to monopolize both upstream and downstream markets. By incorporating dynamic economies of scale in the upstream industry and the R&D competition, Stefanadis (1997) analyzes the welfare impacts of downstream foreclosure in terms of a captive buyer.[7] He shows that the downstream foreclosure deters R&D investment and entails an adverse impact on consumers' welfare. In contrast, Chipty (2001) finds that vertical integration in the cable television industry is associated with vertical foreclosure and entails consumers' welfare gains due to increased efficiency.

Apart from the literature concerned with the competitive and welfare effects of vertical foreclosure, several literatures have examined the condition under which vertical foreclosure is profitable. Higgins (1999) generalizes Salinger's (1988) model by dropping the assumption that the vertically integrated firms do not serve the intermediate input market and shows that vertical foreclosure is not generally

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[7] According to Stefanadis (1997), the captivity refers to the extent to which the downstream buyers are prohibited from purchasing intermediate inputs from other suppliers even though they offer cheaper prices.

profitable, depending on the number of intermediate and final good producers. Choi and Yi (2000) show that there exists a threshold of the correlation coefficient between randomized costs of two upstream firms above which the equilibria are characterized by vertical foreclosure. Their notion of vertical foreclosure differs from the standard definition in the sense that a firm is assumed to foreclose a rival by exclusively supplying specialized intermediate inputs, as opposed to producing general inputs and therefore serving all downstream firms. Based on this notion, vertical foreclosure is in principle plausible in both integrated and disintegrated structures.[8] In contrast with Choi and Yi, I reveal the range of downstream firm's parameters of bargaining power with the labor union and the upstream firm in which a firm will find upstream foreclosure profitable. To the best of my knowledge, the roles of the labor-management and inter-firm bargaining in determining the firm's foreclosure decisions have not been examined in the context of the standard foreclosure theory.

Accordingly, the first chapter contributes to the literature on vertical integration and vertical foreclosure theories in the following ways. Firstly, I emphasize the interaction between the labor-management and inter-firm negotiations as determinants of the optimal organizational structures. I show that a firm may still have an incentive to be vertically integrated if her relative bargaining position in the labor-management bargaining is sufficiently better than that in inter-firm bargaining. Secondly, I show that timing of negotiations or bargaining agendas matter. If both negotiations can be undertaken simultaneously, the vertical integration incentives may deteriorate, and it would never be in the firms' interests to undertake the labor-management prior to inter-firm negotiations. Last but not least, I am the first, to the best of my knowledge, to highlight the interaction between both negotiations, which

[8] However, Choi and Yi (2000) confine their attention merely to the range of correlation coefficient parameters in which there is no foreclosure incentive under the non-integrated structure, which is therefore equivalent to assuming that vertical integration may or may not entail vertical foreclosure.

affects the profitability of vertical foreclosure. If the downstream firm's bargaining positions in both negotiations are sufficiently low, it may not be appealing for the domestic firm to foreclose the foreign downstream firm's access to the key intermediate inputs.

1.3 The Model

1.3.1 Vertical Disintegration under Unionization

Consider two vertically related firms, namely, upstream and downstream firms. The production of final output, q, requires one unit of labor and intermediate materials, which are perfect complements. The upstream firm produces intermediate materials and is a sole supplier to the downstream one. I assume that materials can be produced with marginal cost c and sold to the downstream firm with price m. As such, the upstream firm's profit function is characterized by

$$\pi_m = (m - c)q\,. \tag{1}$$

The downstream industry is unionized, and the downstream firm is a monopoly in the final output market. As such, her main tasks are to employ intermediate materials and labor to produce and market final outputs. Therefore, her profit function can be shown as

$$\pi_{DI} = (p(q) - m - w)q, \tag{2}$$

where $p(q)$ is an inversed demand function satisfying the standard assumptions, i.e., $p'(q) < 0$ and $p''(q) + 2p'(q) < 0$,[9] and w is the negotiated wage paid to a domestic labor union. I follow the standard *right-to-manage* approach to the wage determination under which the downstream firm bargains over the wage with a labor

[9] The inversed demand that satisfies this assumption must not be too convex.

union given the expected employment decisions by the former.[10] I assume that the labor union's objective function takes the following functional form.

$$U(w,q) = wq + (\overline{L} - q)w_o, \tag{3}$$

where $\overline{L}$ denotes the number of union members, and w_o represents the rate of unemployment benefits. Essentially, the union preference (3) constitutes the total income earned by its members, and in the case of agreement breakdown its utility will eventually be $w_o\overline{L}$. As such, the union's surplus entering the labor-management bargaining problem is $U(w,q) - w_o\overline{L} = (w - w_o)q$. One may associate this specification with the Stone-Geary type utility function in which the disagreement point is normalized to zero, and the union is neutral with respect to the wage and employment. This type of a utility function is commonly used in the literature (see Pemberton, 1988).[11]

Based on this disintegrated structure, the sub-game perfect Nash equilibrium of the material price, wage, and employment is determined in three stages. In the first stage, the upstream and downstream firms negotiate over material price (*m*). Then, in the second stage, given the bargained material price, the downstream firm bargains the wage rate (*w*) with the union. In the final stage, the downstream firm combines materials and labor to produce final output q and sell it in the domestic market. At the end of this three-stage game, the consolidated profit and union's welfare are realized. My timing structure goes along with the notion of long-term mode decisions. In particular, the negotiated material prices are irrevocable at the time of the wage negotiation. This seems plausible if the establishment of the vertically linked structure

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[10] My crucial results remain qualitatively unchanged even though the downstream firm and labor union negotiate over both wage and employment or only employment.

[11] The Stone-Geary utility function takes the following form: $U(w,q) = (w - w_o)^{\theta} q^{1-\theta}$, where $0 \le \theta \le 1$. The union is said to be wage (employment)-oriented if $\theta >$ (<)0.5 and neutral if $\theta = 0.5$.

requires a long-term relationship. However, in principle it is also possible to assume that the wage is negotiated at the same time as or prior to the material price. I will account for the former in Sub-section 1.3.4 and briefly discuss the latter in Section 1.4.

The sub-game perfect Nash equilibrium can be solved by using the standard backward induction procedure. In the final stage, the downstream firm decides on the optimal amount of final outputs as well as labor and intermediate materials employed to maximize her individual profits.

$$q_{DI}(w,m) = \arg\max_{q}\{[p(q) - w - m]q\}, \tag{4}$$

where the subscript *DI* denotes the downstream firm under the vertical disintegration structure. Given the negotiated wage and intermediate material prices, the profit-maximizing production must satisfy the first- and second-order conditions.

FOC $$p(q) + qp'(q) = w + m \tag{5A}$$

SOC $$2p'(q) + qp''(q) < 0 \tag{5B}$$

The standard assumptions on demands introduced earlier imply that both necessary and sufficient conditions associated with the maximization problem (4) are trivially satisfied.

By using (5A-B), and Implicit Function Theorem, it follows that

$$\partial q/\partial w = \partial q/\partial m = \left(2p'(q) + qp''(q)\right)^{-1} < 0\,. \tag{6}$$

PROPOSITION 1 *Given the standard assumptions on demands, the optimal decision on final output production is strictly decreasing in the negotiated wage and material price.*

This result is not surprising, however. Increases in either the wage or material price will result in higher cost of production and thus lower demands for both labor and material inputs. This exercise tells us that the upstream firm and the labor union, given a decreasing and not too convex demand for final outputs, also face downward-sloping demands for intermediate materials and labor.

In order to characterize the solutions, I impose an additional assumption on the functional form of the inversed demand for the final output. Without losses of generality, I assume that the demand is linear and have the following form: $p(q) = a - bq$, and the demand for final output is sufficiently high such that $q > 0$ in the equilibrium. By substituting this linear demand into (5A), I can easily solve for the optimal production, market price, downstream firm's profit and union utility.

$$q_{DI}(w,m) = \frac{a-m-w}{2b} \qquad p_{DI}(w,m) = \frac{a+m+w}{2}$$

$$\pi_{DI}(w,m) = \frac{(a-m-w)^2}{4b} \qquad U_{DI}(w,m) = (w-w_o)\left(\frac{a-m-w}{2b}\right) + w_o\bar{L} \qquad (7)$$

Next, I proceed to the second stage of the labor-management negotiation in which the intermediate material price is still treated as exogenously given. To account for the asymmetries of players, I assume that the wage negotiation between the downstream firm and the labor union follows the *Generalized Nash Bargaining*. If the agreement breaks down, the disagreement point for the downstream firm is normalized to zero whereas that for the labor union is equal to $w_o\bar{L}$. Intuitively, since labor cannot be substituted by other inputs, the breakdown implies that the demands for labor and intermediate materials, as well as downstream firm's payoffs, are zero while each union member just receives the unemployment benefit, w_o. Based on the Generalized Nash Bargaining, the negotiated wage is determined by solving the following problem.[12]

[12] Muthoo (1999) shows that a bargaining solution to (8) is the Nash Bargaining solution if and only if it satisfies the following axioms: Invariance to Equivalent Utility Representations, Pareto Efficiency,

$$w_{DI}(m) = \arg\max_{w} \left[\pi_{DI}(w,m)\right]^{\alpha} \left[U(w,m) - w_o \bar{L}\right]^{1-\alpha}, \tag{8}$$

where $\alpha \in [0,1]$ denotes the relative negotiation power of the downstream firm with respect to the labor union. By differentiating (8) with respect to *w*, the first-order condition for the asymmetric Nash bargaining solution can be written as

$$\frac{\alpha}{\pi_{DI}(w,m)} \frac{\partial \pi_{DI}(w,m)}{\partial w} + \frac{1-\alpha}{U(w,m) - w_o \bar{L}} \frac{\partial U(w,m)}{\partial w} = 0. \tag{9}$$

For the sake of further analyses, rather than developing discussions in a generalized way, I shall derive the results based on the linear demand assumed earlier. As such, the first-order condition (9) can be written as

$$\frac{1-\alpha}{w - w_o} - \frac{1+\alpha}{a - m - w} = 0. \tag{10}$$

After simple manipulations, the asymmetric Nash bargaining solution for the wage rate associated with (8) can be portrayed as follows.

$$w_{DI}(m) = A(\alpha)(a - m - w_o) + w_o, \tag{11}$$

where $A(\alpha) = (1-\alpha)/2$. Since $\alpha \in [0,1]$, it is straightforward to show that $\partial w/\partial \alpha = A'(\alpha)(a - m - w_0) < 0$, and $\partial w/\partial m = -A(\alpha) < 0$.

PROPOSITION 2 *Given the linear demand, the asymmetric Nash bargaining solution for the wage premium ($w_{DI}(m) - w_o$) is decreasing in downstream firm's negotiation power with both labor union and intermediate material price.*

The intuition behind Proposition 2 is straightforward. The higher downstream firm's negotiation power implies that the total surplus is allocated more from the labor union to the downstream firm. Since the surplus realized by the downstream firm is decreasing in the wage paid to the labor union, the Nash bargaining solution to the

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Symmetry, and Independence of Irrelevant Alternatives. Since it can be shown that the solution to (8) satisfies those axioms, it is the Nash Bargaining solution.

wage rate must be lowered. Moreover, the higher intermediate material price reduces the downstream firm's surpluses to be shared with the labor union in the labor-management negotiation and therefore decreases the equilibrium wage rate.

Next, I plug in the equilibrium wage rate (11) into the equilibrium final output (q_{DI}) and downstream firm's profit (π_{DI}), derived from the final stage. Then, I have

$$q_{DI}(m) = \frac{(1-A)}{2b}(a-m-w_o) \quad \text{and} \quad \pi_{DI}(m) = \frac{(1-A)^2}{4b}(a-m-w_o)^2 . \qquad (12)$$

Analogous to the wage rate determination, the material price is also determined via the Generalized Nash Bargaining between the downstream and upstream firms, inter-firm bargaining henceforth. The asymmetric Nash bargaining solution for the intermediate material price can be derived by solving the following optimization problem.

$$m = \arg\max_m [\pi_{DI}(m)]^{\beta} [\pi_m(m)]^{1-\beta}$$

$$= \arg\max_m \left[\frac{(1-A)^2}{4b}(a-m-w_o)^2 \right]^{\beta} \left[(m-c)\frac{(1-A)}{2b}(a-m-w_o) \right]^{1-\beta} , \qquad (13)$$

where $\beta \in [0,1]$ is the relative negotiation power of the downstream firm with respect to the upstream one. It should be noticed that in the inter-firm bargaining the disagreement points of both downstream and upstream firms are normalized to zero in that if the agreement breaks down, there is no production, and therefore neither labor nor material inputs will be purchased.

By differentiating (13) with respect to *m* and after some simple manipulations, the first-order condition associated with (11) can be written as

$$\frac{1-\beta}{m-c} - \frac{1+\beta}{a-m-w_o} = 0 . \qquad (14)$$

It can also be easily seen from (14) that the second-order condition is satisfied.

By manipulating (14), the Nash bargaining solution for the intermediate material price can be written as

$$m = B(\beta)(a - c - w_o) + c, \tag{15}$$

where $B(\beta) = (1-\beta)/2$.

From (13), $\partial m/\partial \beta = B'(\beta)(a - c - w_o) < 0$ and $\partial m/\partial \alpha = 0$.

PROPOSITION 3 *Given the linear demand and sequential bargaining structure, the Nash bargaining solution for the intermediate material price is decreasing in downstream firm's relative negotiation power with respect to the upstream firm but independent of that with respect to the labor union.*

The intuition of the first part of Proposition 3 is similar to that of Proposition 2 in that the higher downstream firm's negotiation power suggests that the Nash bargaining solution will be in favor of her. Interestingly, one may observe that the downstream firm's relative bargaining power with respect to the labor union (α) does not enter the first-order condition (14).[13] This can be explained by the fact that the decisions of material purchases are assumed to require relatively long-term commitments compared with the labor-management decision, and the inter-firm negotiation will be undertaken in the expectation of the wage negotiated in the subsequent period. In other words, it takes place in face of the knowledge that some surpluses will be extracted by the union only in next period. Therefore, the downstream firm's relative bargaining position with the labor union will not affect the outcome of the negotiated material price.

By using (15), the sub-game perfect Nash equilibrium of the wage rate, production, the union's welfare, and the consolidated profits can be portrayed as

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[13] This argument no longer holds if the downstream firm copes with foreign outsourcing firms. I will extend my basic structure by incorporating this later.

$$w_{DI} = A(1-B)(a-c-w_o) + w_o$$

$$q_{DI} = (1-A)(1-B)(a-c-w_o)/2b$$

$$U_{DI} = A(1-A)(1-B)^2(a-c-w_o)^2/2b + w_o\overline{L}$$

$$\pi_{DI} + \pi_m = \left[(1-B) + \frac{B(1-B)(1+A)}{1-A}\right]\frac{(1-A)^2}{4b}(a-c-w_o)^2. \qquad (16)$$

By combining Proposition 2, Proposition 3 implies that $\partial w/\partial\beta = (\partial w/\partial m)(\partial m/\partial\beta) > 0$. The sub-game perfect Nash equilibrium of the wage is decreasing in the downstream firm's relative bargaining power with the labor union (α) and increasing in that with the upstream firm (β).[14] The former relationship is obvious as higher bargaining power with the labor union enables the downstream firm to lower the negotiated wage. The latter relationship stems from the fact that the lowered material price obtained from better bargaining power with the upstream firm will increase the downstream firm's surplus shared by the labor union.

1.3.2 Vertical Integration under Unionization

In this sub-section, I consider the case where the downstream and upstream firms are vertically integrated. In line with the disintegrated organizational structure, vertical integration is a special case where the downstream firm has a full control over the upstream firm, and hence she carries the consolidated profits, rather than merely downstream profits, to bargain with her labor union in the later stage. In other words, in the first stage the downstream firm bargains with the upstream firm with $\beta = 1$, thereby setting $m = c$. Then, in the second stage, she negotiates the wage rate with the labor union so as to maximize her consolidated profits. In the final stage, the

[14] It can be easily shown that $\partial w_{DI}/\partial\alpha = A'(\alpha)(1-B)(a-c-w_o) < 0$ and $\partial w_{DI}/\partial\beta = -B'(\beta)A(\alpha)(a-c-w_o) \geq 0$.

production and employment decisions are made. At the end of this timing structure, the consolidated profit and union welfare are realized.

The sub-game perfect Nash equilibrium can be obtained by applying Backward Induction. In the final stage, the integrated firm has to make a production decision so as to maximize her consolidated profits, which can be shown as

$$\pi_{VI} = \left(p(q) - c - w\right)q\,, \tag{17}$$

where subscript *VI* refers to the vertically integrated firm. Apparently, the objective function, as well as the corresponding first- and second-order conditions, is analogous to (4) – (6) except for the fact that *m* is replaced by *c*. As a result, the optimal output, price, consolidated profit, and union's welfare, as a function of the given negotiated wage, can be obtained as

$$q_{VI} = \frac{a-c-w}{2b} \qquad p_{VI} = \frac{a+c+w}{2}$$

$$\pi_{VI} = \frac{(a-c-w)^2}{4b} \qquad U_{VI} = (w-w_o)\left(\frac{a-c-w}{2b}\right) + w_o\bar{L} \tag{18}$$

Next, I plug in (18) into the labor-management negotiation. The Generalized Nash bargaining solution of the wage rate can be formulated in the same way as (8) except for *m* replaced by *c* as before.

$$w_{VI} = \arg\max_{w}\left[\pi_{VI}(w)\right]^{\alpha}\left[U(w) - w_o\bar{L}\right]^{1-\alpha} \tag{19}$$

Following the same optimization procedure, it is straightforward to show that the sub-game perfect Nash equilibrium of the negotiated wage, production, consolidated profit, and labor union's welfare is

$$w_{VI} = A(\alpha)(a-c-w_o) + w_o \qquad q_{VI} = \frac{(1-A)}{2b}\left(a-c-w_o\right)$$

$$\pi_{VI} = \frac{(1-A)^2}{4b}\left(a-c-w_o\right)^2 \qquad U_{VI} = \frac{A(1-A)}{2b}\left(a-c-w_o\right)^2 + w_o\bar{L}\,. \tag{20}$$

Since $\beta \in [0,1]$, and $0 \le B = (1-\beta)/2 < 1$, it follows that $U_{VI} \ge U_{DI}$.

PROPOSITION 4 *The labor union is better-off under the vertical integration compared with the vertical disintegration.*

If the firm is vertically integrated, Proposition 4 shows that the labor union's welfare will be improved in terms of both higher negotiated wage rate and employment. This result is consistent with the well established results that the labor union will be better-off under vertical integration as she can extract larger surpluses from the integrated firm. From my generalization, I further show that under asymmetric bargaining the result holds only when the vertically integrated firm's bargaining power is less than perfect ($\beta < 1$).

1.3.3 Organizational Forms Decisions

Does the firm have an incentive to merge? To answer this question, I have to compare the equilibrium profits under vertical integration with those under vertical disintegration. From the consolidated profits of vertically related firms (16) and a merged firm (20), I have

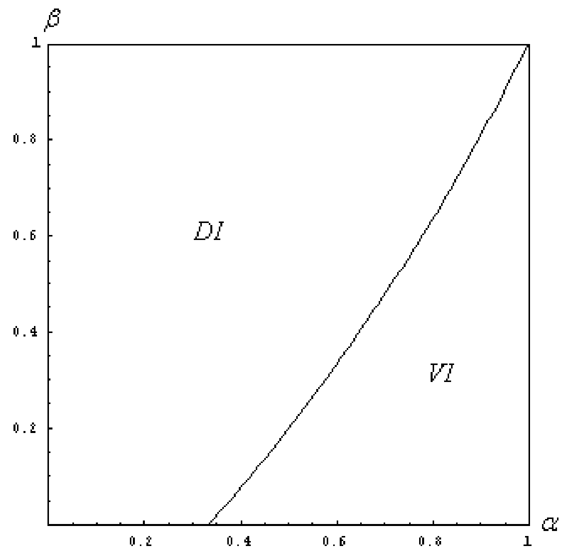
$$\pi_{DI} + \pi_m = \left[(1-B) + \frac{B(1-B)(1+A)}{1-A}\right]\pi_{VI}. \tag{21}$$

Therefore, the firm will have an incentive to merge or to integrate only if

$$\left[(1-B) + \frac{B(1-B)(1+A)}{1-A}\right] < 1. \tag{22}$$

From (22), it is apparent that the vertical integration incentive counts mainly on two parameters of the firm's bargaining power, α and β. The range of these two parameters for which the firm will decide to be vertically integrated can be portrayed by using the following figure.

Figure 1.1: Vertical Integration Incentives under Successive Monopoly.



Before developing further discussions, I, based on Figure 1.1, invoke the following proposition.[15]

PROPOSITION 5 *A downstream firm will (not) have an incentive to merge if the downstream firm's relative bargaining power with respect to the labor union (α) is sufficiently high (low) compared with that with respect to the upstream firm (β).*

According to Figure 1.1, the downstream firm will decide to merge with the upstream firm only when her parameters of relative negotiation power, α and β, lie in the bottom-right area. That is, vertical integration will be profitable only when her bargaining position in the labor-management negotiation is better than that in the inter-firm negotiation. Intuitively, the decision of vertical integration can be rationalized by a tradeoff between the elimination of 'double marginalization'[16] and losses of surpluses extracted by the labor union. On the contrary, under the

[15] Figure 1.1 is drawn by utilizing the Mathematica program package based only on the linear demand assumption. With linear demand, I do not need to impose any restrictions on parameters.

[16] 'Double marginalization' in my context slightly differs from the conventional definition in the sense that I allow for the inter-firm negotiation between the downstream and upstream firms. Based on the conventional context, the upstream firm is able to charge monopoly prices of materials supplied for the downstream firm. By introducing inter-firm negotiations, the material price charged by the upstream firm lies between the monopoly price and her marginal production cost of materials.

disintegrated structure, the firm gains from the better negotiation position with the labor union at the expense of lowered consolidated profits as a corollary of vertical externalities.

Accordingly, if the relative negotiation power with the labor union is sufficiently high compared with that with the upstream firm, the gains from the elimination of double marginalization will outweigh the losses of a deteriorated bargaining position with the labor union, and therefore vertical integration is profitable. On the other hand, if the downstream firm has a better position of the inter-firm negotiation relative to the position of the labor-management negotiation, the losses from merging decisions in terms of the higher negotiated wage may be sufficiently huge such that she better stays disintegrated.

My results elaborated thus far contribute to the literature on and thus provide a clearer insight into the relationship between the labor market and organizational management under non-competitive vertical markets. It is well established that vertical integration always results in higher consolidated profits of an industry in that the successive monopoly when the firm is vertically disintegrated entails double marginalization, which devastates industry profits. Therefore, a firm always has an incentive to internalize all production activities (see Greenhut and Ohta, 1979 and Waterson, 1982 among others). With the presence of a labor union, Zhao (2001) employs the labor-management negotiation based on the Nash bargaining formulation to show that there are no incentives for vertical integration.[17] My generalization shows that, despite the presence of the labor union, the firm may still have an

[17] Zhao (2001) assumes a linear demand and shows that the consolidated profits under vertical disintegration are equal to the profits under merger. As such, he concludes that there are no incentives for a firm to be vertically integrated under the existence of a labor-management negotiation. My calculation can always be collapsed to the Zhao's case by setting $\alpha = 0.5$ and $\beta = 0$ and assuming that both parties bargain over both wage and employment.

incentive to merge if the downstream firm's negotiation power with the labor union is sufficiently high compared to that with the upstream firm.

1.3.4 Parallel Negotiations

In Sub-section 1.3.1, under the disintegrated organizational structure, I assume that the inter-firm negotiation between the downstream and upstream firms over the price of intermediate materials takes place prior to the labor-management negotiation. Although this timing structure can be rationalized by the extent to which an internal contract is in general more long-term than the employment commitment, I could not rule out the possibility that the downstream firm undertakes both negotiations simultaneously.[18] To account for this scenario, the timing structure can be modified from three-stage to two-stage games as follows. In the first stage, the downstream firm at the same time bargains over the wage and material price with the labor union and upstream firm, respectively. Then, given the negotiated wage and transfer material price, the downstream firm chooses the level of production so as to maximize her individual profits. At the end of this two-stage game, the consolidated profit and labor union's welfare are realized.[19]

By using the backward induction procedure, the expressions of the profit-maximizing production, price, downstream firm's profit, and labor union's welfare, as functions of the negotiated wage and transfer material price, are exactly the same as (7), whereas the upstream firm's profit can be written as

$$\pi_m = (m-c)\left(\frac{a-m-w}{2b}\right). \tag{23}$$

[18] It is also possible that the employment commitment may be more long-term than the internal contract. Although this case is rarely likely in reality, the discussions regarding this timing scenario will be relegated to Sub-section 1.3.5.

[19] The change in the timing structure does not affect the equilibrium under vertical integration as a firm always sets $m = c$.

As before, in the first stage the wage rate and material price are determined via the Generalized Nash Bargaining problem. The difference is that in this case I have two independent bargaining problems, namely *parallel bargaining*. If either of negotiations (or both) breaks down, all negotiating parties obtain nil in that labor and materials are perfect complements. The collapse of either of bargaining implies that there is no production taking place, and therefore the consolidated profit is zero while the labor union obtains merely unemployment benefits. Specifically, the Nash bargaining solutions to the wage rate and material price can be obtained by simultaneously solving the following maximization problems.

$$\underset{w}{Max}\, G(w,m) = \left[\frac{(a-m-w)^2}{4b}\right]^{\alpha}\left[(w-w_o)\left(\frac{a-m-w}{2b}\right)\right]^{1-\alpha} \tag{24}$$

$$\underset{m}{Max}\, H(w,m) = \left[\frac{(a-m-w)^2}{4b}\right]^{\beta}\left[(m-c)\left(\frac{a-m-w}{2b}\right)\right]^{1-\beta} \tag{25}$$

By differentiating (24) and (25) with respect to *w* and *m*, respectively, and after some manipulations, the first-order conditions can be obtained as

$$w_{DI} = A(\alpha)(a-m-w_o)+w_o \tag{26}$$

$$m = B(\beta)(a-w_{DI}-c)+c\,. \tag{27}$$

The first-order conditions in (26) and (27) are analogous to the reaction functions in the Cournot-Nash game.[20] Given the linear demand function, since $0 \le A(\alpha), B(\beta) < 1$, the resulting equilibrium of the wage rate and material price is stable and can be shown as

$$w_{DI} = \frac{A(1-B)}{1-AB}(a-c-w_o)+w_o \tag{28}$$

[20] It can be straightforwardly shown that the maximization problems (24) and (25) satisfy the second-order conditions in that both are concave in *w* and *m*.

$$m = \frac{B(1-A)}{1-AB}(a-c-w_o)+c. \tag{29}$$

PROPOSITION 6 *Given the linear demand and parallel bargaining structure, the Nash bargaining solution for the wage (intermediate material price) is increasing (decreasing) in the downstream firm's relative negotiation power with respect to the upstream firm and decreasing (increasing) in that with respect to the labor union.*

Proof: By differentiating (29) with respect to α and β, I have

$$\frac{\partial w}{\partial \alpha} = \frac{(1-B)A'(\alpha)}{(1-AB)^2}(a-c-w_o) < 0 \text{ and } \frac{\partial w}{\partial \beta} = -\frac{A(1-A)B'(\beta)}{(1-AB)^2}(a-c-w_o) \geq 0.$$

$$\frac{\partial m}{\partial \beta} = \frac{(1-A)B'(\beta)}{(1-AB)^2}(a-c-w_o) < 0 \text{ and } \frac{\partial m}{\partial \alpha} = -\frac{B(1-B)A'(\alpha)}{(1-AB)^2}(a-c-w_o) \geq 0. ∎$$

With the parallel bargaining structure, the results according to Proposition 3 no longer hold since from (29) the sub-game perfect Nash equilibrium of the material price depends on the downstream firm's relative bargaining power with respect to both labor union (α) and upstream firm (β). The first part of Proposition 6 is not surprising as higher downstream firm's bargaining power for the wage (material price) negotiation enables her to lower the negotiated wage (material price). The intuition for the second part of Proposition 6 is that, given the parallel bargaining structure, the bargaining position in the labor-management negotiation will affect the bargaining between downstream and upstream firms, and vice versa. That is, the lower negotiated wage (material price) as a result of an increase in the downstream firm's bargaining position will augment the surplus to be shared by the upstream firm (labor union), resulting in an increase in the negotiated material price (wage).

By using (28) and (29), I can solve for the sub-game perfect Nash equilibrium of the production, consolidated profit, and labor union's welfare.

$$q_{DI} = \frac{(1-A)(1-B)}{1-AB}\frac{(a-c-w_o)}{2b}$$

$$\pi_{DI} + \pi_m = \frac{(1-A)^2(1-B^2)}{(1-AB)^2}\frac{(a-c-w_o)^2}{4b}$$

$$U_{DI} = \frac{A(1-A)(1-B)^2}{(1-AB)^2}\frac{(a-c-w_o)^2}{2b} + w_o\overline{L} \quad (30)$$

PROPOSITION 7 *Compared with the case where the inter-firm bargaining takes place prior to the labor-management negotiation under the disintegrated structure, the labor union is better-off when both negotiations are simultaneous.*

Proof: By comparing (30) with (16), since $A(\alpha), B(\beta) \in [0,1/2]$, and thus $(1-AB)^{-2} \geq 1$, it follows that the wage rate, employment, and labor union's welfare must increase. ■

The intuition of Proposition 7 is that when the wage rate and material price negotiations are undertaken simultaneously, the bargaining position of the downstream firm with respect to the upstream firm seems to be improved. In other words, the adverse impacts of double marginalization are mitigated, thereby raising downstream firm's surpluses, which are in turn shared by the labor union via the labor-management negotiation. Note that under this timing structure the results corresponding to Proposition 4 still hold in the sense that the union always prefers the firm to be vertically integrated since $\frac{(1-B)^2}{(1-AB)^2} < 1$.

A change in the timing structure does affect the firm's decision to merge. To show this, it is more convenient to rewrite the consolidated profit of the vertically disintegrated firms in (30) as a function of π_{VI}.

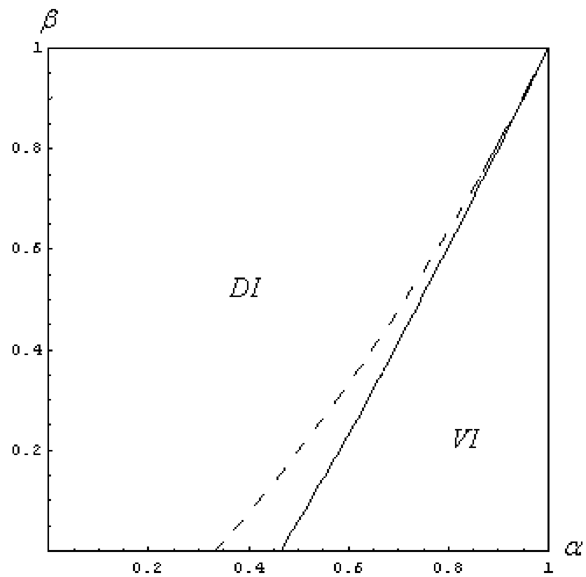
$$\pi_{DI} + \pi_m = \frac{1-B^2}{(1-AB)^2}\pi_{VI} \quad (31)$$

Accordingly, the condition under which the firm will find the vertically integrated structure optimal can be portrayed as

$$\frac{1-B^2}{(1-AB)^2} < 1. \tag{32}$$

Based on (32), I can portray the condition of parameters α and β under which the optimal organizational structures are formed in Figure 1.2.

Figure 1.2: A Change in Vertical Integration Incentives under Successive Monopoly and Parallel Bargaining



PROPOSITION 8 *The firm is more likely to stay vertically disintegrated if I relax the assumption that the inter-firm bargaining serves as long-term commitments such that the wage rate and material price can be simultaneously negotiated.*

Figure 1.2 suggests that when the negotiations for factor inputs, i.e., labor and intermediate materials, switch from the successive bargaining to the simultaneous one, the firm seems to have more incentives to disintegrate or decentralize the organizational structure in that the area for vertical disintegration expands while that for merger contracts. Given the relative bargaining power α and β, the change in timing structures from sequential to parallel negotiations implies that the downstream firm will gain better negotiation with her upstream counterpart. This improvement in the bargaining position can be easily seen by comparing the negotiated material prices in (15) and (29). Clearly, since $(1-A)/(1-AB) \leq 1$, it must follow that the downstream firm can purchase intermediate materials from her upstream counterpart with lower prices if both negotiations can be negotiated at the same time. As a consequence, with the aforementioned tradeoff the change in the timing structure would make the vertically disintegrated organizational structure more attractive.

1.4 A Discussion of Bargaining Agendas

Under the assumption that the inter-firm negotiation is a long-term commitment, Sub-sections 1.3.1-1.3.3 deal with the conditions under which the disintegrated firms have an incentive to be vertically integrated. By the same token, Sub-section 1.3.4 centers on the scenario in which both labor-management and inter-firm negotiations are simultaneously undertaken. To complete my analysis, this section aims to briefly discuss the scenario in which the labor-management bargaining takes place prior to the other.

PROPOSITION 9 *If the labor-management negotiation takes place prior to the inter-firm negotiation, vertical integration will not entail losses of surpluses extracted by a labor union, and hence the integration incentive always exists.*

Proof: Given this timing structure, the generalized Nash bargaining solutions are the reflection of those in Sub-section 1.3.1. Therefore, I can obtain

$$w_{DI} = w_{VI} = A(\alpha)(a-c-w_o)+w_o \text{ and } \pi_{DI}+\pi_m = (1-B^2)\pi_{VI} \leq \pi_{VI}. \blacksquare$$

Since the negotiated wage is determined in the expectation of the negotiated material price, vertical integration does not deteriorate the downstream firm's wage negotiation outcome ($w_{DI} = w_{VI}$). This suggests that vertical integration has to do solely with the gains from the elimination of double marginalization. Therefore, it dominates the disintegrated structure, and my analysis is collapsed to the classical case in which the firm always has an incentive to be vertically integrated. My results may be contributed to the literature on the strategic use of the bargaining agendas pioneered by Fershtman (1990)[21] in the sense that if a disintegrated firm can choose the timing or agendas of negotiations, she will never deal with the labor-management prior to inter-firm bargaining as the absence of the tradeoff enables her to at least obtain higher payoffs by vertical integration. Since I focus on the interaction between both negotiations, which affect the vertical integration incentives, the rest of my analysis will focus on the timing structure in which the inter-firm bargaining occurs prior to the labor-management bargaining.

1.5 Upstream Foreclosure

In this section, I will extend my basic structure of vertical disintegration by introducing the foreign outsourcing firm, who purchases a key intermediate input from the domestic upstream firm and is then eligible to compete in the domestic market, into the model. Following the conventional vertical foreclosure literature (Salinger, 1988), the crucial assumption is that the upstream firm can credibly commit to restricting the supply of key intermediate inputs exclusively to her downstream counterpart only when the firm is vertically integrated. In this sense, upstream foreclosure could be undertaken by vertical integration since the disintegrated upstream firm always has an incentive to sell key intermediate inputs to the foreign

[21] Fershtman (1990) employs the Rubinstein alternating offers bargaining model to show that the timing or agendas of negotiations do affect the outcome. Furthermore, if the players have different evaluations of the agenda, the equilibrium allocation of surpluses may not be efficient.

outsourcer. Although it is by all means unappealing (see Reiffen, 1992 for the criticism of this assumption) as a rational integrated firm may also serve intermediate input markets, this assumption, due to the peculiarities of the labor-management and inter-firm bargaining in my framework, is indispensable for obtaining the closed form solution and developing further analyses. Indeed, the fact that vertical integration results in foreclosure may be rationalized by two arguments. Firstly, the problem of a credible commitment not to supply inputs to downstream rivals can be solved by take-it-or-leave-it offers under vertical integration since it internalizes the losses of monopoly rent via profit sharing (see Martin, et al., 2001 in Section 2 for more detailed discussions). Secondly, the recent empirical evidence has suggested that the integrated firms are likely to exclude their rivals from the access to intermediate inputs (see Chipty, 2001 for the case of the cable television industry).

1.5.1 The Equilibrium with a Foreign Outsourcer

A natural question arising from introducing a foreign outsourcer is that: Why does the firm allow the upstream firm to supply intermediate materials to foreign outsourcer, thereby increasing competition in the final output market? I will relegate the discussions regarding this question to next sub-section. For the time being, I focus specifically on solving the equilibrium with the foreign outsourcer.

To see this more clearly, the structure of vertical disintegration with the presence of a foreign outsourcer can be enumerated as follows. Consider two downstream firms, domestic and foreign firms, producing homogeneous final output, q and q^*, respectively, and competing in the same (domestic) market based on the Cournot competition. I assume that there are no transportation cost and trade frictions in both upstream and downstream markets. In order to produce one unit of final output, both domestic and foreign downstream firms are required to employ one unit of labor and one unit of key intermediate inputs, assumed to be exclusively produced by the domestic upstream firm.[22] Therefore, in order to enter a domestic market, the foreign firm must strategically outsource the production of intermediate inputs by bargaining over its price with the domestic upstream firm. In this sense, the foreign firm is a *strategic outsourcer*.[23] In words, both domestic downstream firm and foreign outsourcer must bargain over the wage rate and the intermediate material price with their own indigenous labor unions and the domestic upstream firm, respectively.

The timing structure is analogous to that in Section 1.3.1. In words, the sub-game perfect Nash equilibrium of the wage rates, material prices, and outputs can be determined by the three-stage game. In the first stage, both domestic downstream firm and foreign outsourcer negotiate with the domestic upstream firm over the material prices, m and m^*, respectively. In the second stage, both domestic and foreign downstream firms bargain with their own indigenous labor unions over the wage rates, w and w^*, respectively. Given the negotiated wages and material prices, in the final stage both firms serve the same market by producing q and q^* so as to maximize their own profits. At the end of this three-stage game, the domestic firm realizes consolidated profits of both downstream and upstream firms whereas the foreign outsourcer realizes profits from serving the domestic market.[24]

By applying the standard backward induction procedure, I start off with the final stage in which both domestic downstream firm and foreign outsourcer decide on the profit-maximizing production, employment, and intermediate input. Given the

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[22] Alternatively, the production of intermediate inputs by a domestic upstream firm are assumed to be sufficiently more efficient than the foreign firm such that it is always more profitable for her to buy intermediate inputs from the domestic upstream firm, rather than producing in house.

[23] My notion of strategic outsourcing is similar to that of Shy and Stenbacka (2003) and Chen et al. (2004)

[24] Given this timing structure, I still abide by my basic structure in which the inter-firm bargaining takes place prior to the labor-management negotiation. However, it should be emphasized that my main results do not qualitatively change if both types of negotiations simultaneously occur.

assumption on the demand function as before, the profit functions of both downstream firms can be given as

$$\pi_{DO} = \left(p(q+q^*) - m - w\right)q \tag{33}$$

and

$$\pi^*_{DO} = \left(p(q+q^*) - m^* - w^*\right)q^*. \tag{34}$$

The subscript *DO* aims to characterize downstream firms with the foreign outsourcing firm. To characterize the equilibrium, I, rather than developing discussions in a general way, will assume the linear functional form of the final output demand as before. By differentiating (33) and (34) with respect to q and q^*, respectively, it is straightforward to show that the optimal outputs and the maximized profits as functions of the negotiated wages and material prices are

$$q_{DO}(w,w^*,m,m^*) = \frac{a-2m-2w+m^*+w^*}{3b}$$

$$q^*_{DO}(w,w^*,m,m^*) = \frac{a+m+w-2m^*-2w^*}{3b}$$

$$\pi_{DO}(w,w^*,m,m^*) = \frac{(a-2m-2w+m^*+w^*)^2}{9b}$$

$$\pi^*_{DO}(w,w^*,m,m^*) = \frac{(a+m+w-2m^*-2w^*)^2}{9b} \tag{35}$$

Next, I move onto the second stage of the labor-management negotiation. The labor unions' objective functions take the same forms as (3). I assume that the rate of unemployment benefits is the same in both countries ($w_o = w_o^*$), and the downstream firms' bargaining power with respect to the labor unions are identical ($\alpha = \alpha^*$). Accordingly, the Nash bargaining solutions to domestic and foreign wage rates can be derived as functions of m and m^* by solving the following maximization problems simultaneously.

$$\underset{w}{Max}\, G(w,w^*,m,m^*) = \left[\frac{(a-2m-2w+m^*+w^*)^2}{9b}\right]^{\alpha}\left[(w-w_o)\left(\frac{a-2m-2w+m^*+w^*}{3b}\right)\right]^{1-\alpha} \quad (36)$$

$$\underset{w^*}{Max}\, G^*(w,w^*,m,m^*) = \left[\frac{(a+m+w-2m^*-2w^*)^2}{9b}\right]^{\alpha}\left[(w^*-w_o)\left(\frac{a+m+w-2m^*-2w^*}{3b}\right)\right]^{1-\alpha} \quad (37)$$

If the negotiations with the indigenous labor unions break down, the domestic downstream firm and the foreign outsourcer obtain zero payoff since no production takes place whereas the unions obtain unemployment benefits, $w_o\overline{L}$ and $w_o\overline{L}^*$, for the domestic and foreign labor unions, respectively. By differentiating (36) and (37) with respect to w and w^*, respectively, the first-order conditions corresponding to the Generalized Nash Bargaining are written as

$$w = \frac{(1-\alpha)}{4}(a-2m+m^*) + \frac{(1-\alpha)}{4}w^* + \frac{(1+\alpha)}{2}w_o \quad (38)$$

and

$$w^* = \frac{(1-\alpha)}{4}(a+m-2m^*) + \frac{(1-\alpha)}{4}w + \frac{(1+\alpha)}{2}w_o \quad (39)$$

Though tedious, solving (38) and (39) for the solutions of w and w^* as functions of m and m^* yields us the following expressions.

$$w = \frac{4(1-\alpha)}{(5-\alpha)(\alpha+3)}(a-2m+m^*) + \frac{(1-\alpha)^2}{(5-\alpha)(\alpha+3)}(a+m-2m^*) + \frac{2(1+\alpha)}{\alpha+3}w_o \quad (40)$$

$$w^* = \frac{(1-\alpha)^2}{(5-\alpha)(\alpha+3)}(a-2m+m^*) + \frac{4(1-\alpha)}{(5-\alpha)(\alpha+3)}(a+m-2m^*) + \frac{2(1+\alpha)}{\alpha+3}w_o \quad (41)$$

Note that in equilibrium Proposition 2 still holds in the sense that an increase in the firms' relative bargaining power with the labor unions will reduce the negotiated wage rates. One may also check that the negotiated wages are decreasing in their own material costs and increasing in opponents' material costs ($\partial w/\partial m = \partial w^*/m^* < 0$ and $\partial w/\partial m^* = \partial w^*/\partial m > 0$).

Then, I substitute (40) and (41) into (35). The optimal productions, downstream and upstream profits can be written as

$$q_{DO} = \frac{1}{3b}\left[\frac{8(1+\alpha)}{(5-\alpha)(\alpha+3)}(a-2m+m^*) + \frac{2(1-\alpha^2)}{(5-\alpha)(\alpha+3)}(a+m-2m^*) - \frac{2(1+\alpha)}{\alpha+3}w_o\right]$$

$$q_{DO}^* = \frac{1}{3b}\left[\frac{2(1-\alpha^2)}{(5-\alpha)(\alpha+3)}(a-2m+m^*) + \frac{8(1+\alpha)}{(5-\alpha)(\alpha+3)}(a+m-2m^*) - \frac{2(1+\alpha)}{\alpha+3}w_o\right]$$

$$\pi_{DO} = \frac{1}{9b}\left[\frac{8(1+\alpha)}{(5-\alpha)(\alpha+3)}(a-2m+m^*) + \frac{2(1-\alpha^2)}{(5-\alpha)(\alpha+3)}(a+m-2m^*) - \frac{2(1+\alpha)}{\alpha+3}w_o\right]^2$$

$$\pi_{DO}^* = \frac{1}{9b}\left[\frac{2(1-\alpha^2)}{(5-\alpha)(\alpha+3)}(a-2m+m^*) + \frac{8(1+\alpha)}{(5-\alpha)(\alpha+3)}(a+m-2m^*) - \frac{2(1+\alpha)}{\alpha+3}w_o\right]^2$$

$$\pi_{MO} = (m-c)q_{DO} + (m^*-c)q_{DO}^* . \quad (42)$$

The subscript *MO* characterizes the upstream firm under the presence of a foreign outsourcing firm. As in the second stage, the first stage also deals with a pair of negotiations: domestic downstream firm versus domestic upstream firm; and foreign outsourcer versus domestic upstream firm. For the analytical purpose, I assume that the relative bargaining power of the domestic downstream firm and the foreign outsourcer with respect to the domestic upstream firm is the same ($\beta = \beta^*$), and the case where two parallel negotiations simultaneously break down is ruled out. Hence, the Nash bargaining solutions to material prices, m and m^*, can be characterized by solving the following asymmetric Nash bargaining problems.

$$\underset{m}{Max}\, H = \left[\pi_{DO}(m,m^*)\right]^{\beta}\left[\pi_{MO}(m,m^*) - \pi_{MO}^{o}(m^*)\right]^{1-\beta} \quad (43)$$

$$\underset{m^*}{Max}\, H^* = \left[\pi_{DO}^*(m,m^*)\right]^{\beta}\left[\pi_{MO}(m,m^*) - \pi_{MO}^{o*}(m)\right]^{1-\beta}, \quad (44)$$

where $\pi_{MO}^{o}(m^*) = \left(\frac{1+\alpha}{4b}\right)(m^*-c)(a-m^*-w_o)$

, $\pi_{MO}^{o*}(m) = \left(\frac{1+\alpha}{4b}\right)(m-c)(a-m-w_o)$.

Essentially, if either of negotiations breaks down, although the payoffs to the domestic downstream firm in case of the break down of (43) and to the foreign outsourcer in case of the break down of (44) are still zero (as no production occurs), the payoffs to the domestic upstream firm is not. Specifically, if the negotiation between domestic downstream and upstream firms breaks down, the upstream firm obtains π^{o}_{MO}, which is the profits from supplying materials to the foreign outsourcer, who becomes the sole producer in final output market. Likewise, if the other bargaining breaks down, the domestic upstream firm earns π^{o*}_{MO}, which is the profits from sharing monopoly rent with the domestic downstream firm.[25]

By differentiating (43) and (44) with respect to m and m^*, respectively, the Nash bargaining solutions to the material prices can be obtained by solving the following first-order conditions.

$$\frac{\beta}{\pi_{DO}(m,m^*)}\frac{\partial \pi_{DO}(m,m^*)}{\partial m}+\frac{1-\beta}{\pi_{MO}(m,m^*)-\pi^{o}_{MO}(m^*)}\frac{\partial \pi_{MO}(m,m^*)}{\partial m}=0 \qquad (45)$$

$$\frac{\beta}{\pi^*_{DO}(m,m^*)}\frac{\partial \pi^*_{DO}(m,m^*)}{\partial m^*}+\frac{1-\beta}{\pi_{MO}(m,m^*)-\pi^{o*}_{MO}(m)}\frac{\partial \pi_{MO}(m,m^*)}{\partial m^*}=0 \qquad (46)$$

One may discern that the asymmetric Nash bargaining problems (43) and (44) are symmetric in the sense that (43) can be obtained by replacing m by m^* and, reciprocally, m^* by m. Hence, in equilibrium it must hold that $m = m^*$. By imposing the symmetry condition on (42), (45) and (46), it can be shown that the Nash bargaining solutions to material prices are given by

$$m = m^* = \Omega(\alpha,\beta)(a - c - w_o) + c, \qquad (47)$$

where $\Omega(\alpha,\beta) = \dfrac{4(5-\alpha)(1-\beta)}{8(5-\alpha)+3\beta(\alpha+3)(1-\alpha)}$.

---

[25] The derivations of π^{o}_{MO} and π^{o*}_{MO} can be directly seen from $\pi_m(m)$ in (13) where the downstream firm is assumed to be a monopoly in the final output market.

By differentiating (47) with respect to α and β, it can be shown that $\partial m/\partial\alpha = \partial\Omega/\partial\alpha(a-c-w_o) \geq 0$ and $\partial m/\partial\beta = \partial\Omega/\partial\beta(a-c-w_o) < 0$, and therefore the results differ from Proposition 3 but are consistent with Proposition 6. With the competition in the final output market, the Nash bargaining solutions to material prices are increasing in the relative bargaining power of the domestic downstream firm and the foreign outsourcer with respect to the indigenous labor unions (α) and decreasing in those with respect to the domestic upstream firm (β). As mentioned previously, the second part is easily understandable as better bargaining positions with the domestic upstream firm should results in lower negotiated material prices. The first part, in contrast, can be explained by the fact that the better positions in the labor-management negotiations will enlarge the surpluses that will be shared by the domestic upstream firm.

By substituting (47) into (40) and (41), the equilibrium wage rates can be revealed as

$$w = w^* = \frac{1-\alpha}{\alpha+3}(1-\Omega(\alpha,\beta))(a-c-w_o)+w_o. \qquad (48)$$

Apparently, this is also consistent with Proposition 6 in that $\partial w/\partial\alpha < 0$ and $\partial w/\partial\beta > 0$. An improvement in the labor-management bargaining positions (α) would entail lower negotiated wage rates, and an increase in the relative bargaining power of the domestic downstream firm and the foreign outsourcer with the domestic upstream firm (β), which surely reduces the negotiated material prices, will result in higher surpluses to be shared with the indigenous labor unions.

By using (47) and (48), the equilibrium production, domestic downstream firm's profit, foreign strategic outsourcer's profit, domestic upstream firm's profit, and domestic firm's consolidated profit can be straightforwardly solved as

$$q_{DO} = q_{DO}^{*} = \frac{2(1+\alpha)}{3b(\alpha+3)}(1-\Omega(\alpha,\beta))(a-c-w_o)$$

$$\pi_{DO} = \pi_{DO}^{*} = \frac{1}{9b}\left[\frac{4(1+\alpha)^2(1-\Omega(\alpha,\beta))^2}{(\alpha+3)^2}\right](a-c-w_o)^2$$

$$\pi_{MO} = \frac{4(1+\alpha)}{3b(\alpha+3)}\Omega(\alpha,\beta)(1-\Omega(\alpha,\beta))(a-c-w_o)^2$$

$$\pi_{DO}+\pi_{MO} = \frac{1}{3b}\left[\frac{4(1+\alpha)^2(1-\Omega)^2}{3(\alpha+3)^2}+\frac{4(1+\alpha)\Omega(1-\Omega)}{\alpha+3}\right](a-c-w_o)^2 \qquad (49)$$

Since the disagreement points of the domestic upstream firm are non-zero, the Nash bargaining solutions derived in (49) will exist only if $\pi_{MO} \geq \pi_{MO}^{o} = \pi_{MO}^{o*}$. One can check that this condition always holds since $3(\alpha+3) < 16$.

1.5.2 Upstream Foreclosure Decisions

The previous sub-section is concerned with the scenario in which the domestic firm welcomes foreign competition by allowing her disintegrated upstream firm to supply the key intermediate inputs for the foreign outsourcer via the asymmetric Nash bargaining. Given that the domestic firm has a full control over key intermediate inputs production, she may strategically foreclose the foreign competition by exclusively procuring intermediate inputs from the upstream firm via vertical integration, which in turn enables her to monopolize the final output market.[26] In this sense, the upstream foreclosure decisions have to do with two tradeoffs: (1) monopoly rents in the final output market versus losses of the upstream firm's surpluses extracted from the foreign outsourcer (2) gains from the elimination of double marginalization versus the losses of the worsened wage negotiation. In this sub-section, I argue that the domestic firm will strategically foreclose foreign

[26] Recall that I assume that the in-house production of intermediate inputs by the foreign firm is sufficiently inefficient such that the only way to enter domestic market is to outsource those materials from domestic firm.

competition if domestic downstream firm's bargaining positions with the indigenous labor union and the upstream firm are sufficiently advantageous.

The condition under which the domestic firm will find strategic foreclosure profitable can be obtained by rewriting the consolidated profits (49) in terms of π_{VI}.

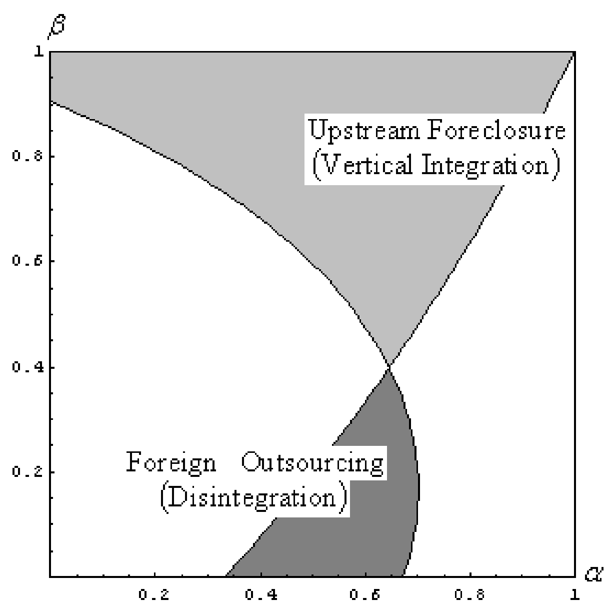
$$\pi_{DO} + \pi_{MO} = \frac{64}{3}\left[\frac{(1-\Omega)^2}{3(\alpha+3)^2} + \frac{\Omega(1-\Omega)}{(\alpha+3)(1+\alpha)}\right]\pi_{VI} \tag{50}$$

It can be shown that the domestic firm will decide to strategically foreclose foreign competition if

$$\frac{64}{3}\left[\frac{(1-\Omega)^2}{3(\alpha+3)^2} + \frac{\Omega(1-\Omega)}{(\alpha+3)(1+\alpha)}\right] < 1 \tag{51}$$

By using (51), I can find the ranges of α and β in which strategic foreclosure is profitable, as shown in Figure 1.3.

Figure 1.3: Upstream Foreclosure Incentives



PROPOSITION 10 *The domestic downstream firm will exercise upstream foreclosure if its relative bargaining power with the indigenous labor union (α) and the upstream firm (β) is sufficiently high.*

Intuitively, if the downstream firm's relative bargaining positions with the indigenous labor union and the upstream firm are sufficiently high, the monopoly rent from being a sole producer in the final output market is also high. In which case, the gains from monopoly rent and elimination of double marginalization will outweigh the losses of upstream firm's surpluses from serving the foreign outsourcer and the worsened negotiated wage, and thus the domestic firm will strategically foreclose foreign competition by integrating the upstream firm to supply intermediate inputs only internally. On the contrary, if her controls over employment and intermediate inputs procurement are low, it will be more profitable to welcome foreign competition, which enables the domestic firm to extract surpluses via the inter-firm negotiation and obtain the lower negotiated wage.

By combining the results corresponding to Proposition 5, Figure 1.3 reveals that the integration incentives may be affected by downstream competition. With the parameters of α and β lying in the dark grey area, the integrated firm under successive monopoly may be self-motivated to be disintegrated in face of downstream competition. The high value of $1-\beta$ (low β) implies that the losses of surpluses extracted from the foreign outsourcing firm are sufficiently high such that the net losses of upstream foreclosure from the first tradeoff dominate the net gains from the second. On the contrary, if the bargaining parameters lie in the light grey area, the disintegrated firm under successive monopoly will choose to merge, thereby excluding a foreign downstream firm from the market. With the low value of $1-\beta$ (high β), the losses of surpluses extracted from the foreign outsourcing firm are sufficiently infinitesimal such that the net gains from the second tradeoff dominate the net losses from the first.

1.6. Conclusion

This chapter is related to the optimal organizational structures with the presence of unionization, inter-firm bargaining, and the strategic anti-competitive effects of vertical integration under the presence of a foreign outsourcer. My basic structure abstracts from the standard successive monopoly framework. Not only do I nest the inter-firm negotiation via the Generalized Nash Bargaining, but I also generalize the labor-management negotiation by taking into account the negotiation asymmetry.

My results contribute to the literature on the interaction between unionization and management in the following ways. It is well established that the firm always has an incentive to be vertically integrated due to the ‘double marginalization’. However, the incentives to merge may be dissipated if the industry is unionized since the vertical integration deteriorates the firm’s bargaining position with the labor union. Given these well-known results, I further reveal that, despite the existence of unionization, the merger incentives remain if the downstream firm’s bargaining power with the labor union is relatively high compared with that with the upstream firm. Furthermore, if labor employment and intermediate inputs procurement can be simultaneously, rather than sequentially, negotiated, the firm is more likely to stay vertically disintegrated. To complete my analysis, I argue that if the disintegrated firm can strategically manipulate the negotiation agendas, she will never undertake the labor-management bargaining prior to the other.

Given my basic structure of vertical disintegration with the inter-firm bargaining and unionization, I extend the model to account for how anti-competitive effects of merger, so called upstream foreclosure, changes the vertical integration incentives. I introduce the foreign downstream firm who may strategically outsource intermediate inputs production in order to enter a domestic market. By invoking the standard foreclosure assumption (Salinger, 1988) that vertical integration provides the upstream firm a credible commitment to cease the intermediate inputs supply to of her foreign downstream rival, a disintegrated firm may exercise upstream foreclosure by vertically integrating those vertically linked firms and enjoy monopoly rent. In contrast, the decisions to supply the inputs externally enable the domestic firm to extract surpluses from the foreign outsourcer via the Generalized Nash Bargaining, thereby facing foreign competition in the final output market. Based on this structure, I show that the foreign outsourcer's access to key intermediate inputs will be strategically foreclosed if the downstream firm has enough bargaining advantages over the labor union and the upstream firm. Accordingly, my extension highlights the pivotal roles of the labor-management and inter-firm negotiations that shed further light on the interaction between intermediate input and final output markets.

Throughout this chapter, the relative bargaining powers are treated as exogenously given. Although exogeneity of players' bargaining powers is justifiable as they depend on factors exogenous to the players, such as the labor standard, vertical market structures, degree of unionization, etc., it may be interesting to endogenize the relative bargaining powers in light of future research. For example, the domestic government may choose the relative negotiation powers in the labor-management negotiation to maximize the country's welfare.

This chapter omits some plausible cases, such as the domestic firm as a purchaser of intermediate inputs from foreign firms and foreign outsourcing under vertically integrated domestic firms. Although the omissions make it less than exhaustive, I have specifically pointed out the importance of the labor-management and inter-firm negotiations on the antitrust issue. The antitrust practitioners may choose the set of parameters such that it is of domestic firm's interests to welcome international competition.

CHAPTER II
OUTSOURCING, LABOR PRODUCTIVITY, AND WAGE INEQUALITY IN US: A PRIMAL APPROACH

2.1 Introduction

For the last two decades, I have observed a remarkable increase in outsourcing in the world. Two strands of literature investigating this ongoing phenomenon have emerged. The first strand takes the view that the increase in outsourcing emanates from the decline in transaction costs in connection with the intensified use of information technology (see, for instance, Abraham and Taylor, 1996).[27] The main research question in this literature concerns the impact of outsourcing activities on productivity. In the second strand, the trade-related aspects of outsourcing have attracted increasing attention (see, for instance, Feenstra and Hanson, 1996, 1999). The main subject here is the impact of outsourcing on wage inequality for skilled and unskilled workers. The former strand centers on a firm's decision to contract out business activities and does not distinguish between international and domestic outsourcing[28] (I have coined the term "general outsourcing" to describe this) or between skilled and unskilled labor productivity, whereas the latter strand deals with the role of mainly international outsourcing as a mechanism for moving unskilled-intensive production to unskilled-abundant countries, thereby affecting wage differentials within industries.[29]

Is there any link between these two strands? In this chapter, I argue that, given the nature of competitive economies, the skilled and unskilled labor productivity impacts of general and international outsourcing and their wage differentials may be

[27] In this view, outsourcing may also be termed a "make-or-buy" decision (Grossman and Helpman, 2002), "vertical disintegration" (Holmes, 1999), "fragmentation" (Arndt and Kierzkowski, 2001), "vertical specialization" (Hummels *et al.*, 2001).

[28] Girma and Görg (2004) argue that since the subsequent productivity effects are of their interests, it should not matter whether outsourcing takes place internationally and domestically.

[29] For a theoretical treatment of international outsourcing, see Feenstra and Hanson (1996), Deardorff (2001), Jones (2000) and Jones and Kierzkowski (2001).

related. My idea is that either general outsourcing or international outsourcing may be biased toward skilled labor productivity, and thus the biased impacts on skilled labor productivity may result in wage differentials between skilled and unskilled workers in labor markets. I attempt to empirically investigate such linkages based on six-digit NAICS US manufacturing industries. I also examine what type of outsourcing is more significant in explaining the linkages.

Previous studies have investigated either the impacts of outsourcing on the overall labor productivity (Abraham and Taylor, 1996; Girma and Görg, 2004; and Amiti and Wei, 2006 among others) or the impacts of international outsourcing on the relative demand for skilled labor (Feenstra and Hansen, 1996; and Anderton and Brenton, 1999 among others). The present chapter contributes to the former literature in the sense that I attempt to investigate the effects of both general and international outsourcing on the relative productivity of skilled and unskilled workers, instead of the overall labor productivity. Moreover, my results may also be complementary with the latter literature if the labor productivity impact of general outsourcing is skilled-biased.[30]

The mechanisms through which general and international outsourcing shift the relative demand for skilled workers, are different. According to the standard Heckscher-Ohlin theory, the industries in developed economies, where skilled labor is well endowed, import the unskilled-intensive intermediate inputs. This will shift the relative demand for skilled workers and therefore explain the intra-industry wage differential between skilled and unskilled labor. In contrast, general outsourcing may also explain the shift in the relative demand for skilled workers if productivity gains

[30] A fundamental difference between general outsourcing (contracting out the production of intermediate inputs at arm's length) and the purchase of other factors of production, such as capital and raw materials, is that a firm faces the decisions whether a particular intermediate input will be internalized (produced in house) or contracted out at arm's length (outsourced).

from general outsourcing are more pronounced for skilled workers. The reason for the skilled-biased effect associated with general outsourcing is that each stage of production is different in skilled labor intensity. If the industries contract out the unskilled-intensive production of intermediate inputs, the productivity improvement from allocating the existing labor to skilled-intensive production should be more substantiated for skilled workers, thereby shifting the relative demand for skilled workers.

I adopt a primal approach. That is, I directly estimate the constant elasticity of substitution (CES) value-added function for the US manufacturing case.[31] Hence, my framework may be subject to the potential endogeneity problem, resulting in inconsistent estimators, due to the fact that outsourcing decisions may be endogenously determined by other industry-specific factors. I tackle this problem by employing two-step non-linear estimators with instrument variables. Such a primal approach is different from that employed in existing studies in this area, in which a dual approach, estimating cost-share function, has commonly been used. However, according to Mundlak (1996), the estimates based on a primal approach, unlike indirect estimators of the cost function, can optimally utilize all the available information and therefore are statistically efficient.

The literature on the impacts of outsourcing on the relative demands for skilled workers typically assume the Cobb-Douglas value added function and derive the short-run cost function based on the assumption of constant returns to scale. However, in this chapter I employ the CES specification. The CES value added function may be more appealing than the Cobb-Douglas one for the following reasons. First, it does not assume the degree of factor substitutability a priori. Furthermore, it

[31] In an approach similar to mine, Egger and Egger (2006) construct an equation of the unskilled labor average productivity, using the constant elasticity of the substitution production function, and estimate it to see the impact of international outsourcing on unskilled labor productivity in the case of the EU.

may convey efficient and unbiased estimates if the true production function is not homogenous of degree one.

The main benefit of this approach lies in the fact that it provides us with a unified framework in which I can link outsourcing and labor productivity and then link labor productivity and wage differentials. For the first link, the primal approach, estimating production functions, enables us to construct a marginal productivity of skilled and unskilled labor. Furthermore, I can investigate the segregated impacts of general and international outsourcing on skilled and unskilled labor productivity, respectively.[32] For the second link, by utilizing the marginal productivities of skilled and unskilled workers in the two different outsourcing environments, I can examine the impact of the outsourcing activities on wage differentials, given the nature of competitive economies.

My main findings can be elaborated as follows. First, general and international outsourcing entails positive non-neutral technological shifts of skilled and unskilled workers. More importantly, they are all skill-biased in the sense that non-neutral productivity gains from specialization in core-competent activities are more pronounced for skilled workers. Second, on average, general and international outsourcing brings about a productivity improvement for both unskilled and skilled workers in both the short run and the long run. However, I further find that, in the case of international outsourcing, the positive productivity gains prevail only in high-tech industries. Finally, the wage gaps in the US between skilled and unskilled workers during the period 2002-2005 are affected to a greater degree by general outsourcing than by international outsourcing, both in the short run and in the long run.

[32] As elaborated in next section, neither of the literature strands distinguishes between the skilled and unskilled labor productivity impacts of general and international outsourcing.

In summary, my results show that the wage inequality of US manufacturing industries during 2002-2005 is mainly due to the skill-biased labor productivity effect of general outsourcing rather than that of international outsourcing. Accordingly, in addition to the existing literature emphasizing the role of international trade in intermediate inputs as a way of explaining the increasing wage inequality within industries, the present chapter shows that the productivity mechanism through which both domestic and international outsourcing affects labor productivity with a bias toward skilled workers, thereby changing their rewards, may be another rationalization of the relationships among outsourcing, labor productivity, and wage inequality.

The organization of this chapter can be outlined briefly as follows. In Section 2.2, the two strands of the outsourcing literature are outlined. I elaborate on the theoretical discussions regarding value-added analysis and CES frameworks in Section 2.3. The empirical methodology and data measurement are discussed in Section 2.4. Section 2.5 presents the empirical results and economic analyses. Section 2.6 concludes.

2.2 Review of the Literature

The present chapter represents a link between two strands of literature on outsourcing. On the one hand, this chapter is compatible with those dealing with the labor productivity impacts of outsourcing. On the other hand, my methodology can also be extended to capture the essence of the literature on outsourcing as the explanatory variable for wage inequality between skilled and unskilled workers within industries. Accordingly, this section presents a brief review of both strands of the literature.

2.2.1 Outsourcing and Labor Productivity

Among the very first studies offering a more detailed analysis of offshore outsourcing and its effects on productivity[33] is that of Egger and Egger (2006). They rigorously explore the impacts on productivity of low-skilled workers using data on 22 manufacturing industries in 12 EU nations during 1992-1997. Based on a narrow definition of international outsourcing and using the CES production function, they find that a 1 percent rise in offshore outsourcing brings about a drop in low-skilled labor productivity by 0.18 percent in the short run. In the long run, nevertheless, an improvement in productivity can be observed.

Amiti and Wei (2006) study the impact of offshore outsourcing on overall labor productivity, rather than on low-skilled labor productivity, utilizing the data of 96 US manufacturing industries during 1992-2000. They find a positive effect of offshore material and service outsourcing on overall labor productivity, but large positive effects exist for service outsourcing. Specifically, they show that an increase of 1 percentage point in the intensity of service outsourcing leads to an increase in labor productivity from 0.30 to 0.37 percentage points.

Focusing on general outsourcing with plant-level data, Girma and Görg (2004) analyze the impact of service outsourcing on labor productivity for three segregated UK manufacturing industries during 1982-1992. They find that labor productivity is positively affected by service outsourcing.

Analyzing data for 652 establishments covering 12 subsectors of the electronic industry in the Republic of Ireland during 1990-1995, Görg and Hanley (2003) estimate the effect of offshore outsourcing on labor productivity. They segregate the sample into sub-sectors of plants operating either downstream or upstream and find that a positive impact of outsourcing on labor productivity prevails downstream.

[33] See Olsen (2006) for a more complete survey on impacts of outsourcing on productivities

Although these studies have contributed to the literature by showing the existence of a link between outsourcing and productivity, I think that, as far as US manufacturing industries are concerned, the productivity impacts of outsourcing are still not clear in the following senses. First, I do not really know whether international outsourcing matters more than general outsourcing in the study of labor productivity in the US. Second, most of them assume a Cobb-Douglas production function in their studies, while Egger and Egger (2006) assume a CES production function with perfect substitution between unskilled and skilled labor. Hence, to us, it is unclear whether production function specifications matter or not. Third, I am not sure whether a skill-biased productivity impact of outsourcing exists in US industries. This third point is important because it would give us an insight into the effect of outsourcing on wage inequality between skilled and unskilled labor for the US manufacturing sectors.

2.2.2 Outsourcing and Wage Inequality

This strand of literature focuses on the impact of outsourcing, defined as imports of intermediate goods, on wage differentials between skilled and unskilled workers. Feenstra and Hanson (1996, 1999) provide one of the first empirical assessments of the impact of international outsourcing on the relative demand for unskilled and skilled workers using data from US manufacturing industries during the 1980s and 1990s. As usual, the dual approach is employed in such a way that the translog cost share equation for non-production workers is derived from the cost minimization problem. They conclude that international outsourcing has a positive impact on the wage gap in the US. Interestingly, Feenstra and Hanson (1999) show that technological progress plays an equally important role in explaining the wage gap. Since then, these have been considered the two main competing hypotheses for the wage-differentials impact of outsourcing.

An analogous approach to the empirical investigation of the impact of outsourcing on wage inequality has been undertaken by various authors using non-US data. For instance, Anderton and Brenton (1999) estimate the impact of international outsourcing on UK textile and mechanical engineering industries.[34] However, they find that international outsourcing has no significant impact on the non-production wage share in general. Diehl (1999) provides empirical evidence for the impact of international outsourcing on German manufacturing industries between 1978 and 1990. He finds that international outsourcing has only a weak impact on the skill structure of employment in German manufacturing. However, Geishecker (2002) finds a negative effect of international outsourcing on the relative demand for unskilled workers in the case of Germany. Concerning a large relocation of unskilled jobs to China and a sharp decline in the importance of manufacturing as a corollary of the opening up of the Chinese economy, Hsieh and Woo (2005) show that the relative demand for skilled workers in Hong Kong increased sharply at exactly the same time when outsourcing to China began to increase in the early 1980s.

The literature seems to suggest that international outsourcing is skill-biased in that skilled workers earn more than unskilled workers do. However, I feel that I need to further investigate a more detailed mechanism for factors that affect wage inequality for the following reasons. First, since most of the studies in this strand use a dual approach to estimating cost-share functions, they assume away the important element of production technology and instead argue that international trade in intermediate inputs plays a role akin to exporting unskilled jobs abroad. In fact, Feenstra and Hanson (1999) show the importance of considering technology when seeking to explain the wage gap. The fact that outsourcing and technological progress

[34] In contrast with Feenstra and Hanson (1996), Anderton and Brenton (1999) do distinguish between international outsourcing in low- and high-wage countries. The idea is that low-skilled activities are typically outsourced to low-wage countries.

can affect wage inequality implies that a systematic interaction between outsourcing and technology may exist. Second, since outsourcing activities can be interpreted as firms contracting business out at arm's length (see Grossman and Helpman, 2002 among others), there is no fundamental difference between international and domestic outsourcing. In this regard, I may want to know which type of outsourcing is more related to technology and thus has a greater explanatory power for wage inequality

2.3 Background of Value-Added Analysis and Production Theory

In this section, I will briefly outline a primal approach to directly estimating production function, a constant elasticity of substitution production function, which was also used in Egger and Egger (2006).[35] Furthermore, my empirical strategy of investigating the outsourcing impacts on labor productivity and on their wage differentials will be elaborated.

2.3.1 A Primal Approach to Value-Added Analysis

Consider an industry *i* where *i* = 1,…, *n*, producing a single gross output Q_i with the following production function expressed in a primal form:

$$Q_i = Q_i(K_i, H_i, L_i, \mathbf{O_i}), \tag{52}$$

where K_i, H_i, and L_i are given quantities of capital stock, skilled labor, and unskilled labor, respectively, and $\mathbf{O_i}$ is a vector of domestically and internationally sourced intermediate inputs. Following Fuss, McFadden, and Mundlak (1978), the real value added of industry *i* is defined as

$$V_i(K_i, L_i, H_i) = Q_i - \mathbf{O_i}. \tag{53}$$

[35] They estimated a derived average labor productivity equation, but I estimate the production function itself.

Since my objective is to analyze the economic impacts of both general and international outsourcing on skilled and unskilled labor productivities, I will focus on the role of $\mathbf{O}_i$, the index of either general or international outsourcing. Furthermore, one of the econometric issues arising out of my primal approach is the extent to which the choice of intermediate inputs is endogenous. To address this, instead of using the production function (52), I will estimate the real value-added function (53) in that the intermediate inputs will not enter this function directly.

In a similar way to Egger and Egger (2006), I will consider the following CES specification:[36]

$$V_i = A_i \left\{ K_i^{*\rho} + H_i^{*\rho} + L_i^{*\rho} \right\}^{\frac{r}{\rho}}$$

$$= e^{\alpha + \gamma \mathrm{O}_i} \left\{ K_i^{\rho} + \left(e^{\beta_H \mathrm{O}_i} H_i \right)^{\rho} + \left(e^{\beta_L \mathrm{O}_i} L_i \right)^{\rho} \right\}^{\frac{r}{\rho}}. \quad (54)$$

Here, $A_i \equiv e^{\alpha + \gamma \mathrm{O}_i}$ represents the "technological level" for industry i,[37] with α and γ representing parameters of an independent technology shifter and a factor-neutral technology effect of outsourcing, respectively, and r refers to the degree of scale economies. Elasticities of substitution (σ) between labor and capital can be measured by $(1-\rho)^{-1}$.

Also, K_i^*, H_i^*, and L_i^* are optimally chosen capital, skilled labor, and unskilled labor by industry i in term of efficiency units, in order to maximize profits. Since my objective is to reveal the productivity impacts of outsourcing on workers, I assume that the productivity impacts of outsourcing work through two channels:

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[36] For the sake of computational simplicity, I implicitly assume that the contributions of each factor of production to value added are equally weighted. Though this assumption is rather strong, allowing for different weights for value-added contributions does not change my main results qualitatively.

[37] Since I center on the impacts of outsourcing on labor productivity, I need to assume that the effects of other factors on technology level, such as innovation and product development, is comprehensively taken into account by A_i.

neutral (γ) and labor-augmenting technological shifts. As such, the capital-augmenting effect, without loss of generality, is normalized to unity, and the efficiency unit of capital is thus equal to the amount of capital employed; that is, $K_i^* \equiv K_i$. Furthermore, since there are two groups of labor, skilled labor (H_i) and unskilled labor (L_i),[38] the efficiency units of labor are defined as $H_i^* \equiv a_H(\mathrm{O}_i)H_i$ and $L_i^* \equiv a_L(\mathrm{O}_i)L_i$, where $a_H\left(\mathrm{O}_i\right) = e^{\beta_H \mathrm{O}_i}$ and $a_L\left(\mathrm{O}_i\right) = e^{\beta_L \mathrm{O}_i}$ are measures of skilled- and unskilled-augmenting technical progress, respectively, and β_H and β_L are parameters for skilled- and unskilled-augmenting effects of outsourcing, respectively.

2.3.2 The Impacts of Outsourcing on Productivity

As discussed later, in the empirical analyses I aim to estimate the CES production function (54) based on six-digit NAICS US manufacturing industries. Once all parameters embedded in (54) have been estimated, I can infer some implications regarding the impacts of outsourcing on the productivity of skilled and unskilled workers. Unlike Egger and Egger (2006) and Amiti and Wei (2006), as I center on empirically investigating how the roles of outsourcing differently affect the productivities of unskilled and skilled labor, I shall derive the marginal value added of unskilled and skilled workers, denoted by MV_{Li} and MV_{Hi}, respectively, as the proxies of unskilled- and skilled-labor productivity.[39] By differentiating (54) with respect to L_i and H_i and using a natural logarithm, I have

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[38] In contrast with existing studies on the impact of international outsourcing, such as that of Feenstra and Hanson (1996), I assume that substitutions between skilled and unskilled workers, skilled workers and capital, and unskilled workers and capital, are equal. Nevertheless, I also tried the case where unskilled and skilled workers are perfect substitutes. I find that my results are qualitatively unchanged.

[39] To us, the *marginal* value added of workers may better reflect their productivity and thus be economically more appealing, compared with value added per worker, in that the impacts of outsourcing on skilled and unskilled labor are allowed to differently affect their productivities. Moreover, by looking at marginal impacts, I am able to capture some links between productivity and the relative demand for labor.

$$\ln MV_{Li} = \ln(rH_i^{\rho-1}) + \rho\beta_L \mathrm{O}_i + \frac{\rho}{r}\left(\alpha + \gamma \mathrm{O}_i\right) + \left(1 - \frac{\rho}{r}\right)\ln V_i \tag{55}$$

$$\ln MV_{Hi} = \ln(rH_i^{\rho-1}) + \rho\beta_H \mathrm{O}_i + \frac{\rho}{r}\left(\alpha + \gamma \mathrm{O}_i\right) + \left(1 - \frac{\rho}{r}\right)\ln V_i, \tag{56}$$

where $MV_{Li} = \partial V_i / \partial L_i$ and $MV_{Hi} = \partial V_i / \partial H_i$.

To capture the impact of outsourcing on unskilled and skilled labor productivity proxied by their marginal value added, it is straightforward to derive the elasticities of unskilled- and skilled-labor productivity with respect to outsourcing indexes from (55) and (56). Therefore, I will report the productivity impacts of outsourcing by elasticities of the marginal productivity of both skilled and unskilled workers with respect to outsourcing:

$$\eta_{L\mathrm{O}} = \beta_L \rho \mathrm{O}_i + \frac{\gamma\rho}{r}\mathrm{O}_i + \left(1 - \frac{\rho}{r}\right)\eta_{V\mathrm{O}} \tag{57}$$

$$\eta_{H\mathrm{O}} = \beta_H \rho \mathrm{O}_i + \frac{\gamma\rho}{r}\mathrm{O}_i + \left(1 - \frac{\rho}{r}\right)\eta_{V\mathrm{O}}, \tag{58}$$

where $\eta_{V\mathrm{O}} = \partial \ln V / \partial \ln \mathrm{O}_i$.

My primal approach to productivity analysis, in contrast with the existing literature which assumes a log-linearized Cobb-Douglas production function, [40] enables us to segregate the productivity effects of outsourcing in more details. As shown in (57)-(58), one can separate the total productivity impact of outsourcing into three parts: *factor-productivity* effect, *technology* effect, and *value-added* effect.

First, the factor-productivity effect of outsourcing is represented by the first term in (57) and (58), and shows the partial effect of outsourcing on productivity vis-à-vis technology improvement augmented to that factor of production; that is, β_L in

[40] See Olsen (2006) for a survey of literature using a Cobb-Douglas production function for the empirical analysis of the relationship between outsourcing and productivity.

the unskilled equation and β_H in the skilled equation. One may observe that productivity impacts of outsourcing across skilled groups are different solely according to the factor-productivity effect. Second, the technology effect of outsourcing is represented by the second terms in (57) and (58), and captures that part of the effect of outsourcing which affects labor productivity through neutral technological progress. As one can see from the equations, if there is no impact from outsourcing (that is, even if $\beta_H = 0$ and $\beta_L = 0$), the factors employed still play a role in determining the marginal productivity of labor. Lastly, the value-added effect is captured by the final terms of (57) and (58), and is meant to account for the impacts of outsourcing on overall value added. Given that outsourcing has an effect on productivity, the improvement of factor productivities, either by neutral or non-neutral effects, or both, will give rise to changes in the employment of factor of productions and therefore the overall value added.

2.3.3 The Linkages among Outsourcing, Productivity, and Wage Inequality

This section examines the impacts of international outsourcing on the relative marginal productivity of skilled and unskilled workers.[41] By using the profit maximization condition, the wage inequality represented by the ratio of skilled to unskilled wages must be equal to the ratio of skilled to unskilled marginal value added. Intuitively, in a competitive economy where firms reward factors of production to an extent equal with the value of their marginal product, an increase in the marginal productivity of skilled workers relative to that of unskilled workers must entail an

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[41] A number of studies have examined the roles of international outsourcing on explaining the evidence of rising relative skilled wage during 1980s in most OECD and newly industrialized economies, such as Feenstra and Hanson (1996, 1999) (US), Feenstra and Hanson (1997) (Mexico) Anderton and Brenton (1999) (UK), Geishecker (2002) (Germany), Hsieh and Woo (2005) (Hong Kong), and so forth.

increase in the wages of skilled labor relative to those of unskilled labor. That is, based on (55) and (56), it is straightforward to show that

$$\frac{w_H}{w_L} = \frac{\partial V_i / \partial H_i}{\partial V_i / \partial L_i} = e^{\rho(\beta_H - \beta_L)\mathrm{O}_i}(H_i / L_i)^{\rho - 1}. \quad (59)$$

From (59), it is straightforward to figure out the elasticities of relative skilled wages with respect to outsourcing indexes:

$$\eta_{w\mathrm{O}} = \frac{d\ln(w_H / w_L)}{d\ln \mathrm{O}_i} = \rho(\beta_H - \beta_L)\mathrm{O}_i. \quad (60)$$

Since it is well established that outsourcing more or less accounts for the widening of the wage inequality gap, I expect that the estimated parameters will satisfy $\beta_H > \beta_L$.[42] Intuitively, (60) implies that outsourcing can account for wage inequality only if its impacts on labor is skill-biased ($\beta_H > \beta_L$).

This ends my theoretical discussions regarding the linkages among outsourcing, factor-augmenting technological progress, labor productivity, and wage inequality. Based on the theoretical analysis I have developed thus far, the empirical estimation of the impacts of outsourcing on labor productivity linking to the literature on mainstream wage inequality will be thoroughly discussed in the next section.

2.4 Data and Empirical Methodology

2.4.1 Data

I use three main datasets from the US Census Bureau *Annual Survey of Manufactures* (ASM) for the period 2002-2005 and the *US International Trade Statistics* and *Bureau of Economic Analysis* (BEA).

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[42] Elaborated in Section 2.2, these empirical findings are confirmed by a number of studies in various economies. Nevertheless, the results make use of the dual approach in the sense that a relative increase in the relative demand for skilled workers is derived from either cost or profit functions. In contrast to these studies, my methodology is to directly estimate production functions to see whether the same results are confirmed.

The disaggregated production, detailed intermediate inputs, capital stocks, and employment data are retrieved from the ASM for the period 2002-2005. This provides 322 six-digit NAICS manufacturing industries categorized according to three-digit NAICS manufacturing industries. Based on a three-digit classification, the US manufacturing sectors can be divided into 21 sub-sectors. The manufacturing sector (sectors 31-33) comprises establishments engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products.

Table 2.1: Summary of Statistics.

Variables	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Value added	1268	6285659	9561474	132908	1.05E+08
K	1268	479131.8	1107001	4364	1.66E+07
H	1268	12753.45	17864.56	299	188148
L	1268	30339.41	43168.11	514	471589
*Gen*O	1268	0.734529	0.113525	0.289509	0.983395
*Inter*O	1268	0.087344	0.095714	0.004174	0.403511

Note: 1) Value added and capitals are in terms of $1,000. Non-production and production workers are in terms of the average number of persons engaged in non-production and production activities, respectively. 2) Mean values are calculated across cross-section and time horizons.

Table 2.2: Correlation matrix of variables.

	Value added	*K*	*H*	*L*	*Gen*O	*Inter*O
Value added	1.0000					
K	0.4151	1.0000				
H	0.7129	0.2876	1.0000			
L	0.5982	0.2756	0.7892	1.0000		
*Gen*O	0.1220	0.0646	-0.1529	-0.0670	1.0000	
*Inter*O	0.1114	0.1166	0.0488	-0.1660	0.1444	1.0000

Note: 1) Value added and capitals are in terms of $1,000. Non-production and production workers are in terms of the average number of persons engaged in non-production and production activities, respectively. 2) Mean values are calculated across cross-section and time horizons.

Combined from these data sources, the relevant variables employed in my empirical estimations are value added (V_{it}), capital stock (K_{it}), production workers (L_{it}), non-production workers (H_{it}), general outsourcing index ($GenO_{it}$), and international outsourcing index ($InterO_{it}$) at six-digit NAICS manufacturing industries. Value added is proxied by the value of sales, shipments, receipts, revenue, or business done, less the cost of materials and service purchases. Capital stock is proxied by buildings, land, and machinery. Production workers are the average number of persons engaged in production activities while non-production workers are those employed in non-production activities. As conventionally utilized, the skilled and unskilled workers are proxied by non-production and production workers.

The index of general outsourcing intensity ($GenO_{it}$) is the ratio of "cost of intermediate inputs received" by an establishment to total non-energy production costs, which is directly calculated from the ASM dataset at the six-digit NAICS manufacturing-industry level. The index of international outsourcing ($InterO_{it}$), following the broad definition of Feenstra and Hanson (1996), is defined as the share of intermediate inputs imported:

$$InterO_{it} = \sum_{j} \frac{D_{ijt} M_{jt}}{Q_{jt}},$$

with D_{ijt} referring to the ratio of intermediate input *j* purchased by industry *i* to total non-energy production costs employed by industry *i*, calculated using the annual input-output tables from 2002-2005 based on the BEA 1992 benchmark tables in which NAICS industries are disaggregated at the three-digit level. The term (M_{jt} / Q_{jt}) is the ratio of imported intermediate input *j* (M_j) to total production *j* (Q_j) calculated by using the international trade data at the three-digit NAICS industry level from the *US International Trade Statistics*, US Census Bureau. A summary of statistics and their correlation matrixes are presented in Tables 1 and 2, respectively.

Since the ASM is available only for four years (2002-2005), ones may cast doubt on if the variation in the outsourcing indices is sufficient over the years.

However, the cross-industry variation of the outsourcing indexes measured at the six-digit NAICS disaggregation level may be sufficient to offset the little variation across the time horizon. I acknowledge that the extension of my dataset will shed light on improvement of the empirical results and leave it for future research.

2.4.2 Econometric Methodology: A Primal Approach

Short-run estimation

Using annual data from 2002 to 2005, I first employ the fixed effect non-linear least squares to estimate the CES specification in (54) in order to account for the industry-specific and time-specific effects. Hence, the econometric model under the CES specification as in (54) can be modified by introducing an industry dummy (ϕ_i) and a time dummy (λ_t). By taking a natural logarithm and adding the stochastic error term, ε_{it} it can be specified as follows:[43]

$$\ln V_{it} = \alpha + \gamma \mathrm{O}_{it} + \frac{r}{\rho} \ln\left(K_{it}^{\rho} + \left(e^{\beta_H \mathrm{O}_{it}} H_{it} \right)^{\rho} + \left(e^{\beta_L \mathrm{O}_{it}} L_{it} \right)^{\rho} \right) + \phi_i + \lambda_t + \varepsilon_{it} . \quad (61)$$

As noted in Amiti and Wei (2006), Egger and Egger (2006), and Girma and Görg (2004), there might be an econometric problem of potential endogeneity of outsourcing. That is, the estimated parameters may be biased. To tackle this problem, I shall employ a two-step non-linear least squares estimation (see Greene, 2003, pp. 183-186)[44] as follows:

$$\ln V_{it} = \alpha + \gamma \hat{\mathrm{O}}_{it} + \frac{r}{\rho} \ln\left(K_{it}^{\rho} + \left(e^{\beta_H \hat{\mathrm{O}}_{it}} H_{it} \right)^{\rho} + \left(e^{\beta_L \hat{\mathrm{O}}_{it}} L_{it} \right)^{\rho} \right) + \phi_i + \lambda_t + \varepsilon_{it} . \quad (62)$$

The variables of outsourcing intensity are instrumented by 1) the average unit production (w_L) and non-production labor (w_H) cost, 2) the ratio of high-tech capital

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[43] The stochastic error term, ε_{it} can be interpreted as neutral technological shocks.

[44] The two-step non-linear least squares estimator, as first shown by Murphy and Topel (1985), has an important and desirable asymptotic property. That is, under the standard conditions assumed for the non-linear least squares estimators, the second-step estimators are consistent and asymptotically normally distributed with an asymptotic covariance matrix.

to total capital (T), and 3) the ratio of energy consumption to total production cost ($ENERGY$). All these variables are from the ASM for the period 2002-2005. Intuitively, the first instrument is employed in that, as discussed in Girma and Görg (2004), outsourcing is a substitute for in-house production and will therefore lead to a decline in the total wage bill. Hence, in some sense the outsourcing intensities might be correlated with wages as an opportunity cost that might have been incurred for in-house employees if the production activities had not been contracted out. The second and third instruments are introduced to capture the idea that the outsourcing decisions may be associated with the industry-specific high-tech capital intensity (T) and the rate of energy consumption. The first-stage regression shows that all instrumental variables are strongly correlated with the general or international outsourcing.[45]

$$\underset{}{GenO_{it}} = \underset{(.0844)}{.3497^*} + \underset{(.0226)}{.0608^*\, w_{L\,it}} + \underset{(.0322)}{.0032 w_{H\,it}} - \underset{(.0046)}{.0468^*\, T_{it}} + \underset{(.0042)}{.0118^*\, ENERGY_{it}}$$

$$R^2 = .1754 \quad F = 79.04^*$$

$$InterO_{it} = \underset{(.0060)}{-.0618^*} + \underset{(.0017)}{.0045^*\, w_{L\,it}} + \underset{(.0021)}{.0141^*\, w_{H\,it}} - \underset{(.0004)}{.0002 T_{it}} - \underset{(.0004)}{.0014^*\, ENERGY_{it}}$$

$$R^2 = .1567 \quad F = 49.70^*$$

Furthermore, it is well known that a potential instrumental variable is not only strongly correlated with the endogenous variable, but also exogenous. A number of reasons may justify the exogeneity of the aforementioned instrumental variables. First, since there are a large number of firms in an industry in my dataset, a firm is unlikely to be a monopsony in the labor market. Hence, it is justifiable that the unit labor costs are exogenous to the firms. Moreover, since our time horizon in the dataset is relatively short, high-tech capital and energy consumption intensities, which reflect the nature of industry production and the industry-specific technological level, are

[45] Robust standard errors are in parentheses. The asterisks * represent statistical significance at 1 percent.

unlikely to be fluctuated over time and therefore could be treated as exogenously given.

I estimate the two regressions using $GenO_{it}$ and $InterO_{it}$, called Model 1 and Model 2, respectively.

Long-Run Estimation

For the long-run regression, I use mean values across the time dimension. These cross-sectional estimates can be interpreted as "long-run" effects. These interpretations are based on well-established studies on the estimation of short-run and long-run effects in a static panel model.[46] Accordingly, I will drop the time subscript, *t*, in (61), and the parameters are estimated at mean values of all the variables as follows:

$$\ln V_i = \alpha + \gamma \mathrm{O}_i + \frac{r}{\rho}\ln\left(K_i^{\rho} + \left(e^{\beta_H \mathrm{O}_i} H_i\right)^{\rho} + \left(e^{\beta_{Li} \mathrm{O}_i} L_i\right)^{\rho}\right) + \varepsilon_i \qquad (63)$$

$$\ln V_i = \alpha + \gamma \hat{\mathrm{O}}_i + \frac{r}{\rho}\ln\left(K_i^{\rho} + \left(e^{\beta_H \hat{\mathrm{O}}_i} H_i\right)^{\rho} + \left(e^{\beta_L \hat{\mathrm{O}}_i} L_i\right)^{\rho}\right) + \varepsilon_i\,. \qquad (64)$$

As before, I estimate the two regressions using $GenO_i$ and $InterO_i$, called Model 3 and Model 4, respectively. Furthermore, the outsourcing variables in two-step IV estimations are instrumented by the average unit production and non-production labor cost, the ratio of high-tech capital to total capital, and capacity utilization, as in the short-run estimations.

It could also be argued that, due to the different sizes of the industries, the stochastic error term ε_i is likely to be heteroskedastic, thereby conveying a biased estimator of σ^2 under the standard non-linear least square. To tackle this problem, Models 1-4 will be estimated by utilizing heteroskedasticity-robust standard errors.

[46] See Baltagi (2001) and Pirotte (1999).

2.5 Empirical Results and Analyses

My estimation strategy comprises two parts. First, I perform the short-run and long-run analyses based on the CES production function, and then the corresponding elasticities of the marginal value added of skilled and unskilled workers will be calculated and analyzed. I then try to link the productivity impacts of outsourcing on wage inequality by using equation (60). Without restrictions on parameters across equations, the non-linear regressions for all specifications in both the short run and the long run are performed by using zero as the starting value of parameter estimates except for $r=1$ and $\rho=0.5$.[47]

Table 2.3: Parameter Estimates of short-run models.

Dependent Variable: ln(Value added)				
	Model 1 (*Gen*O **)**		**Model 2 (** *Inter*O **)**	
Parameters	**Fixed Effect**	**IV**	**Fixed Effect**	**IV**
α	-5.9475(2.135)***	-18.3872(9.12)**	-4.9164(3.59)	-5.1697(6.365)
γ	-23.4518(4.704)***	-42.0244 (20.20)**	-37.0467(6.75)***	-85.7194(41.24)*
r	.9777(.012)***	1.0117(.013)***	.9673(.013)***	.9521(.015)***
ρ	0.0858(.016)***	0.0435(.020)**	0.1069(.039)***	0.0993(.062)
β_H	34.5244(5.853)***	61.7217(25.83)**	55.7848(9.372)***	139.9588(61.27)**
β_L	16.5745(4.816)***	25.9667(13.33)*	45.4241(11.745)***	96.9162(46.86)**
No. Obs.	1,268	1,268	1,268	1,268
Adjusted R-squared	0.8529	0.8549	0.8166	0.8059
LR Test 1(p-value)	95.72(.000)***	74.27(.000)***	6.36(.011)**	14.74(.000)***
LR Test 2(p-value)	3.52(.061)*	0.95(.3292)	6.07(.014)**	11.56(.001)***
LR Test 3(p-value)	332.61(.000)***	385.57(.000)***	129.95(.000)***	121.30(.000)***

Note: 1) Robust standard errors are in parentheses. 2) * Statistically significant at a 10 percent level. 3) ** Statistically significant at a 5 percent level. 3) *** Statistically significant at a 1 percent level. 4) Likelihood Ratio Test 1 is based on the null hypothesis that $\beta_H = \beta_L$. 5) Likelihood Ratio Test 2 is based on the null hypothesis that the technology is characterized by CRTS. 6) Likelihood Ratio Test 3 is based on the null hypothesis that the elasticities of substitution are unity. 7) The LR statistic is distributed as a chi-squared distribution with 1 degree of freedom.

2.5.1 The Impacts of Outsourcing on Labor Productivity

[47] With these starting values, the exceptional convergence property is obtained. Still, the results are robust to a variation of starting values.

Table 2.3 presents the short-run results of the CES specification based on Model 1 and Model 2, in which the indexes of outsourcing refer to general outsourcing ($Gen\text{O}$) and international outsourcing ($Inter\text{O}$), respectively.

First, the parameter of technology level (α) exhibits negative values, and the neutral technological shift (γ) is also negative and statistically significant at a 10 percent level of significance when both the general and international outsourcing indexes are employed. In particular, the negative effect of the neutral technological shift may be explained by the presence of the incomplete contract. When the firms contract out their production activities at arm's length, the cost of customizing inputs are likely to increase, thereby undermining the overall firms' productivities. The roles of the incomplete contract in characterizing the outsourcing equilibrium have been examined by a number of recent literatures, e.g. Grossman and Helpman (2005) among others.

Secondly, the elasticities of substitution ($\sigma = (1-\rho)^{-1}$) are equal to 1.046 in the case of general outsourcing, compared with 1.11 in the case of international outsourcing.[48] The elasticities of substitution between capital and labor seem larger when the index of international outsourcing is applied.[49] In light of this, I also perform the Likelihood Ratio Test (LR Test 3) under the null hypothesis that the CES specification is characterized by unit elasticities of substitution.[50] My results for the LR Test 3 show that the null hypothesis can be rejected at a 1 percent level of significance across all specifications. Since my result rejects the null hypothesis and

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[48] The elasticities of substitution are calculated from the results of two-step IV estimations in Models 1 and 2. If the results from fixed effect estimations are employed, they will be equal to 1.094 and 1.12 for general and international outsourcing, respectively.

[49] The well-behaved production function requires that the parameter ρ is less than unity.

[50] Since it can be shown that the elasticities of substitution under the Cobb-Douglas value-added function must be equal to unity, in so doing the abovementioned null hypothesis is equivalent to specifying a negligible value of ρ (=0.0001).

therefore is in favor of the more generalized CES specification, it inevitably casts doubts on the appropriateness of the Cobb-Douglas functional forms, which confine elasticities of substitution only to unity and are typically assumed when the relationship between outsourcing and labor productivity is of researchers' interest.

Thirdly, technology is characterized by constant returns to scale (r = 1.011672 for two-step IV estimations) when general outsourcing is utilized, and its endogeneity is taken into account.[51] Moreover, when international outsourcing is applied, technology for which the returns to scale (RTS) are decreasing also holds (r = .9629 and .9673 for pooled and fixed estimations, respectively). The latter result, based on the international outsourcing index, is consistent with Egger and Egger (2006). Intuitively, the extent to which the technology of firms exhibits decreasing RTS in the short run may be explained by the presence of adjustment costs of capital and labor market frictions, such as labor hoarding, labor unions, and so forth. Due to imperfections of this kind, firms may be unable, in the short run, to fully adjust factors of production, that is, capital and labor, to meet production demands, and therefore they will choose to over-utilize these factors. In light of this, LR Test 2 is calculated based on the null hypothesis that technology is characterized by constant returns to scale (CRTS). Apparently, under two-step IV estimation, when the general outsourcing index is utilized, the aforementioned hypothesis cannot be rejected, whereas when using the international outsourcing index, it was rejected with a 1 percent level of significance across all estimations.

Last and most importantly, both measures of outsourcing consistently confirm that outsourcing has a significant and positive impact on the non-neutral

[51] Nevertheless, for the fixed effect estimation, the results are in favor of decreasing RTS, and the hypothesis that technology is characterized by CRTS (LR Test 2) is rejected with a 10 percent level of significance.

technological effects of both skilled (β_H) and unskilled (β_L) workers, and is skill-biased ($\beta_H > \beta_L$). LR Test 1 is based on the null hypothesis that outsourcing affects skilled- and unskilled-augmenting technological improvement identically ($H_o : \beta_H = \beta_L$). I find that it is statistically rejected at a 1 percent level of significance for general outsourcing and at a 5 percent level of significance for international outsourcing. The intuition for positive unskilled- and skilled-augmenting effects of general and international outsourcing may suggest that, in fact, labor-augmenting outsourcing does prevail regardless of its locations. This may shed light on the fact that, contrary to most studies, which regard the notion of outsourcing as imported intermediate inputs, the general outsourcing – that is, the domestic outsourcing – index might also be important to explain the wage inequality.[52]

Intuitively, the labor-augmenting effects might be explained by the gains from specialization in core-competent activities (see Grossman and Helpman, 2002). These gains emanate from the fact that when a firm contracts out some less competent activities at arm's length to more specialized intermediate-inputs partners, it can relocate labor resources to some particular core-competent production activities, thereby improving the productivity of workers. Furthermore, the skill-biased productivity effects of general and international outsourcing may imply that US manufacturers are likely to outsource unskilled-intensive activities and perform skilled-intensive ones in-house. Therefore, the gains from specialization in the remaining skilled-intensive ones are more pronounced for skilled workers. The bias of outsourcing, in contrast, is a particularly useful result to explain the well-

[52] The notion of outsourcing referring to imported intermediate inputs is first explored by Feenstra and Hanson (1996). In contrast, the aggregated definition including both domestic and international outsourcing is according to Abraham and Taylor (1996).

established fact that the notion of outsourcing can more or less explain the phenomenon of skilled wage inequality in most industrialized economies.

Table 2.4: Parameter Estimates of long-run models.

Dependent Variable: ln(Value added)				
	Model 3 (*Gen*O **)**		**Model 4 (** *Inter*O **)**	
Parameters	**Non-linear LS**	**IV**	**Non-linear LS**	**IV**
α	-7.5324(4.103)*	-41.5121(22.495)*	-4.8222(6.425)	-4.8516(13.38)
γ	-24.5503(8.315)***	-78.5870(44.605)*	-36.357(12.11)***	-66.1725(57.697)
r	.9817(.023)***	1.0031(.025)***	.9716(.025)***	.9675(.028)***
ρ	0.0756(.024)***	0.0207(.010)**	0.1068(.069)	0.1025(.135)
β_H	36.6341(10.34)***	113.6803(56.188)**	56.145(17.017)***	108.3935(91.86)
β_L	16.4138(8.628)*	47.1627(38.343)	42.9939(22.870)*	69.5043(64.281)
No. Obs.	322	322	322	322
Adjusted R-squared	0.8584	0.8584	0.8173	0.8005
LR Test 1(p-value)	32.43(.000)***	19.68(.000)***	2.34(.126)	3.87(.049)**
LR Test 2(p-value)	0.63(.426)	.02(.8951)	1.19(.276)	1.29(.255)
LR Test 3(p-value)	83.01(.000)***	92.04(.000)***	30.26(.000)***	23.76(.000)***

Note: 1) Robust standard errors are in parentheses. 2) * Statistically significant at a 10 percent level. 3) ** Statistically significant at a 5 percent level. 3) *** Statistically significant at a 1 percent level. 4) The LR Test 1 is based on the null hypothesis that $\beta_H = \beta_L$. 5) The LR Test 2 is based on the null hypothesis that the technology is characterized by CRTS. 6) Likelihood Ratio Test 3 is based on the null hypothesis that the elasticities of substitution are unity. 7) The LR statistic is distributed as a chi-squared distribution with 1 degree of freedom. 8) Instrumental variable regression assuming the indexes of outsourcing to be endogenous and using the following instruments: average units production and non-production labor costs, the ratio of high-tech capital to total capital, and capacity utilization proxied by the ratio of energy consumption to total production cost. All instruments are statistically significant at a 5 percent level of significance.

In Table 2.4, the cross-sectional estimators estimate the long-run effect in static panel models.

Model 3 and Model 4 are based on the indexes of general outsourcing and international outsourcing, respectively, and are estimated by employing the standard non-linear least squares and the two-step non-linear IV estimations to account for the potential endogeneity problem of outsourcing indexes. As mentioned in the previous section, the outsourcing proxies are instrumented by the following instrumental variables: average unit costs of production and non-production labor, the ratio of high-tech capital to total capital, and capacity utilization.[53] From a comparison of short-run parameter estimates of Model 1 and Model 2 (Table 3), I find the following main comparisons.

First, the long-run estimations for economies of scale show CRTS; that is, the values of *r* are closer to unity. Furthermore, the LR Test 2, the null hypothesis of which is $H_o : r = 1$, is accepted in all specifications.[54] This might be explained by the fact that, although firms may deviate from constant-scale economies in the short run, the short-run deviations can be adjusted to CRTS, as those imperfections in markets for factors of production are dissipated in the long run. Differently put, this result may imply that firms, at least in the long run, can fully adjust factors of production to meet constant-scale economies despite the adjustment cost of capital and labor market frictions in the short run. Another possibility is that in the long run, firms are able to outsource the capital-intensive production activities to foreign economies, thereby adjusting the scale economies via foreign direct investment.

The above results of decreasing RTS in the short run together with the characterization of CRTS in the long run, when employing the international outsourcing index, may imply that the assumption of CRTS technology conventionally imposed on the short-run cost function in order to estimate the impacts of international outsourcing on the relative demand for skilled workers is not suitable. The dual approach, in which the short-run cost function is empirically estimated based on the assumption that the underlying technology is characterized by CRTS, is widely employed in a number of studies, such as Anderton and Brenton (1999) and Geishecker (2002), among others. Provided that the short-run production function is

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[53] In the first step regression, all the abovementioned instruments are statistically significant at a 5 percent level of significance.

[54] LR statistics (LR Test 2), which are distributed as a chi-squared distribution with 1 degree of freedom, are statistically insignificant across all specifications.

in fact separated from CRTS, such an assumption will bring about biased parameter estimates.

Second, the parameter estimates, though identical to the short-run results, seem statistically less significant in the long run than in the short run, especially when two-step IV estimations are carried out.[55] Relative to those of NLS, the neutral and non-neutral productivity shifts under two-step IV estimations are magnified. Despite this, my results regarding the impacts of outsourcing on labor productivity and wage inequality are qualitatively unchanged.

Third, the elasticities of substitution (σ) are in the long run equal to 1.021 and 1.114 for two-step IV estimations in Models 3 and 4, respectively.[56] My results suggest that the assumption of Cobb-Douglas technology, invoked in various studies on the productivity impacts of outsourcing, may not be appealing either for short-run or for long-run analyses. To be more concrete, the null hypothesis that the Cobb-Douglas functional form is nested in a CES specification under LR Test 3, as in the short-run results, is rejected at a 1 percent level of significance across all specifications. Given that the true value-added function takes a CES functional form, the conventional approach to the productivity impacts of outsourcing that simply assumes the Cobb-Douglas function may yield inconsistent parameter estimates.[57]

Lastly, the positive labor-augmenting effects and skill-biased effects of general and international outsourcing are strikingly robust across all long-run estimations. Specifically, the parameters β_H and β_L are positive and statistically

[55] Parameter estimates under non-linear least squares (NLS) are statistically significant at at a 10 percent level of significance. Under two-step IV estimation, though parameter estimates in Model 3 of general outsourcing are statistically significant at a 5 percent level of significance, except for β_L, they seem statistically insignificant in Model 4 of international outsourcing.

[56] I choose to report results corresponding to two-step IV estimation as it takes into account potential endogeneity problem and therefore may convey more consistent parameter estimates. Nonetheless, the main implications do not change when the results of NLS are calculated.

[57] Log-linearized specification of empirical models derived from the Cobb-Douglas technology is widely used by a number of studies (see Amiti and Wei, 2006, for instance).

significant at a 10 percent level of significance for most specifications, and $\beta_H > \beta_L$ is consistently observed and statistically confirmed by the significance of LR Test 1.[58] My short-run and long-run results, therefore, infer that labor-augmenting gains from specialization when firms contract out some unproductive activities at arm's length, and skill-biased effects of outsourcing do prevail in both the short run and the long run. Given a perfectly competitive labor market, the latter results suggest that general and international outsourcing can explain the widened wage inequality in both the short run and the long run.[59]

Table 2.5: The elasticities of the productivity impacts of general outsourcing.

Industry	**Short Run**		**Long Run**	
	η_{LO}	η_{HO}	η_{LO}	η_{HO}
Food Manufacturing	5.6391	6.9479	7.1496	8.3079
Beverage and Tobacco Product Manufacturing	5.8364	7.1517	7.3931	8.5572
Textile Mills	3.7737	4.9495	4.1892	5.2298
Textile Product Mills	4.1276	5.3163	4.6362	5.6883
Clothing Manufacturing	2.6869	3.7517	2.3036	3.2461
Leather and Allied Product Manufacturing	3.3930	4.5204	3.4401	4.4378
Wood Product Manufacturing	3.8363	5.0126	4.2518	5.2929
Paper Manufacturing	4.5279	5.7632	5.4107	6.5039
Printing and Related Support Activities	-0.3385	0.4261	-2.1551	-1.4785
Petroleum and Coal Products Manufacturing	6.9101	8.3198	9.3536	10.6012
Chemical Manufacturing	5.1817	6.4522	6.3471	7.4716
Plastics and Rubber Products Manufacturing	3.8481	5.0262	4.2751	5.3178
Nonmetallic Mineral Product Manufacturing	1.9921	3.0217	1.3949	2.3061
Primary Metal Manufacturing	4.6067	5.8453	5.5181	6.6144
Fabricated Metal Product Manufacturing	2.2066	3.2403	1.6257	2.5406
Machinery Manufacturing	2.7329	3.8038	2.3805	3.3282
Computer and Electronic Product	2.4788	3.5327	2.0134	2.9461
Electrical Equipment and Components	3.5072	4.6730	3.8436	4.8754
Transportation Equipment Manufacturing	3.9847	5.1749	4.5029	5.5563
Furniture and Related Product Manufacturing	2.3326	3.3833	1.8631	2.7930
Miscellaneous Manufacturing	1.7733	2.7598	0.9051	1.7782
All Industries	3.4338	4.5765	3.5906	4.6020

Note: All elasticities are evaluated at mean values.

[58] As shown in Table 2.4, LR Test 1 rejects the null hypothesis $\beta_H = \beta_L$ with a 5 percent level of significance except for the NLS result in Model 4.

[59] Therefore, my results are consistent with the well-established results that an increasing relative wage of skilled workers within industries can be explained by the notion of outsourcing. The long-run interpretations have been explored by Feenstra and Hanson (1996, 1999) and Hsieh and Woo (2005), and the short-run results are confirmed by Anderton and Brenton (1999), Geishecker (2002), and Amiti and Wei (2006).

Table 2.5 and Table 2.6 (shown later) are central to my analyses of the labor productivity impacts of outsourcing. By using (57) and (58) and the estimated values of parameters manifested earlier, Table 2.5 and Table 2.6 show the elasticities of marginal value added of unskilled and skilled labor with respect to general outsourcing and international outsourcing, respectively. Note that all elasticities are evaluated at mean values of the variables.[60]

Note also that I use two-step IV estimates in Models 1-4 to calculate the relevant elasticities elaborated in the previous section. The reason why I utilize two-step IV results in Models 1-2 is that not only does it take into account the potential endogeneity problem, thereby conveying more consistent parameter estimates, but it also accounts for industry- and time-specific effects as does fixed-effect ones. In addition, estimates from two-step IV estimation under Model 3 are employed despite their statistical insignificance in that it accounts for the endogeneity problem embedded in outsourcing indexes. Nevertheless, my essential analyses are invariant of the econometric techniques chosen.

According to Table 2.5, calculated from the IV results in Models 1 and 3, I observe that, both in the short run and in the long run, general outsourcing brings about unskilled and skilled productivity improvements, and is skill-biased in the sense that productivity gains from general outsourcing are more pronounced for skilled workers. Specifically, a 1 percent increase in the general outsourcing index entails 3.43 and 4.57 percent increases in the marginal value added of unskilled and skilled workers, respectively, in the short run. In the long run, positive productivity gains of this nature are slightly intensified to 3.59 and 4.6 percent increases in the marginal value added of unskilled and skilled workers, respectively.

[60] The natural interpretation of the elasticities of marginal value added of unskilled and skilled workers with respect to outsourcing indexes evaluated at mean variable values is the marginal effects of outsourcing on a representative firm.

It will be recalled that in (57) and (58), I mention three productivity effects of outsourcing: factor-productivity effect, technology effect, and value-added effect. The estimation results tell us that the total productivity gain of general outsourcing emanates mainly from the fact that positive factor productivity ($\beta_H, \beta_L > 0$) and value-added effects ($\eta_{VO} > 0$) dominate the negative technology effect ($\gamma < 0$). I also observe a skill-biased effect of general outsourcing. This result is solely due to $\beta_H > \beta_L$ in my estimation. Note that, in comparison with (57), the elasticity in (58) differs only by the size of β_H in the direct term. So, the skill-biased effect of general outsourcing ($\eta_{HO} > \eta_{LO}$) stems solely from the skill-biased factor-augmenting effect of general outsourcing ($\beta_H > \beta_L$).

My results show that general outsourcing is the most beneficial for labor productivity in food, beverage, petroleum, coal, and chemical manufacturing, whereas the reverse effect is observed in printing and related support activities. These results are somewhat consistent with Girma and Görg (2004) in the sense that, without separating skilled and unskilled productivity effects, the impacts of general outsourcing are rather mixed. They find that it has positive impacts on the chemical and engineering sectors, but not on the electronics sector. I show that, by segregating the impacts on skilled and unskilled labor, positive effects are mostly observed and depend crucially on the productivity trade-off in terms of factor productivity and value-added gains at the expense of technology loss.

Table 2.6 reveals the short-run and long-run elasticities of the marginal value added of unskilled and skilled labor with respect to international outsourcing calculated from the IV results in Models 2 and 4, respectively. Interestingly, the impacts of international outsourcing on the marginal value added of unskilled and skilled workers are dynamically different from those of general outsourcing. Even though international outsourcing in general brings about labor productivity gains in both the short run and the long run, this positive impact seems to die out over time. Specifically, in the short run, a 1 percent increase in international outsourcing brings about 0.633 and 1.006 percent improvements in unskilled- and skilled-labor productivity, respectively, whereas in the long run, 0.117 and 0.465 percent productivity gains can be expected from them.

Table 2.6: The elasticities of the productivity impacts of international outsourcing.

Industry	**Short Run**		**Long Run**	
	η_{LO}	η_{HO}	η_{LO}	η_{HO}
Food Manufacturing	-0.2178	-0.0964	-0.2392	-0.1259
Beverage and Tobacco Product Manufacturing	-0.2511	-0.1287	-0.2653	-0.1511
Textile Mills	-0.1856	-0.1060	-0.1825	-0.1082
Textile Product Mills	-0.1553	-0.0748	-0.1583	-0.0832
Clothing Manufacturing	-0.0942	0.0533	-0.1628	-0.0252
Leather and Allied Product Manufacturing	-0.1033	0.0529	-0.1789	-0.0332
Wood Product Manufacturing	-0.0740	-0.0509	-0.0651	-0.0436
Paper Manufacturing	-0.1652	-0.1136	-0.1494	-0.1012
Printing and Related Support Activities	-0.1675	-0.0982	-0.1606	-0.0960
Petroleum and Coal Products Manufacturing	-0.2756	-0.2004	-0.2500	-0.1797
Chemical Manufacturing	11.0613	12.4408	7.9380	9.2247
Plastics and Rubber Products Manufacturing	-0.1562	0.0269	-0.2520	-0.0812
Nonmetallic Mineral Product Manufacturing	-0.0349	0.2077	-0.2300	-0.0037
Primary Metal Manufacturing	-0.2273	-0.1220	-0.2338	-0.1356
Fabricated Metal Product Manufacturing	-0.0378	0.1746	-0.1896	0.0085
Machinery Manufacturing	0.4707	0.7973	0.0665	0.3711
Computer and Electronic Product	6.939	7.9481	4.5819	5.5236
Electrical Equipment and Components	2.0223	2.5973	0.8921	1.4284
Transportation Equipment Manufacturing	-0.1203	0.0963	-0.2641	-0.0621
Furniture and Related Product Manufacturing	-0.0762	-0.0525	-0.0670	-0.0448
Miscellaneous Manufacturing	-0.1494	0.0070	-0.2154	-0.0695
All Industries	0.6328	1.0060	0.1165	0.4646

Note: All elasticities are evaluated at mean values.

First, let us examine the short-run case. I observe a smaller productivity elasticity of both low- and high-skilled workers with respect to international outsourcing relative to that of general outsourcing. By comparing parameter estimates from Model 1 of general outsourcing, the neutral and non-neutral technological shifts of international outsourcing under Model 2 seem magnified. With unchanged signs of parameters, the fact that factor productivity and value-added effects are positive while the technology effect is negative still holds. Therefore, by evaluating at mean values, the positive productivity effects of international outsourcing in the short run imply that the former still dominates the latter. Interestingly, the short-run productivity impact of international outsourcing seems to be in favor of labor employed merely in high-tech industries, specifically, chemicals, and computer and electronic product manufacturers.

Second, in the case of the long run, I observe the smaller and positive productivity elasticity of both low- and high-skilled workers with respect to international outsourcing, in comparison with general outsourcing, for overall US manufacturing. The main reason for the positive values is the fact that positive factor productivity and value-added effects are more pronounced than the negative value added in the long run. In the long run, the results are more obvious when looking at individual industries in the sense that both positive and negative signs are observed. In fact, long-run productivity gains for workers do not prevail in all industries; only high-tech industries, including chemicals, machinery, computers and electronics, and electrical equipment and component manufacturers gain from a long-term labor productivity improvement by internationally sourcing intermediate materials.

The above results seem to be consistent with those of Siegel and Grilliches (1991) and Egger and Egger (2006) as far as international outsourcing is concerned. The results turn out to be particularly important for linking the relationships among outsourcing, labor productivity, and wage inequality for skilled and unskilled workers.

2.5.2 The Impacts of Outsourcing on Wage Inequality

Aside from the productivity impacts of outsourcing, the role of outsourcing in explaining the wage inequality in the US manufacturing sector is of interest in that my results reveal that general and international outsourcing is skill-biased ($\beta_H > \beta_L$). Given the extensive discussions on the relationship between globalization and wage inequality, the impacts of general and international outsourcing on wage inequality can be inferred by using (60). The elasticities of wage inequality, as before, are evaluated at mean values.

Table 2.7: The short-run and long-run impacts of general and international outsourcing on wage inequality.

Industry	*Gen*O		*Inter*O	
	S-R η_{wO}	L-R η_{wO}	S-R η_{wO}	L-R η_{wO}
Food Manufacturing	1.3088	1.1583	0.1214	0.1133
Beverage and Tobacco Product Manufacturing	1.3153	1.1641	0.1224	0.1142
Textile Mills	1.1757	1.0406	0.0796	0.0743
Textile Product Mills	1.1887	1.0521	0.0805	0.0751
Clothing Manufacturing	1.0648	0.9424	0.1475	0.1376
Leather and Allied Product Manufacturing	1.1274	0.9977	0.1562	0.1457
Wood Product Manufacturing	1.1763	1.0411	0.0231	0.0215
Paper Manufacturing	1.2353	1.0933	0.0516	0.0482
Printing and Related Support Activities	0.7646	0.6767	0.0693	0.0646
Petroleum and Coal Products Manufacturing	1.4096	1.2476	0.0752	0.0702
Chemical Manufacturing	1.2705	1.1245	1.3795	1.2868
Plastics and Rubber Products Manufacturing	1.1781	1.0427	0.1831	0.1708
Nonmetallic Mineral Product Manufacturing	1.0296	0.9112	0.2427	0.2263
Primary Metal Manufacturing	1.2387	1.0963	0.1053	0.0982
Fabricated Metal Product Manufacturing	1.0337	0.9149	0.2124	0.1981
Machinery Manufacturing	1.0708	0.9477	0.3265	0.3046
Computer and Electronic Product	1.0539	0.9327	1.0095	0.9417
Electrical Equipment and Components	1.1658	1.0318	0.5750	0.5363
Transportation Equipment Manufacturing	1.1902	1.0534	0.2166	0.2020
Furniture and Related Product Manufacturing	1.0508	0.9300	0.0237	0.0222
Miscellaneous Manufacturing	0.9865	0.8731	0.1564	0.1458
All Industries	1.1428	1.0114	0.3732	0.3481

Note: All elasticities are evaluated at mean values.

Table 2.7 shows the short-run and long-run impacts of general and international outsourcing on wage inequality based on CES results, by evaluating elasticities of wage inequality with respect to the indexes of outsourcing. Since my results for skill-biased general and international outsourcing ($\beta_H > \beta_L$) are strikingly robust, I can observe that both general and international outsourcing entails wage inequality between skilled and unskilled workers. However, I can see that, both in the short run and in the long run, the wage inequality are more affected by general outsourcing than by international outsourcing. According to Table 2.7, in the short run, a 1 percent increase in general and international outsourcing leads to 1.14 and 0.37 percent increases in wage inequality, respectively. Meanwhile, in the long run, on average, a 1 percent increase in general and international outsourcing entails 1.01 and 0.348 percent increases in the wage gap, respectively. The impacts of general and international outsourcing on wage inequality seem to die out over time (from 1.14 to 1.01 for general outsourcing and from 0.37 to 0.348 for international outsourcing). Intuitively, this might be interpreted as the fact that, in the face of outsourcing opportunities, unskilled and skilled workers are more substitutable over time.

In other words, the elasticities of wage inequality with respect to outsourcing tell us that international outsourcing can explain the widely observed phenomenon of increased wage differentials in most industrialized economies. My results provide another insight into the role of domestic outsourcing. Compared with the conventional argument based on trade-related aspects of international outsourcing – that is, imports of unskilled intensive intermediate inputs reduce the relative demand for unskilled workers – my results shed further light on the skill-biased effect of both general and international outsourcing in explaining wage differentials. In this sense, I find that general outsourcing has a more intensified impact on wage inequality.

2.6 Concluding Remarks

This chapter has investigated the role of general and international outsourcing in the productivity and wage gaps of skilled and unskilled workers in US manufacturing. I have estimated a nested CES value-added function using six-digit NAICS US manufacturing industries during 2002-2005. The main findings are as follows.

First, both general and international outsourcing activities have a skill-biased impact on labor productivity. However, the skill-biased impact of general outsourcing is larger than that of international outsourcing. Second, the wage gap between skilled and unskilled labor, defined as their marginal productivity gap, can be better explained by general outsourcing than by international outsourcing. This implies that the wage inequality of US manufacturing industries during 2002-2005 is mainly due to the skill-biased labor productivity effect of general outsourcing rather than that of international outsourcing. Third, I find that the CRTS property of the production function holds only in the long run, whereas the unit elasticity of substitution property seems to be an inappropriate assumption for both short-run and long-run analyses. Since these properties of the production function are presumed when the dual approach of short-run estimations in examining the impact of outsourcing on the labor demand and productivity is employed, my results suggest that such assumptions might entail biased estimates.

CHAPTER III

OUTSOURCING TYPES, RELATIVE WAGES, AND THE DEMAND FOR SKILLED WORKERS: THE NEW EVIDENCE FROM US MANUFACTURING

3.1 Introduction

The pivotal roles of international outsourcing and skill-biased technology in explaining the dramatic increase in relative wages of skilled workers in industrialized economies have been extensively documented and analyzed in the literature.[61] In this literature, the notion of outsourcing is typically confined mainly to the imported intermediate inputs. For analytical purposes, using imported intermediate inputs can be justified, given that imports of intermediate inputs should be expected to affect the relative demand for manufacturing workers and relative wages,[62] nevertheless, some important insights into the role of different types of outsourcing cannot be sufficiently emphasized.

In principle, firms differ in the extent of their specialization in activities along the vertical chain of production. Some firms may engage in many activities along the chain, extending from upstream (intermediate inputs) production to downstream (final goods) production, while some other firms may specialize either in upstream or downstream production. The upstream production of intermediate inputs may involve an intensity of skills different from that of the downstream production of final goods.

Firms that specialize in downstream production may outsource their upstream materials, while firms that specialize in upstream production outsource their downstream materials. Both types of firm may also outsource their services, for

[61] See, for instance, Feenstra and Hanson (1996, 1999) for US, Feenstra and Hanson (1997) for Mexico, Anderton and Brenton (1999) for the UK, Geishecker (2002) for Germany, and Hsieh and Woo (2005) for Hong Kong.

[62] Note that it is generally accepted that changes in the labor supply fail to account for this phenomenon.

example, repair and maintenance services for machinery, communication services, financial services, and IT services, in order to focus on their core activities.[63] If upstream production is more skill-intensive, outsourcing downstream production can reduce their dependency on unskilled workers and hire more skilled workers to take advantage of the increasing productivity of the upstream activities driven by specialization. Given this difference in skill intensity along production chain, the negative impacts on the relative skilled labor demand would likewise be expected if they outsource upstream production. Obviously, types of outsourcing that are different may have different impacts on both the demand for skilled-workers and on relative wages. Therefore, focusing on the various types of outsourcing activities should enable us to get richer results. To the best of my knowledge, these refined notions of outsourcing have largely been unexplored in the literature.

A study by Amiti and Wei (2006) is perhaps the closest to that in this chapter. Their paper analyzes the impacts of both material and service outsourcing on overall labor productivity. They argue that, by engaging in material and service outsourcing, firms can delegate parts of the production process that are inefficient to other, more efficient firms. They can then focus on those activities in which they have comparative advantage and increase output. Consequently, the average productivity of the remaining workers should increase. It should be noted, however, that Amiti and Wei (2006) only look at aggregate workers; they do not really examine the impact of outsourcing activities on the demand for skilled workers relative to that for unskilled workers. Furthermore, in contrast with this study, they do not really decompose material outsourcing any further. My approach, which further separates material

[63] The above decomposition of outsourcing into three different types is consistent with the definition of outsourcing put forward by Grossman and Helpman (2002, 2005). They basically define outsourcing as the extent to which the production materials, parts, or service activities are contracted out to outside partners.

outsourcing into upstream and downstream material outsourcing, allows us to capture the notion of the vertical specialization of firms along different stages of the production process and to examine the impacts of this vertical specialization on the labor market.

My empirical estimations are based on the disaggregated six-digit NAICS US data on manufacturing industries (sectors 31-33). To investigate the more detailed impacts of outsourcing, I combine two datasets. The first is the *2002 Annual Survey of Manufacturers*, which contains six-digit NAICS data on US manufacturing, such as estimates for employment, plant hours, payrolls, value added by manufacturers, capital expenditures, and cost of materials for most manufacturing industries. The second dataset is the *2002 Economic Census*, which contains detailed data on production structures and costs, and also on downstream and upstream material and service outsourcing. In addition to these two data sources, I use the *US International Trade Statistics*, provided by the US Census Bureau, for the data on imports.

My empirical strategy is to estimate the relative demand for skilled workers derived from a modified version of the translog cost function pioneered by Brown and Christensen (1981). My results show that upstream material outsourcing is not skill-biased, whereas downstream material and service outsourcing is skill-biased. My results thus partly contrast with conventional findings, which assert that outsourcing is always skill-biased.

The intuitions behind my results can be explained as follows. Downstream material- and service-outsourcing activities enable skill-intensive firms to reallocate their resources to the upstream production activities, which are skill-intensive. The productivity of skilled workers engaged in the upstream production activities will then be enhanced. Accordingly, these kinds of outsourcing activities should have a positive impact on the relative wages of skilled workers. Upstream material-outsourcing activities, on the other hand, have an opposite impact. They enable firms to specialize in those downstream production activities which are not skill-intensive, thereby having a negative impact on the relative wages of skilled workers.

I also report two further interesting results. First, I find that, when disaggregating capital into machinery and buildings, the former is a substitute for, and the latter a complement of, skilled workers. This is partly in contrast with the existing empirical evidence, which shows capital stocks and skilled workers as complements.[64] Second, I also show that technological progress is skill-biased.

This chapter is organized as follows. Section 3.2 briefly reviews the existing empirical results on the impact of outsourcing activities on the relative demand for skilled workers. Section 3.3 discusses my empirical model and its derivation, together with my empirical strategy. Section 3.4 gives detailed descriptions of my data and data measurement. Section 3.5 presents my empirical results, and Section 3.6 offers some conclusions.

3.2 Overview of the Related Literature

Throughout the 1980s and 1990s, the US economy witnessed a widening gap between skilled and unskilled wages. Various theoretical propositions have been put forward to explain this phenomenon. Trade economists, for instance, have argued that the gap can be attributed to international trade in intermediate goods, or "outsourcing" as it is often referred to in the literature. Feenstra and Hanson (1996) were the first to empirically verify this outsourcing-based theoretical proposition. They show that around 15-33 percent of the relative increase in wages of skilled workers can indeed

[64] See Geishecker (2002), Anderton and Brenton (1999), and Feenstra and Hanson (1997).

be explained by international outsourcing. Later, Feenstra and Hanson (1999), using imported intermediate inputs, revealed that skill-biased technological change can also significantly explain the observation. Subsequent to the publication of these two seminal papers, many authors have replicated these results using data from other industrialized countries, such as the UK, Germany, and Hong Kong, and have found supporting evidence.[65]

More recently, some papers have shed further light on the issues of wage inequality. Blum (2004), for instance, shows that a structural shift in the sectoral composition of the economy could also explain the rising wages of, and demand for, skilled workers. His argument is motivated by an observation that in the US, there have been some falls in the level of employment and capital accumulation in the manufacturing sector and, at the same time, some increases in the level of employment and capital accumulation in the non-manufacturing sector, for example, in services and in the retail and wholesale trade sectors. He further asserts that if capital is complementary to skilled workers in the non-manufacturing sector, the above sectoral shift would have caused an increase in the wage inequality between skilled and unskilled workers in the economy. He empirically tested his assertion using US data and shows that the sectoral reallocation from manufacturing to services, retail, and wholesale trade sectors can indeed account for the increasing wage gap.

In contrast to Blum's (2004) model, in which capital is immobile across countries, Sachs and Schatz (1998) develop a model in which capital is allowed to flow outside the country. They show that such a capital outflow can raise the relative wages of skilled workers in the non-traded goods sectors. Despite the above essential difference, both models do indeed highlight the important role of capital inputs and

[65] See Feenstra and Hanson (1997) for Mexico, Anderton and Brenton (1999) and Hijzen et al. (2005) for the UK, Geishecker (2002) for Germany, and Hsieh and Woo (2005) for Hong Kong.

structural change in explaining the wage inequality between skilled and unskilled workers. This chapter will also investigate the role of capital inputs empirically. In particular, I will decompose capital inputs into two categories. The first category is machinery and equipment, and the second is buildings and other structures. I show that different capital inputs will have different implications for relative wages and for demand for skilled workers.

The study of Amiti and Wei (2006) is, in content, perhaps the closest paper to mine. They evaluate the impacts of international outsourcing, or offshoring in their terminology, on the productivity of the US manufacturing sector. The starting point of their paper is the twin stylized observations of increasing trends in productivity and international outsourcing in the US in recent decades. In their framework, production technology is determined by both material and service offshoring. They argue that if firms are able to internationally fragment the inefficient parts of their production process by outsourcing, they can then specialize in other parts of the production process where they have a comparative advantage. Accordingly, the average productivity of labor in the economy should increase. In addition to the specialization effect, the average productivity will also increase due to a host of other effects such as restructuring effects, learning externalities, and variety effects brought about by offshoring.[66] Their empirical results substantiate their argument. They are able to show that outsourcing does make a positive impact on overall labor productivity. Unfortunately, few conclusions can be drawn about the impact of outsourcing on wage inequality.

Interestingly, in an earlier work, Amiti and Wei (2006), using a similar framework, found that offshoring has either a small negative effect on employment

[66] A more detailed description of these effects can be found in Amiti and Wei (2006).

when a disaggregated manufacturing sector is used, or no effect at all when a more aggregated manufacturing sector is used. Thus, the effect of offshoring on employment seems to be inconclusive.

The present chapter departs from Amiti and Wei (2006) by focusing specifically on the impacts of outsourcing on the relative wages of skilled to unskilled workers and on the demand for skilled workers, instead of on the impacts of outsourcing on overall productivity and employment. The notion of outsourcing in my context follows that of Abraham and Taylor (1996) in the sense that outsourcing and in-house production are substitutes; therefore, they should affect the demand for labor regardless of location. As such, rather than merely focusing on the trade-related aspects of outsourcing, I take into consideration both domestic and international outsourcing. This chapter also differs from their papers in many other respects. First, I categorize workers as skilled or unskilled, while they view workers as one whole group. Second, I further decompose outsourcing activities into upstream and downstream material outsourcing and service outsourcing, while they look at aggregate material and service outsourcing. Third, I estimate a cost share of skilled workers using a cross-industry analysis, while they estimate a production function using a panel data analysis. Finally, this chapter focuses on a more disaggregated level of the manufacturing sector than theirs does.

The main contributions of this chapter are as follows. To the best of my knowledge, this chapter is the first empirical investigation that looks at various types of outsourcing activities; that is, upstream and downstream material outsourcing, and service outsourcing.[67] Next, it produces a new empirical finding that shows that

[67] It should also be noted that the present chapter also departs from Görg and Hanley (2003) in the sense that they split sample industries into upstream and downstream industries, but I look at the impacts of outsourcing upstream and downstream activities by manufacturing industries.

outsourcing is not always skill-biased. Downstream material outsourcing and service outsourcing are skill-biased, but upstream material outsourcing is not.

3.3 The Empirical Model

My empirical strategy is to estimate a relative demand for skilled workers. The most essential structural variables in my analysis are those that capture various types of outsourcing activities.

The production function for an industry *i* is given by the following expression:

$$Y_i = F_i\left(L_{Hi}, L_{Li}, K_i; out_i^s, out_i^m, T_i\right). \qquad (65)$$

The output for industry *i*, Y_i, depends on three primary factors, namely high-skilled workers, L_{Hi}, low-skilled workers, L_{Li}, and capital, K_i. The service outsourcing, out_i^s, material outsourcing, out_i^m, and the level of production technology, T_i are assumed to enter the production function via neutral and non-neutral technological shifts. Note that Amiti and Wei (2006) use a production function similar to that in (65), but their variables are confined to a neutral technological shift fashion. Furthermore, I disaggregate the labor input according to the skill attributes in order to capture the impacts of outsourcing on the relative demand for skilled workers.

Subsequently, I derive a short-run cost function, assuming that capital stock K_i is quasi fixed, in order to take into account the extent to which it may be different from its long-run equilibrium. Accordingly, the short-run (variable) cost function, where the levels of capital and output are fixed, can be derived from the following optimization problem:

$$c_i\left(w_{Hi}, w_{Li}; K_i, Y_i, out_i^s, out_i^m, T_i\right) = \underset{L_{Hi}, L_{Li}}{Min}\, w_{Hi}L_{Hi} + w_{Li}L_{Li} \quad \text{subject to (65).} \qquad (66)$$

The next step is to choose a functional form fitting the short-run unit cost function (66). Following Brown and Christensen (1981), the unit cost function (66) can be approximated by a general translog function with variable and quasi fixed input-factors. For notational simplicity, I temporarily drop the industry subscript *i*. Without loss of generality, I also impose symmetry and linear homogeneity restrictions. Expression (66) can be further written into

$$\ln c = \alpha_o + w'\alpha + z'\beta + \frac{1}{2}\mathrm{H}'\Omega\mathrm{H}\,, \tag{67}$$

where $w' = (\ln w_H \quad \ln w_L), \alpha' = (\alpha_H \quad \alpha_L)$, $z' = (\ln K \quad \ln Y \quad \ln out^m \quad \ln out^s \quad \ln T)$, $\beta' = (\beta_K \quad \beta_Y \quad \beta_M \quad \beta_S \quad \beta_T)$, $\mathrm{H}' = (w' \quad z')$, and Ω is a 7×7 matrix of coefficients.

The crucial property of the translog function can be derived by differentiating (67) with respect to $\ln w_k$, $k = H, L$. Let $WS_k = (\partial \ln c / \partial \ln w_k) = L_k w_k / c$, $k = H, L$ denote the cost share of skilled and unskilled workers in variable costs. Since skilled and unskilled workers are the only variable factors of production, the share of both factors must add up to unity and only one of them is linearly independent. As such, I focus on the estimation of the skilled workers' cost-share equation. By differentiating (67) with respect to $\ln w_{Hi}$, and invoking the symmetry assumption and linear homogeneity restriction, I obtain

$$WS_{Hi} = \alpha_H + \gamma \ln \frac{w_{Hi}}{w_{Li}} + \phi_{HK} \ln K_i + \phi_{HY} \ln Y_i + \phi_{HS} \ln out_i^s + \phi_{HM} \ln out_i^m + \phi_{HT} \ln T_i \,. \tag{68}$$

In addition, since the linear homogeneity property of the translog function must be satisfied, the following parameter restrictions are inevitably required:

$$\alpha_H + \alpha_L = 1 \text{ and } \gamma_{HL} + \gamma_{HH} = \gamma_{LH} + \gamma_{LL} = \phi_{Hj} + \phi_{Lj} = 0\,, \tag{69}$$

where $j = K, Y, M, S$, and *T*.

It is conventionally known that the cost share is essentially an expression of the relative demand for skilled workers, which in turn reflects not only the relative employment but also the relative factor prices. However, I am going to modify the above specification for the following reasons.

First, it is questionable whether the relative-wage term in (67) should be incorporated in the estimation. This is because the dependent variable is a composite measure of not only the relative demand for skilled workers, but also relative wages. Hence, the relative-wage term should be excluded from the estimation of (67) since relative wages are unlikely to be exogenous and there is a problem of a definitional relationship between the share of skilled workers' wage bills and the wage terms. Furthermore, as noted by Berman, et al. (1994), the cross-industry variation in wages provides little information, because the wage differential across industries is mainly explained by the difference in the skill content of workers, so I do not expect high-wage industries to economize on the high-skilled workers. As such, an estimation of (67), with the relative-wage term included, would yield biased coefficients. Accordingly, I drop the relative-wage term from the estimation of (67).

Second, the empirical model analogous to (67) has been prevalently employed to explore the impacts of material outsourcing on the relative demands for skilled workers in various economies by many studies, such as Hanson and Harrison (1999), Anderton and Brenton (1999), Dell'mour et al. (2000), Geishecker (2002), and Hsieh and Woo (2005). None of them, to the best of my knowledge, has actually investigated the possibility that various types of sourced materials that are utilized in different stages of production have different effects on the relative demand for skilled workers. Outsourcing or contracting out some activities along the vertical chain of the production process enables firms to specialize in other activities along the vertical chain where they have a comparative advantage. For instance, General Motors may outsource activities that deal with the product design and the production of high-tech components (upstream activities), and may specialize in car production (downstream activity), whereas Apple may outsource the production of its iPod players (Apple's downstream activity), and specialize in R&D and product design (upstream activity). Consequently, it seems unrealistic to assume that upstream outsourcing should have the same impact on the relative demand for skilled workers as downstream outsourcing.

Therefore, I believe that it is worthwhile to further investigate the role of various types of outsourcing such as upstream and downstream material outsourcing and also service outsourcing. Accordingly, out_i^m in (68) will be further broken down into upstream material outsourcing (out_i^{mu}) and downstream material outsourcing (out_i^{md}).

Lastly, the vector of three-digit NAICS manufacturing industry dummies (D_i) is also introduced to control for industry-fixed effects. By adding a stochastic error term u_i with $E(u_i) = 0$ and $Var(u_i) = \sigma^2$, the estimated econometric model can be specified as follows:

$$\begin{aligned} WS_{Hi} = {} & \alpha_H + \phi_{HK} \ln K_i + \phi_{HY} \ln Y_i + \phi_{HS} \ln out_i^s + \phi_{HM_u} \ln out_i^{mu} + \phi_{HM_d} \ln out_i^{md} \\ & + \phi_{HT} \ln T_i + \phi_{HD} D_i + u_i . \end{aligned} \tag{70}$$

In addition to the wage-share equation, I also estimate the following employment-share equation to control for inter-industry differences in the relative wages of skilled workers:

$$\begin{aligned} ES_{Hi} = {} & \alpha_H + \gamma \ln \frac{w_{Hi}}{w_{Li}} + \phi_{HK} \ln K_i + \phi_{HY} \ln Y_i + \phi_{HS} \ln out_i^s + \phi_{HM_u} \ln out_i^{mu} + \phi_{HMd} \ln out_i^{md} \\ & + \phi_{HT} \ln T_i + \phi_{HD} D_i + u_i , \end{aligned} \tag{71}$$

where ES_{Hi} is the share of skilled-worker employment in the total employment and w_{Hi} / w_{Li} is the relative wages of skilled to unskilled workers. Admittedly, as is also noted in Anderton and Brenton (1999), the ad hoc specification of (71) is less satisfactory from a theoretical point of view. Nevertheless, it should give us some interesting insights into the impact of various types of outsourcing on the employment of skilled workers. It should also enable us to compare my results with those obtained in previous studies that also estimate such an employment equation, such as, Machin et al. (1996).

Two econometric problems may arise when estimating specifications (69) and (70), and they need to be corrected. Firstly, due to the variation in the size of the industries in my sample, the stochastic-error term u_i is likely to be heteroskedastic, thereby producing a biased estimator of σ^2 in the standard ordinary least squares (OLS) method. To tackle this problem, I employ White's (1980) heteroskedastic-robust standard-error procedure in the estimation of (70) and (71).

Secondly, there may be an endogeneity-bias problem in the estimation of (70) and (71). That is, the industry-specific level of technology (T_i), which is measured by high-technology capital stocks such as computers and data processing equipment, may be correlated with an unobserved variable in the error term. In order to verify whether there is indeed such a problem, I run an Instrumental Variable (IV) regression and apply a Hausman Test to the results. I use the rate of energy consumption ($ENERGY_i$) and value added per establishment (VN_i) as my instruments, and express them as a logarithm. The first instrumental variable aims to capture the industry-specific production performance. That is, the industries which utilize high-tech capital (such as computers) intensively are likely to have lower energy consumption than the industries which rely intensively on low-tech capital (such as machinery, engines, etc). The second instrumental variable may represent the competitiveness in the industries in the sense that highly competitive industries should be characterized by low value added per establishment. It is likely that the market structures should affect the choices of technology levels. The preliminary regression shows that these instrumental variables are strongly correlated with the industry-specific level of technology (T_i).[68]

$$\underset{}{\ln T_i} = \underset{(.1434)}{2.0369*} - \underset{(.0227)}{.1419*} ENERGY_i - \underset{(.0134)}{.0787*} VN_i, \quad R^2 = .1627 \quad F = 36.86*$$

As is well known, a potential IV also needs to be exogenous. The exogeneity of both IVs may be justifiable since in the cross-industry analysis the levels technology and market structures are industry-specific and therefore exogenous to each industry. This assumption, however, may not hold for the sufficiently long time period in the panel dataset since the level of industry-specific technology may evolve and therefore be dependent on other economic factors.

3.4 Data

3.4.1 Data Sources

My data are retrieved from the following data sources provided by the US Bureau of Census: the *2002 Annual Survey of Manufactures (ASM)*, the *2002 Economic Census*, and the *US International Trade Statistics*. The *2002 ASM* provides six-digit NAICS statistics for the manufacturing industry. The manufacturing sector (sectors 31-33) in this survey is defined as comprising establishments that engage in the mechanical, physical, or chemical transformation of materials, substances, or components into new products.

[68] The asterisks * mean statistical significance at 1 percent. Robust standard errors are in parentheses.

Table 3.1: Three-digit NAICS manufacturing industry code (Sectors 31-33).

2002 NAICS Code	Report Title
311	Food Manufacturing
312	Beverage and Tobacco Product Manufacturing
313	Textile Mills
314	Textile Product Mills
315	Apparel Manufacturing
316	Leather and Allied Product Manufacturing
321	Wood Product Manufacturing
322	Paper Manufacturing
323	Printing and Related Support Activities
324	Petroleum and Coal Products Manufacturing
325	Chemical Manufacturing
326	Plastics and Rubber Products Manufacturing
327	Nonmetallic Mineral Product Manufacturing
331	Primary Metal Manufacturing
332	Fabricated Metal Product Manufacturing
333	Machinery Manufacturing
334	Computer and Electronic Product Manufacturing
335	Electrical Equipment, Appliance, and Component Manufacturing
336	Transportation Equipment Manufacturing
337	Furniture and Related Product Manufacturing
339	Miscellaneous Manufacturing

From this survey, I obtain data on the wages and employment of skilled and unskilled workers across the manufacturing sector. Although this survey also provides data on materials used in the production, unfortunately it does not provide sufficiently detailed statistics on material and service outsourcing, or on proxies for technology capital. As noted by Feenstra and Hanson (1999), I do not normally think of, say, the purchase of steel by a US automobile producer as outsourcing. But it is more common to consider the purchase of automobile parts by such a company as outsourcing. Moreover, unlike the existing empirical studies on the impacts of outsourcing on the relative demand for labor, there is no reason to confine the extent of outsourcing merely to sourcing of materials.[69] I therefore supplement the above data with the *2002 Economic Census*.

From the *2002 Economic Census*, I obtain detailed information on the cost and production structure of manufacturing firms and also on their use of technological capital (e.g. computers, data processing equipment, etc.), their purchase of intermediate materials (e.g. components, containers, packaging, etc.), and services (e.g. communication services; accounting, auditing, and bookkeeping services; computer services, etc.). I focus specifically on the six-digit NAICS manufacturing-sector data (sectors 31-33).

My combined data from the *2002 ASM* and the *2002 Economic Census* yields 474 six-digit NAICS manufacturing industries.

3.4.2 Dependent Variables

Using both data sets, I can express the wage share of skilled workers in industry i (WS_{Hi}) in equation (70) as the ratio of the total wage bills of non-production workers to the total annual payrolls. The employment share of skilled workers in industry i (ES_{Hi}) in equation (71) is measured by the ratio of the total number of non-production workers to the total number of workers.

3.4.3 Outsourcing

Upstream material outsourcing (out_i^{mu}) is measured by the share of the total production costs taken up by the costs of intermediate parts and materials employed in the upstream production stage. The downstream material outsourcing (out_i^{md}) is measured by the share of the costs of contracting-out activities, such as reprocessing,

[69] For example, in Feenstra and Hanson (1999) and Amiti and Wei (2006), the (imported) materials are used as proxies of "broad measures" of material outsourcing. One can argue that these measures may be imprecise as the use of raw materials should not by definition be considered as the result of outsourcing decisions of firms.

repackaging, and blending, in the total production costs. The scatter plots of WS_{Hi} against $\ln out_i^{mu}$ and $\ln out_i^{md}$ are represented in Figure 3.1 and Figure 3.2, respectively. As expected, the former shows a negative relationship between $\ln out_i^{mu}$ and WS_{Hi}, while the latter shows a positive correlation between $\ln out_i^{md}$ and WS_{Hi}. Thus, different types of material outsourcing, that is, upstream- or downstream-material outsourcing, should have different impacts on the relative demand for skilled workers.

Figure 3.1: WS_{Hi} vs. $\ln out_i^{mu}$

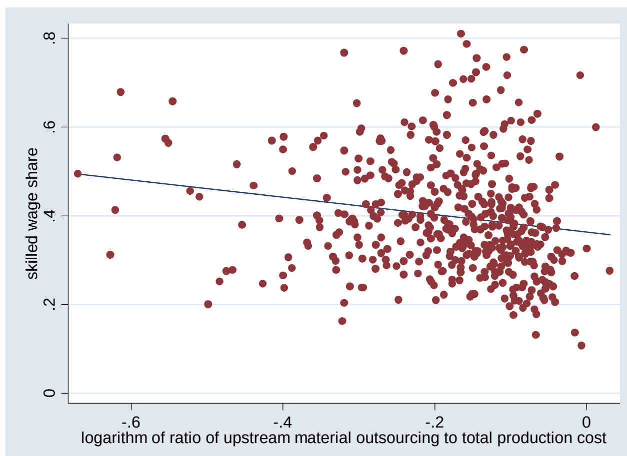
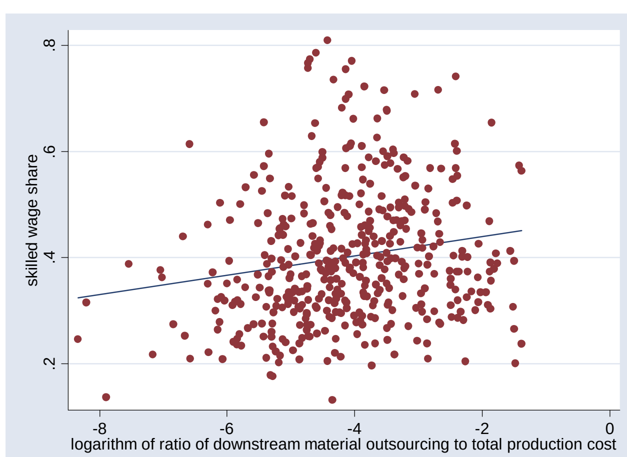
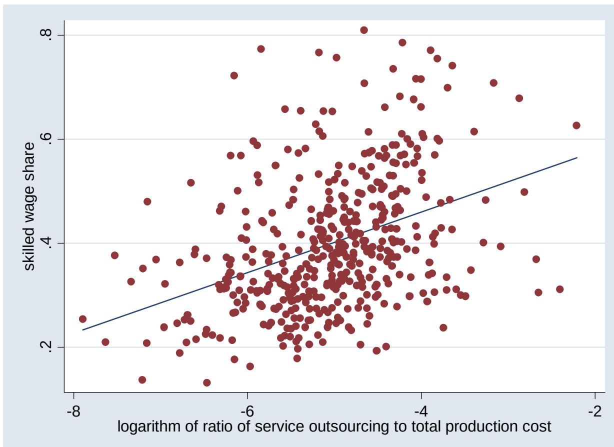


Figure 3.2: WS_{Hi} vs. $\ln out_i^{md}$



Service outsourcing (out_i^s) is measured by the share of services purchased in the total production costs of industry *i*. Examples of services that are outsourced are repair and maintenance services of machinery and equipment; communication services; accounting, auditing, and bookkeeping services; and computer and hardware services. Figure 3.3 depicts a positive relationship between $\ln out_i^s$ and WS_{Hi}.

Figure 3.3: WS_{Hi} vs. $\ln out_i^s$

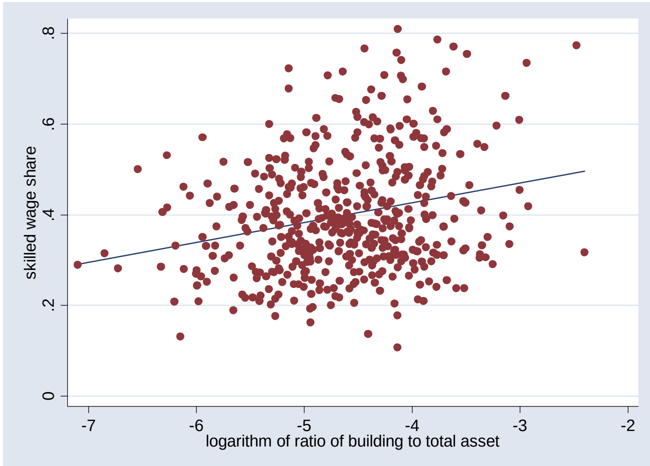


3.4.4 Control and Instrumental Variables

Capital Inputs

Similar to Geishecker (2002), I use the value of buildings and other structures (K_i^{BLD}), and also machinery and equipment (K_i^{MCH}) in industry *i*, as proxies for the total amount of capital inputs employed in industry *i* (K_i). The expected sign of the coefficient of $\ln K_i$ could be either negative or positive, depending on whether or not capital inputs and high-skilled workers are substitutes.

<u>Figure 3.4</u>: WS_{Hi} vs. $\ln K_i^{BLD}$



<u>Figure 3.5</u>: WS_{Hi} vs. $\ln K_i^{MCH}$

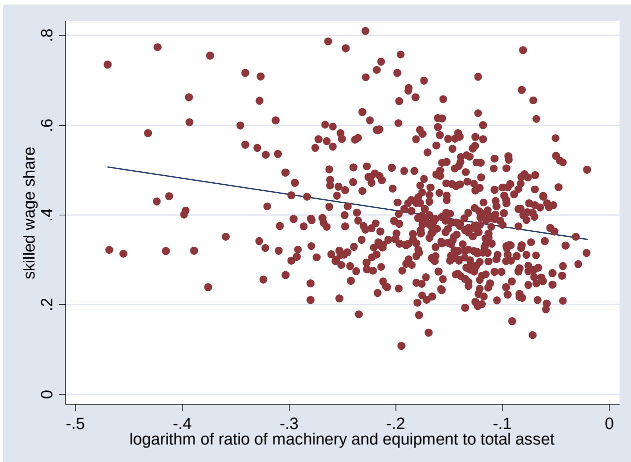


Figure 3.4 depicts a positive relationship between the ratio of the total value of buildings and other structures to the total value of the assets and the wage share of skilled workers. Figure 3.5 depicts a negative relationship between the ratio of the total value of machinery and equipment to the total value of the assets and the wage share of skilled workers. The relationship portrayed in Figure 3.5 is the exact opposite of the one portrayed in Figure 3.4. It appears that machinery and equipment, and skilled workers are substitutes. Where firms are machinery- and equipment-intensive, their workers tend to have a lower wage share. By contrast, buildings and other

structures, and skilled workers are complements. The skilled workers of firms that are more buildings and other structures-intensive tend to have a higher wage share. I should thus expect that these two types of capital input will affect the demand for skilled workers differently.

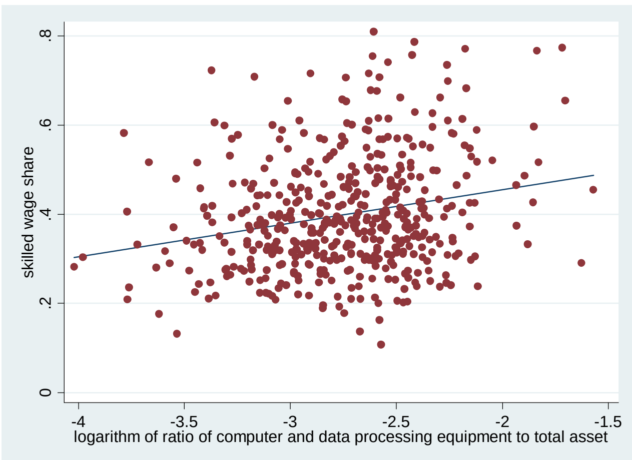
Industrial Production

I also control for industry size using the logarithm of the total amount of sales ($\ln Y_i$) as a proxy. A larger size industry would be expected to have a larger demand for skilled workers. This implies that the coefficient of $\ln Y_i$ should be positive.

Industry-Specific Technology

The level of technology of an industry *i* (T_i) is measured by the ratio of high-technology capital to the total value of assets of industry *i*. As in Amiti and Wei (2006), I proxy high-technology capital using the value of computers and data-processing equipment used in industry *i*. WS_{Hi} and $\ln T_i$, as shown in Figure 6A, are positively related. This implies that high-technology capital and skilled workers are complements, and thus I should expect that the regression coefficient for high-technology capital has a positive sign.

Figure 3.6: WS_{Hi} vs. $\ln T_i$



Import Shares

In the analysis, I also control for the impact of imports on workers' wages and employment. I know from the standard Heckscher-Ohlin theory that when domestic production is supplanted by imports, a substitution of this kind should negatively affect wages and employment. I thus incorporate the industrial import-share (IM_i) variable in my regressions. This variable is proxied by the ratio of the imports of industry *i*'s product (six-digit NAICS) to its total domestic consumption. The data are retrieved from the *US International Trade Statistics*, US Bureau of Census.

Instrumental Variables

As mentioned previously, I run IV regressions with a heteroskedasticity-robust variance estimator using the rate of energy consumption ($ENERGY_i$) and value added per establishment (VN_i) as my instruments for the level of technology (T_i). The former is measured by the ratio of electricity and fuel consumption used in production to the total capital expenditure, and the latter is the ratio of the total industry value added to the total number of establishments.

Statistics summarizing all the variables elaborated above and the matrix of correlations among these variables are presented in Table 3.2 and 3.3, respectively.

Table 3.2: Summary Statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
WS_{Hi}	473	0.3987	0.1287	0.1077	0.8093
ES_{Hi}	473	0.2921	0.1181	0.0871	0.7156
$\ln K_i$	473	11.5768	1.4024	6.7604	15.8128
$\ln K_i^{BLD}$	468	9.6267	1.5399	4.8442	15.0105
$\ln K_i^{MCH}$	473	0.3987	0.1287	0.1077	0.8093
$\ln Y_i$	473	15.1939	1.1954	11.6991	19.0873
$\ln out_i^m$	473	-0.1590	0.2133	-3.2124	-0.0348
$\ln out_i^{mu}$	471	-0.1883	0.1379	-1.0087	-0.0306
$\ln out_i^{md}$	459	-4.1124	1.2732	-10.4188	-0.4770
$\ln out_i^s$	469	-5.0816	0.9087	-8.6866	-2.2080
$\ln T_i$	468	-2.7487	0.3910	-4.0203	-1.5696
$\ln IM_i$	473	-2.0171	1.3284	-13.5	-0.0104

Table 3.3: Correlation Matrix of Independent Variables.

	$\ln K_i^{BLD}$	$\ln K_i^{MCH}$	$\ln Y_i$	$\ln out_i^{mu}$	$\ln out_i^{md}$	$\ln out_i^{s}$	$\ln T_i$	$\ln IM_i$
$\ln K_i^{BLD}$	1							
$\ln K_i^{MCH}$	0.6512	1						
$\ln Y_i$	0.4203	0.6426	1					
$\ln out_i^{mu}$	0.0965	0.1141	0.255	1				
$\ln out_i^{md}$	-0.0688	-0.0561	-0.1412	-0.4494	1			
$\ln out_i^{s}$	-0.0794	-0.0871	-0.1838	-0.2705	0.5024	1		
$\ln T_i$	0.077	0.1202	0.1629	0.0549	0.0792	0.2957	1	
$\ln IM_i$	-0.0699	-0.1279	-0.3968	-0.2546	0.2164	0.0963	0.0292	1

3.5 Empirical Results

Tables 3.4 to Table 3.7 present my regression results. Column (1) in all tables shows the results I obtained using a regression specification that uses aggregated capital inputs and material outsourcing. Column (2) gives the results I obtained when the control variable imports are excluded from the regression. Column (3) presents my results when capital inputs were further disaggregated into buildings and other structures ($\ln K_i^{BLD}$) and machinery and equipment ($\ln K_i^{MCH}$). Finally, Column (4) presents the results I obtained when material outsourcing was further decomposed into upstream material outsourcing, $\ln out_i^{mu}$, and downstream material outsourcing, $\ln out_i^{md}$.[70]

3.5.1 The Wage Share of Skilled Workers

According to the standard Heckscher–Ohlin paradigm, imports and domestic production are substitutes, and hence imports should affect relative wages and the demand for skilled workers. Therefore, to take into consideration this import effect, I also run a regression with import share ($\ln IM_i$) as an explanatory variable. The result of this regression is presented in Column (1). Consistent with Leamer (1998), I find

[70] Since values of material outsourcing are missing for some industries, the number of observations in the actual estimation is slightly reduced to 465 and 452 observations.

that the import share is not significant, which suggests that international trade has no influence on the wage gap between skilled and unskilled workers.

As revealed in Table 3.4, the coefficients of all structural variables for all specifications are statistically significant at the 5 percent significance level.[71] The aggregate proxy for capital inputs (see Columns (1) and (2)) is statistically significant and has negative sign, implying that capitals and skilled workers are substitutes. My results are thus consistent with Geishecker's (2002) result that shows a negative relationship between capitals and the relative demand for skilled workers.

Table 3.4: OLS estimation with heteroskedasticity-robust variance estimators for non-production wage share

Variable	(1)	(2)	(3)	(4)
$\ln K_i$	-0.0705(.0126)***	-0.0691(.0121)***	----	----
$\ln K_i^{BLD}$	----	----	0.0280(.0081)***	0.0222(.0078)***
$\ln K_i^{MCH}$	----	----	-0.0955(.0117)***	-0.0984(.0117)***
$\ln Y_i$	0.0742(.0143)***	0.0722(.0133)***	0.0681(.0137)***	0.0763(.0133)***
$\ln out_i^m$	-0.1027(.0480)**	-0.1034(.0483)**	-0.1265(.0491)***	----
$\ln out_i^{mu}$	----	----	----	-0.1162(.0495)**
$\ln out_i^{md}$	----	----	----	0.0112(.0046)**
$\ln out_i^s$	0.0446(.0070)***	0.0446(.0069)***	0.0430(.0067)***	0.0352(.0075)***
$\ln T_i$	0.0621(.0162)**	0.0612(.0156)***	0.0620(.0154)***	0.0713(.0151)***
$\ln IM_i$	0.0027(.0039)	----	----	----
Constant	0.1740(.1231)	0.1817(.1172)	0.2443(.1234)*	0.2035(.1214)*
R-squared	0.5490	0.5485	0.5778	0.5948
F statistic	24.36***	25.30***	27.93***	26.84***
No. of Obs.	465	465	465	452

Note: 1) robust standard errors in parentheses, 2) * statistically significant at 10 percent, 3) ** statistically significant at 5 percent, 4) *** statistically significant at 1 percent.

To see this more clearly, the capital stock is separated out into two components, buildings and other structures ($\ln K_i^{BLD}$) and machinery and equipment

[71] These results are also consistent with *F*-tests. As reported in Table 3.4, the results, based on *F* statistics, assert that all coefficients are *jointly* statistically significant at the 5 percent level of significance.

($\ln K_i^{MCH}$) in Columns (3) and (4). I found that $\ln K_i^{BLD}$ has a positive effect, whereas $\ln K_i^{MCH}$ has a negative effect. My results suggest that buildings and other structures are complementary to skilled workers, while machinery and equipment are not.

In line with Amiti and Wei (2006), the coefficients of $\ln Y_i$ are positive and statistically significant at the 1 percent level of significance in all regression specifications. This suggests that larger industries are more likely to be characterized by a higher wage share of skilled workers. Employing skilled workers is relatively more expensive than employing unskilled workers, and larger firms would be more able to afford it as they can tap the benefit of the economies of scale.

The estimated coefficients of material outsourcing ($\ln out_i^m$) in Columns (1), (2), and (3) are all negative and statistically significant at a 5 percent level of significance. This result is in contrast to those of Feenstra and Hanson (1996, 1999), Anderton and Brenton (1999), and Geishecker (2002), who all find a positive relationship. In these papers, material outsourcing is proxied by imported intermediate materials. The negative relationship between material outsourcing and the wage share of skilled workers as depicted in Columns (1), (2), and (3) may be consistent with the results of studies done by Siegel and Griliches (1991) and Egger and Egger (2006). These show that material outsourcing leads to a short-run deterioration in the overall productivity of labor and therefore in the efficiency of production. If indeed there is a negative short-run effect of material outsourcing, then I should expect a negative relationship between material outsourcing and relative wages of skilled workers.

I further break down material outsourcing into upstream ($\ln out_i^{mu}$) and downstream material ($\ln out_i^{md}$) outsourcing. From the results presented in Column

(4), I can see that upstream material outsourcing negatively affects the wage share of skilled workers, while downstream material outsourcing positively affects the wage share of skilled workers. As elaborated previously, materials used in upstream production stages include intermediate parts and materials, and activities involved in downstream production stages include reprocessing and repackaging activities. The former is often more skill-intensive than the latter. Consequently, in contrast with performing these skill-intensive activities in-house, outsourcing them from the market is unlikely to yield a rise in the wages paid to skilled workers in downstream industries, and thus a negative relationship of this kind may indeed prevail. On the other hand, contracting out downstream materials allows firms to specialize in the production of upstream materials, therefore resulting in higher productivity and thus higher wage shares for skilled workers. Accordingly, a positive relationship between downstream material outsourcing and the wages of skilled workers relative to those of unskilled workers does prevail.

I also show that service outsourcing has a positive impact on relative wages. Service outsourcing in my context includes purchases of communication, accounting, auditing, bookkeeping, and computer services. This result is consistent with Amiti and Wei (2006).

The coefficients of the level of technology ($\ln T_i$) are positive and statistically significant at a 1 percent level of significance. This suggests that technology is skill-biased. This result confirms the findings of previous studies such as those of Anderton and Brenton (1999), Geishecker (2002), and Amiti and Wei (2006): technology and skilled workers are complementary. So as I show here, higher technology results in a larger wage share for skilled workers.

In my regressions, I also include dummies for industries. As expected, chemical, machinery, computer, and electronic products are relatively skill-intensive, while textile mills, clothing, leather and allied products, and wood product manufacturing are not.[72]

Table 3.5: Instrumental variable estimates with heteroskedasticity-robust variance estimators for non-production wage share.

Variable	(1)	(2)	(3)	(4)
$\ln K_i$	-0.0967(.0162)***	-0.0942(.0152)***	----	----
$\ln K_i^{BLD}$	----	----	0.0243(.0083)***	0.0180(.0082)**
$\ln K_i^{MCH}$	----	----	-0.1101(.0138)***	-0.1126(.0131)***
$\ln Y_i$	0.0975(.0177)***	0.0940(.0162)***	0.0843(.0164)***	0.0927(.0157)***
$\ln out_i^m$	-0.1420(.0529)***	-0.1432(.0533)***	-0.1537(.0533)***	----
$\ln out_i^{mu}$	----	----	----	-0.1326(.0496)***
$\ln out_i^{md}$	----	----	----	0.0122 (.0047)**
$\ln out_i^s$	0.0380(.0083)***	0.0380(.0082)***	0.0388(.0076)***	0.0305(.0085)***
$\ln T_i$	0.1350(.0302)***	0.1330(.0293)***	0.1108(.0274)***	0.1188(.0257)***
$\ln IM_i$	0.0047(.0043)	----	----	----
Constant	-0.0490(.1655)	-0.0345(.1566)	0.0811(.1616)	0.0458(.157)
R-squared	0.5189	0.5190	0.5641	0.5823
F statistic	22.48***	23.19***	26.01***	25.39***
Hausman test statistic(p-value)	2.32(1.00)	16.12(0.9111)	0.97(1.00)	3.01(1.00)
No. of Obs.	465	465	465	452

Note: 1) robust standard errors in parentheses, 2) * statistically significant at 10 percent, 3) ** statistically significant at 5 percent, 4) *** statistically significant at 1 percent, 5) Hausman specification test is distributed as chi-squared distribution with degrees of freedom equal to the number of instruments under the null hypothesis that $\ln T_i$ is uncorrelated with the error term.

Finally, as noted by Feenstra and Hanson (1997), the estimation of the wage-share equations might be subject to not only a potential heteroskedasticity problem, but also an endogeneity problem, thereby resulting in inefficient and biased estimators. More specifically, it is possible that $\ln T_i$ is correlated with an unobserved variable in the error term (u_i). To verify this, I run IV regressions and apply the Hausman test for the endogeneity problem to the results. My null hypothesis posits

[72] The results of industry dummies are suppressed.

that $\ln T_i$ is not correlated with u_i. The result of the Hausman test shows that the null hypothesis cannot be rejected, suggesting that there is no endogeneity problem. As pointed out by Hausman (1978), when $\ln T_i$ is indeed uncorrelated with the unobserved variable in u_i, the OLS and IV estimators would essentially produce the same qualitative results.[73] Indeed, when I compare the results from the OLS regressions in Table 3.4 and the results from IV regressions in Table 3.5, I observe that the explanatory variables that are significant in the OLS regressions are also significant in IV regressions, and they all have the same predicted signs.

3.5.2. The Employment Share of Skilled Workers

Table 3.6: OLS estimation with heteroskedasticity-robust variance estimators for non-production employment share.

Variable	(1)	(2)	(3)	(4)
$\ln(w_H/w_L)$	-0.1563(.0289)***	-0.1550(.0287)***	-0.1731(.0291)***	-0.1872(.0312)***
$\ln K_i$	-0.0560(.0123)***	-0.0550(.0116)***	----	----
$\ln K_i^{BLD}$	----	----	0.0255(.0076)***	0.0208(.0074)***
$\ln K_i^{MCH}$	----	----	-0.0811(.0113)***	-0.0858(.0114)***
$\ln Y_i$	0.0613(.0135)***	0.0601(.0125)***	0.0579(.0128)***	0.0666(.0125)***
$\ln out_i^m$	-0.0850(.04347)*	-0.0854(.0436)*	-0.1051(.0447)**	----
$\ln out_i^{mu}$	----	----	----	-0.1019(.0491)**
$\ln out_i^{md}$	----	----	----	0.0095(.0043)**
$\ln out_i^s$	0.0391(.0066)***	0.0391(.0066)***	0.0382(.0064)***	0.0323(.0073)***
$\ln T_i$	0.0502(.0157)***	0.0495(.0151)***	0.0520(.0149)***	0.0620(.0148)***
$\ln IM_i$	0.0015(.0037)	----	----	----
Constant	0.1708(.1139)	0.1745(.1092)	0.2409(.1160)**	0.2106(.1174)*
R-squared	0.5523	0.5521	0.5790	0.5969
F statistic	23.02***	23.90***	24.80***	23.50***
No. of Obs.	465	465	465	452

Note: 1) robust standard errors in parentheses, 2) * statistically significant at 10 percent, 3) ** statistically significant at 5 percent, 4) *** statistically significant at 1 percent.

In this sub-section, I discuss the results of my OLS and IV estimations of the employment-share equation (71). They are reported in Tables 3.6 and 3.7, respectively. The result of the Hausman test for the endogeneity problem is reported

[73] That is, the estimators from OLS and IV estimation should differ only by the sampling errors.

in Table 3.7. It shows that the null hypothesis of no correlation between $\ln T_i$ and u_i cannot be rejected for all specifications, thus suggesting that there is no endogeneity problem.[74]

I also include the relative-wage variable, $\ln(w_H / w_L)$, in the estimations and find that the coefficients of $\ln(w_H / w_L)$ have a negative sign and are statistically significant at a 1 percent level of significance. This implies that an increase in $\ln(w_H / w_L)$ triggers a replacement of skilled workers by unskilled workers.

Table 3.7: Instrumental variable estimates with heteroskedasticity-robust variance estimators for non-production employment share.

Variable	(1)	(2)	(3)	(4)
$\ln(w_H / w_L)$	-0.1860(.0319)***	-0.1826(.0310)***	-0.1913(.0303)***	-0.2042(.0324)***
$\ln K_i$	-0.0798(.0160)***	-0.0775(.0148)***	----	----
$\ln K_i^{BLD}$	----	----	0.0231(.0077)***	0.0178(.0076)**
$\ln K_i^{MCH}$	----	----	-0.0941(.0134)***	-0.0984(.0128)***
$\ln Y_i$	0.0822(.0172)***	0.0792(.0154)***	0.0714(.0153)***	0.0801(.0147)***
$\ln out_i^m$	-0.1143(.0478)**	-0.1150(.0481)**	-0.1247(.0485)**	----
$\ln out_i^{mu}$	----	----	----	-0.1132(.0494)**
$\ln out_i^{md}$	----	----	----	0.0105(.0044)**
$\ln out_i^s$	0.0348(.0076)***	0.0347(.0076)***	0.0355(.0072)***	0.0292(.0081)***
$\ln T_i$	0.1100(.0296)***	0.1078(.0283)***	0.0897(.0262)***	0.0990(.0249)***
$\ln IM_i$	0.0035(.0041)	----	----	----
Constant	0.0099(.1504)	0.0203(.1424)	0.1296(.1473)	0.1028(.1460)
R-squared	0.5295	0.5301	0.5700	0.5884
F statistic	21.79***	22.54***	24.02***	22.66***
Hausman spec. test statistic(p-value)	0.09(1.00)	2.88(1.00)	1.39(1.00)	0.6(1.00)
No. of Obs.	465	465	465	452

Note: 1) robust standard errors in parentheses, 2) * statistically significant at 10 percent, 3) ** statistically significant at 5 percent, 4) *** statistically significant at 1 percent, 5) Hausman specification test is distributed as chi-squared distribution with degrees of freedom equal to the number of instruments under the null hypothesis that $\ln T_i$ is uncorrelated with the error term.

I show that the independent variable, $\ln IM_i$, is not significant (see Column (1)). This suggests that the conventional H-O framework cannot really explain the

[74] The coefficients of instruments in the first stage regression are statistically significant at a 1 percent level of significance for all specifications with the adjusted R-squared ranging from 0.5766 to 0.6172.

change in the employment share of skilled workers. I also show that capital inputs have a negative impact on the employment share of skilled workers (see Column (2)). When I break down capital inputs into buildings and other structures, and machinery and equipment, I find that the former are skill-biased, while the latter are not (see Columns (3) and (4)). Next, I also show that industry size has a positive impact on employment share.

As with my previous results, I find that aggregate material outsourcing has a negative impact on the relative demand for skilled workers. When I separate material outsourcing into upstream and downstream material outsourcing, I find that the latter has a positive impact on the relative demand for skilled workers, whereas the former has a negative impact. I also show that service outsourcing has a positive impact on the relative demand for skilled workers.

The coefficients of $\ln T_i$ are positive. This suggests that technology is skill-biased. This is consistent with my earlier results from the estimation of the wage-share equation. Lastly, I find that chemical, fabricated metal, machinery, computers, and electronic products are skill intensive, while textile, clothing, leather, and wood products are not.

3.6 Concluding Remarks

In this chapter, I estimate the impacts of outsourcing on relative wages and the demand for skilled workers using six-digit NAICS US manufacturing-sector data. I break down outsourcing into three categories, namely upstream and downstream material outsourcing, and service outsourcing. My results show that downstream material outsourcing and service outsourcing have a positive impact on the wages of skilled workers relative to those of unskilled workers and the relative demand for skilled workers, while upstream material outsourcing has the opposite impact.

The positive impact of downstream material and service outsourcing on relative wages and the demand for skilled workers can be explained by the idea that these types of outsourcing allow firms to specialize in the upstream production activities, which usually employ a greater number of skilled workers. Therefore, an increased attention to upstream production activities will naturally induce firms to hire more skilled workers. In contrast, downstream production activities and services tend to be less skill-intensive than upstream production activities; hence, firms that focus more on the former do not really require numerous skilled workers. Accordingly, their demand for skilled workers will fall.

My empirical results also shed further light on the different roles played by different types of capital inputs. I discover that the nature of the relationship between capital inputs and skilled workers depends on the types of capital input employed in the production process. I find that machinery and equipment are substitutes for skilled workers, while buildings and other structures are complementary to skilled workers. With regard to the role of technology, I find a positive relationship between technology and the demand for skilled workers. It can thus be concluded that technology is skill-biased.

It may be more interesting in future research to rigorously investigate the roles of domestic and international outsourcing as explanatory factors for wage inequalities. Furthermore, a natural extension to my empirical analysis would be to conduct a dynamic panel-data analysis rather than a cross-sectional analysis like that carried out for this chapter. Such an analysis should enable us to obtain richer results.

Unfortunately, more recent detailed six-digit NAICS manufacturing-sector data are not available at the time of writing. I therefore leave this to my future research.

CHAPTER IV
THE IMPACT OF MATERIAL AND SERVICE OUTSOURCING ON EMPLOYMENT AND LABOR SUBSTITUTION IN THAILAND'S MANUFACTURING INDUSTRIES

4.1 Introduction

Most of literature concerned with the economic impacts of outsourcing on the labor market focuses mainly on developed countries.[75] Due to technical advances in information technology and greater liberalization of trade globally, the current surge in outsourcing activities spurs the 'fear of job losses' in terms of 'exporting jobs' to developing countries (see Amiti and Wei, 2006). Should developing economies also fear the effects of outsourcing? To answer this question, the present chapter empirically investigates the impacts of offshore outsourcing of materials and services on the relative demands for unskilled and skilled workers in the Thailand's manufacturing sector from 1999 to 2003.[76]

In contrast with the manufacturing sector in OECD countries, Thailand's manufacturing sector is both a recipient and a source of outsourcing. Both issues have important implications on the labor market but require different empirical frameworks to study their impacts on the economy. In this thesis, I will confine my attention mainly to Thailand's manufacturing sector as a source of outsourcing. Therefore, the empirical methodology employed in this chapter lies in the spirit of that applied for OECD countries.

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[75] Following Feenstra and Hanson (1996, 1999), a number of literatures have analyzed the impacts of outsourcing on labor markets in various economies, such as Anderton and Brenton (1999) for UK, Geishecker (2002) for Germany, and Hsieh and Woo (2005) for Hong Kong, among others.

[76] As discussed later, there are two indexes of outsourcing of my interests: material outsourcing and service outsourcing. The former follows the broad definition of international outsourcing, the imports of intermediate inputs as in Feenstra and Hanson (1996). The service outsourcing refers to service purchases of establishments as in Morrison and Siegel (2001).

Even though the positive relationship between outsourcing and relative demand for skilled labor is observed especially in industrialized economies (see Feenstra and Hanson, 1996, 1999, Anderton and Brenton, 1999, and Geishecker, 2002, for example), it may be desirable, at least to us, to investigate whether such a relationship holds in developing economies.[77] In the study by Feenstra and Hanson (1996) on the United States manufacturing sector, the extent of material outsourcing is given by the share of imports from a particular industry located abroad in total domestic demand for products in that industry. In their paper, outsourcing is derived as an import penetration measure. Using the variable cost function with capital as a fixed input, they concluded that 15 to 33 percent of the increase in the cost share of non-production workers could be explained by the international outsourcing. According to their study, the offshore outsourcing of intermediate inputs and the technological changes is biased towards non-production workers, thus outsourcing leads to higher non-production workers' wage share.[78]

Following Feenstra and Hanson (1996, 1999), a number of studies have been conducted in various developed economies to empirically investigate the impacts of outsourcing on the relative demand for skilled workers. Among others, Anderton and Brenton (1999) employed outsourcing proxied as in Feenstra and Hanson (1996) distinguishing between intermediate imports from developed and developing economies based on four-digit ISIC for two UK sectors, textile and non-electrical machinery sectors. Their results showed that international outsourcing accounts for roughly 40 percent of the total increase in the wage bill share of skilled workers.

[77] Most literatures on the impacts of outsourcing on the relative demand for skilled labor focus on the dataset collected from industrialized economies. The presence of outsourcing as an explanatory for widened wage inequalities within industries is consistently confirmed by those literatures.

[78] According to Feenstra and Hanson (1999), technological improvement proxied by expenditures on computers accounts roughly for 35 percent of the rising non-production wage share whereas outsourcing explains about 15 percent.

Based on the German manufacturing sector from 1991-2000, Geishecker (2002) find international outsourcing is indeed an important factor that could explain the decrease in the relative demand for unskilled workers in Germany. Specifically, by controlling for skill-biased and capital upgrading effects, international outsourcing is revealed to explain roughly 24 percent of the decline in the relative demand for unskilled workers in the German manufacturing sector.

Hsieh and Woo (2005) empirically investigate the impacts of a large reallocation of unskilled activities to China on skill structure of the Hong Kong labor market and a sharp decline in the importance of the Hong Kong manufacturing sector. They find that the extent of outsourcing from Hong Kong to China has entailed strong and persistent relative demand shifts favoring skilled workers in Hong Kong since the early 1980s. The evidence reveals that the reallocation of workers from manufacturing to outsourcing services accounts for roughly 15 percent of the aggregate relative demand shifts, and the increased utilization of skilled workers within individual manufacturing industries accounts for roughly 30 percent of the aggregate shift. They conclude that Hong Kong's experience is similar to that of the developed countries highlighting the importance of outsourcing.

This chapter contributes to the rapidly expanding outsourcing literature in a number of ways. Firstly, this chapter studies the impact of outsourcing on the labor market by using micro-level data from the Thailand's manufacturing sector. This is the first study to explore the impact of outsourcing on the Thailand's manufacturing sector. Secondly, unlike the existing literatures, the notion of outsourcing in this chapter is beyond the standard trade-related material input as service outsourcing may have equally important impacts on the labor markets. Finally, to the best of my knowledge, the present chapter is the first to capture the second-order impacts of outsourcing on the relative demands for unskilled and skilled labor. That is, outsourcing may not only shift the relative demands for variable factors but may also affect them vis-à-vis the substitution effects among all other factors of production.

This chapter adopts a dual approach to investigating the effects of outsourcing on the relative demands for unskilled and skilled workers in Thailand's manufacturing industries by using firm-level data. I formulate a translog cost function in a more generalized fashion in such a way that there are three variable factors of production: unskilled workers, skilled workers, and raw materials,[79] with both material and service outsourcing taken into consideration. Thus the notion of outsourcing in this chapter is beyond the trade in intermediate material inputs. By using Iterative Three-stage Least Squares (I3SLS) estimation,[80] my results reveal that material outsourcing has negative impacts on the relative demands for both unskilled and skilled workers, whereas service outsourcing shifts the demands towards skilled workers at the expense of unskilled ones. Despite this, both types of outsourcing have been shown to be skill-biased, in the sense that the negative impacts of material outsourcing are more intensified for unskilled workers, whereas the positive impacts of service outsourcing are stronger for the skilled, and these more or less account for rising wage inequalities in the Thailand's manufacturing sector. Besides the *'shift'* effects of outsourcing on labor demands, I also analyze the second-order *'rotating'* effects or changes in responsiveness of a particular type of factor demand with respect to factor prices by estimating the Hicks-Allen partial elasticities of substitution. The results manifest that

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[79] The existing literatures, such as Anderton and Brenton (1999) and Geishecker (2002), assume that unskilled and skilled workers are the only variable factors of production. However, this assumption is too restrictive in the sense that it does not allow for complementarities between unskilled and skilled workers. Therefore, in this study this assumption is relaxed.

[80] As pointed out later in this chapter, there are two main econometric issues inevitably taken into considerations: invariance of parameter estimates with respect to factor share equations arbitrarily dropped and endogeneity of the quasi-fixed capital and outsourcing decisions.

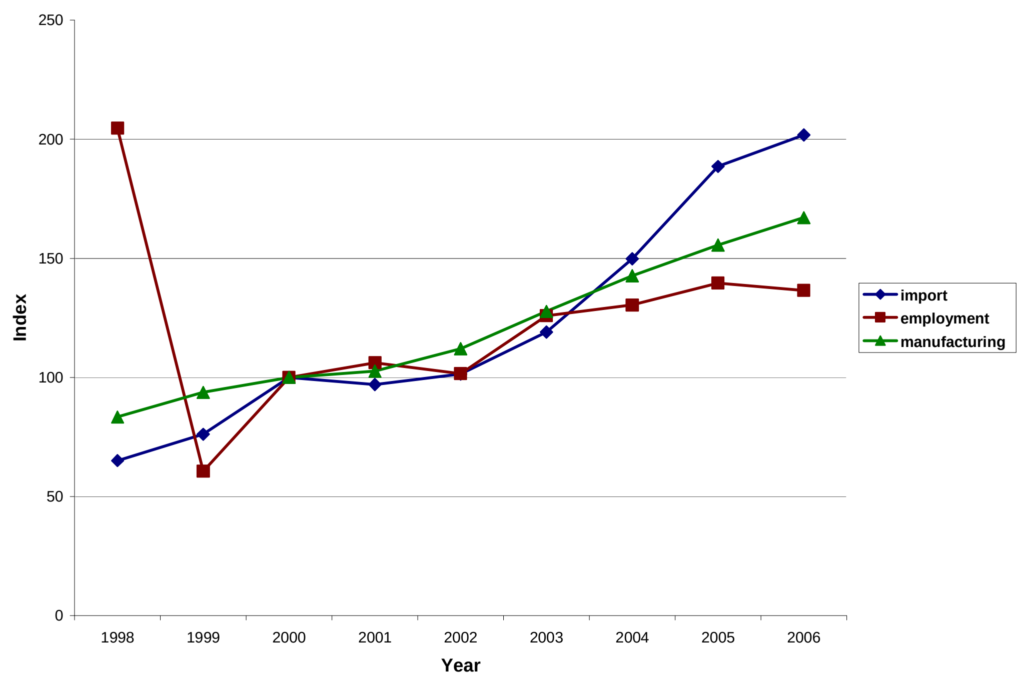
material and service outsourcing play a different role in changing substitutability of the factor inputs.

The organization of this chapter can be briefly outlined as follows. Section 4.2 is concerned with the overview of outsourcing in the Thailand's manufacturing sector. Section 4.3 will enumerate my translog cost function framework, and its extension to second-order impacts of outsourcing based on the Hicks-Allen elasticities of substitution. In Section 4.4, data sources and measurements will be discussed, and in Section 4.5 empirical results will be represented and analyzed. The concluding remarks are given in section 4.6.

4.2 Offshore Outsourcing in the Thailand's Manufacturing Sector

Figure 4.1: The Import, Employment, and Manufacturing Indices (2000 = 100)

(Source: Bank of Thailand)



The manufacturing sector is a key driving force of economic growth in Thailand economy in terms of both production and GDP contribution. Since the late 1990s, the Thailand's manufacturing sector has been characterized by sustained growth as shown by manufacturing index in Figure 4.1. This expansion can be explained by increases in both domestic and international demand for its goods.

The recent evidence suggests that the competitiveness of the Thailand's manufacturing sector has deteriorated due to increases in the domestic price level and wages. To sustain their competitiveness in the international market, local manufacturers have increasingly contracted out their business activities overseas, so called offshore outsourcing, so as to achieve more efficient operations in their production. For instance, in the plastic industry the R&D activities are internationally sourced due to the lack of technology and human capital, and the textile and fashion industries are outsourcing their marketing and packaging activities to gain more familiarity with the foreign market.

As do industrialized economies, the prevalence of outsourcing has triggered concerns of domestic job losses as its impact, at least on local workers' and public's points of view, is tantamount to 'exporting jobs'. An example can be found in the conflict between Thai Airways International Public Company Limited and its labor union (see *Bangkok Post*, February 11, 2005). The labor union protested against the outsourcing of new cabin crew to various international agencies to protect 5,200 local crew staffs.

Figure 4.2: Material Outsourcing vs. Unskilled Wage Share.

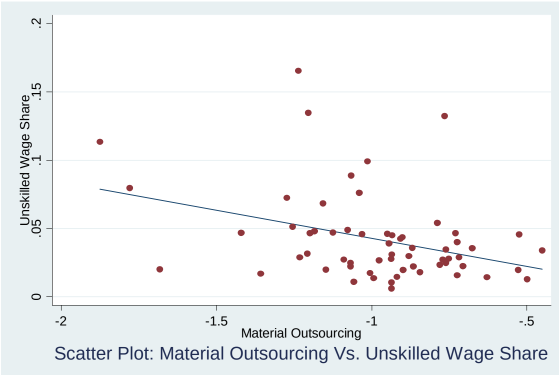


Figure 4.3: Material Outsourcing vs.Skilled Wage Share.

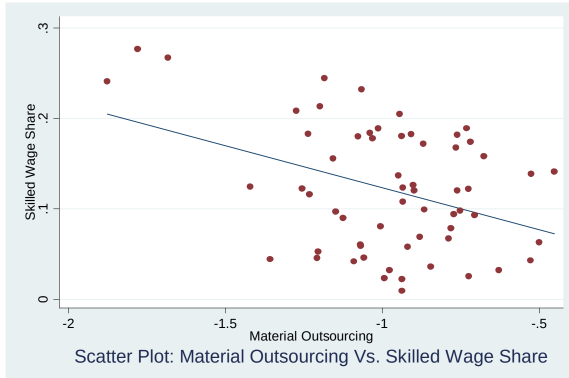


Figure 4.4: Service Outsourcing vs. Unskilled Wage Share.

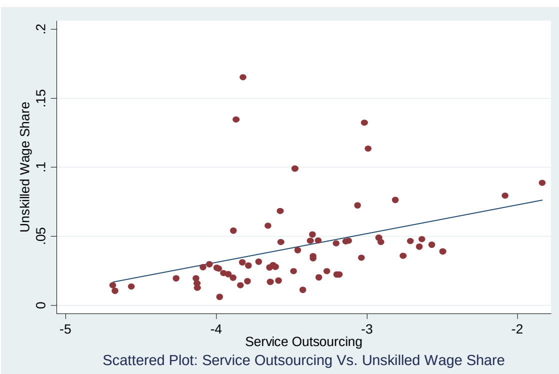
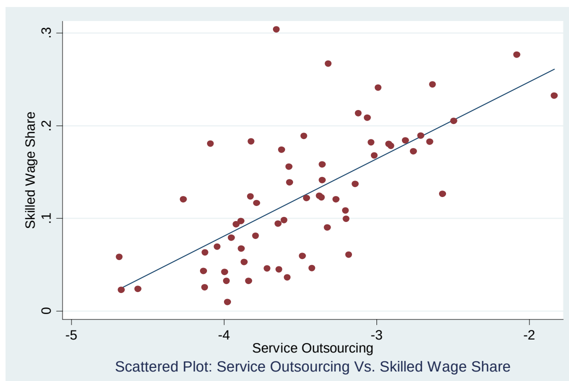


Figure 4.5: Service Outsourcing vs.Skilled Wage Share.



Figures 4.2-4.5 represent my establishment-level dataset grouped into 62 industries at 4-digit ISIC Rev.3 and averaged across the time horizon of 1999 to 2003.[81] I can discern from the Figures that material and service outsourcing affects the relative demands for unskilled and skilled workers differently. In words, material

[81] Both material and service outsourcing indexes in Figures 4.2-4.5 are represented in logarithm forms.

outsourcing seems to entail a decline in demands for both unskilled and skilled workers, which may imply that the outsourcing of intermediate inputs is labor-intensive. In contrast, service outsourcing increases the demand for both unskilled and skilled workers but it seems to be in favor of skilled workers. From the Figures above, it is clear that the 'fear of job losses' stemming from offshore outsourcing also exists in developing countries such as Thailand. In this chapter, I will analyze the impacts of both material and service outsourcing on the relative demand for unskilled and skilled workers in the manufacturing industries of Thailand.

4.3 The Empirical Model

To empirically investigate the economic impacts of outsourcing on the relative demands for skilled and unskilled workers, it is important to estimate a cost function which is sufficiently flexible to show the effects of outsourcing on the firms' labor demands. Following Morrison and Siegel (2001), my model is based on a non-homothetic variable cost function incorporating the quasi-fixed capital and *external shift* factors.[82] For a given industry *i*, where i = 1,…,n, the short-run (dual) cost function can be expressed in an implicit form as:

$$G_i = G(\mathbf{w_i}, K_i, Y_i, \mathbf{T_i}) \tag{72}$$

where $\mathbf{w_i}$ is a vector of variable input prices, including unskilled workers, skilled workers, and raw materials; K_i is the quasi-fixed capital stock; Y_i is output; and $\mathbf{T_i}$ is a vector of external trade and technological factors, including the indexes of

[82] Despite those three variable factors, my framework, unlike Morrison and Siegel's (2001), is based on the non-homothetic translog cost function rather than the Generalized Leontief cost function.

outsourcing, and technological progress.[83] Therefore, the short-run total cost function is equal to $C_i = G(\mathbf{w_i}, K_i, Y_i, \mathbf{T_i}) + w_K K_i$, where w_K is the market price of capital stock.

Somewhat different from Feenstra and Hanson (1996, 1999), my methodology is to assess whether the outsourcing variables have significantly affected the shares of unskilled and skilled workers, and whether these effects are biased towards skilled workers, thereby resulting in an increase in the relative demand for skilled workers. Following the approach of Berman, et al. (1994), by assuming that capital is a quasi-fixed factor, I will employ the non-homothetic translog functional form of a variable cost function. By assuming symmetry, i.e. $\gamma_{ij} = \gamma_{ji}$, $\phi_{ij} = \phi_{ji}$, and $\delta_{ij} = \delta_{ji}$, and temporarily dropping the time and industry subscripts, the cost function is given as:

$$\begin{aligned}
\ln G = {} & \alpha_0 + \alpha_L \ln(w_L) + \alpha_H \ln(w_H) + \alpha_M \ln(w_M) + \gamma_{HL} \ln w_H \ln w_L + \gamma_{HM} \ln w_H \ln w_M \\
& + \gamma_{LM} \ln w_L \ln w_M + \frac{1}{2}\gamma_{HH} (\ln w_H)^2 + \frac{1}{2}\gamma_{LL} (\ln w_L)^2 + \frac{1}{2}\gamma_{MM} (\ln w_M)^2 + \beta_K \ln K \\
& + \phi_{LK} \ln w_L \ln K + \phi_{HK} \ln w_H \ln K + \phi_{MK} \ln w_M \ln K + \frac{1}{2}\delta_{KK} (\ln K)^2 + \beta_Y \ln Y \\
& + \phi_{LY} \ln w_L \ln Y + \phi_{HY} \ln w_H \ln Y + \phi_{MY} \ln w_M \ln Y + \delta_{KY} \ln K \ln Y + \frac{1}{2}\delta_{YY} (\ln Y)^2 \\
& + \beta_o \ln O + \phi_{Lo} \ln w_L \ln O + \phi_{Ho} \ln w_H \ln O + \phi_{Mo} \ln w_M \ln O + \delta_{Ko} \ln K \ln O \\
& + \delta_{Yo} \ln Y \ln O + \frac{1}{2}\delta_{oo} (\ln O)^2 + \beta_T \ln T + \phi_{LT} \ln w_L \ln T + \phi_{HT} \ln w_H \ln T \\
& + \phi_{MT} \ln w_M \ln T + \delta_{KT} \ln K \ln T + \delta_{YT} \ln Y \ln T + \delta_{oT} \ln O \ln T + \frac{1}{2}\delta_{TT} (\ln T)^2 \qquad (73)
\end{aligned}$$

where O is the indexes of outsourcing, and T is the index of technological progress. For a well defined cost function, it must satisfy the condition of linear homogeneity in variable factor prices. This implies that I have to impose the following parameter restrictions on (73).

[83] As shown in next section, in the empirical estimation, I will break down the notion of outsourcing into the indexes representing material and service outsourcing.

$$\alpha_L + \alpha_H + \alpha_M = 1 \tag{74A}$$

$$\gamma_{HL} + \gamma_{HH} + \gamma_{HM} = \gamma_{LL} + \gamma_{LH} + \gamma_{LM} = \gamma_{ML} + \gamma_{MH} + \gamma_{MM} = \phi_{Lj} + \phi_{Hj} + \phi_{Mj} = 0 \tag{74B}$$

where $j = K, Y, O,$ and T. With these restrictions, I could estimate the translog cost function. Nevertheless, gains in estimation efficiency can be obtained by directly estimating the cost-minimizing variable factor demand equations, which are represented in terms of cost share equations. By employing Sheppard's Lemma and logarithmically differentiating equation (73) with respect to variable input prices, it is straightforward to show that $S_k \equiv w_k k/C \equiv \partial \ln C / \partial \ln w_k$, where k = L, H, and M. Furthermore, the adding-up condition requires that the summation of three factor shares must be equal to unity ($S_L + S_H + S_M = 1$), and therefore only two equations are linearly independent. In light of this, I choose to drop the material share equation and estimate the followings:

$$S_L = \alpha_L + \gamma_{LL} \ln w_L + \gamma_{HL} \ln w_H + \gamma_{ML} \ln w_M + \phi_{LK} \ln K + \phi_{LY} \ln Y + \phi_{Lo} \ln O + \phi_{LT} \ln T \tag{75}$$

$$S_H = \alpha_H + \gamma_{HH} \ln w_H + \gamma_{HL} \ln w_L + \gamma_{HM} \ln w_M + \phi_{HK} \ln K + \phi_{HY} \ln Y + \phi_{Ho} \ln O + \phi_{HT} \ln T \tag{76}$$

The share equations (75) and (76) can be deemed as a composite representation of the demands for unskilled and skilled labor respectively. To estimate these share equations empirically, it is indispensable to specify a stochastic framework. Typically, a random disturbance term u_k is added to each share equation and assumed to be multivariate normally distributed with the zero mean vector, $E(\mathbf{u}) = 0$, and the variance matrix, $Var(\mathbf{u}) = \Omega$. Furthermore, my model specifications also include time-specific (μ_t) and industry-specific (λ_i) dummies. These time- and industry-specific effects are meant to capture persistent industrial differences and overall technological progress affecting the industries. Accordingly, my fully specified econometric model can be portrayed as follows.

$$S_{Lit} = \alpha_L + \gamma_{LL} \ln w_{Lit} + \gamma_{HL} \ln w_{Hit} + \gamma_{ML} \ln w_{Mit} + \phi_{LK} \ln K_{it} + \phi_{LY} \ln Y_{it} + \phi_{Lo} \ln O_{it} + \phi_{LT} \ln T_{it} + \mu_t + \lambda_i + u_{Lit} \quad (77)$$

$$S_{Hit} = \alpha_H + \gamma_{HH} \ln w_{Hit} + \gamma_{HL} \ln w_{Lit} + \gamma_{HM} \ln w_{Mit} + \phi_{HK} \ln K_{it} + \phi_{HY} \ln Y_{it} + \phi_{Ho} \ln O_{it} + \phi_{LT} \ln T_{it} + \mu_t + \lambda_i + u_{Hit} \quad (78)$$

Note that, as thoroughly elaborated in next section, there are two indexes of outsourcing (O_{it}) employed in my empirical investigation, offshore outsourcing of intermediate materials (OM_{it}) and services (OS_{it}). Whereas the former aims to capture international trade in intermediate inputs as in Feenstra and Hanson (1996, 1999), the latter reflects productivity impacts of service outsourcing (see Amiti and Wei, 2006). Interestingly, the impacts of outsourcing on the relative demand for skilled workers are two-fold in developing economies. On the one hand, the positive relationship may be explained by the fact that outsourcing is in fact skill-biased (see Egger and Egger, 2006) in the sense that outsourcing entails labor productivity improvements that are biased towards skilled workers. Given the competitive labor market, outsourcing would shift the relative demand for skilled labor.[84] On the other hand, the standard Heckscher-Ohlin (H-O) Theorem suggests that outsourcing should be in favor of unskilled labor demand in developing economies, which is well-endowed in unskilled labor. Specifically, since industries in developing countries, the Thailand's manufacturing sector in my case, are well-endowed with unskilled workers, the standard H-O model predicts that firms will be specialized in unskilled-intensive production activities and import skilled-intensive intermediate inputs from developed countries. Given these opposing effects, it might be important to

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[84] Egger and Egger (2006) investigate the impacts of international outsourcing on the productivity of low skilled workers. Although they find that international outsourcing improves productivity of low-skilled labor at least in long run, the productivity impacts are biased towards high-skilled labor and capital stock, thereby reducing the relative demand for unskilled labor.

empirically identify the effects of outsourcing on the relative skilled labor demand in developing economies.

One attractive feature of the non-homothetic translog functional form of dual cost function (73) is that it does not impose any restrictions on the elasticities of substitution between two variable inputs a priori (see Berndt, 1991). It may be interesting to investigate the impacts of outsourcing on substitution among unskilled labor, skilled labor, and raw materials, as a by product of parameter estimates in the system of share equations (77) and (78). Apart from the shift effects of outsourcing on the relative demand for skilled workers as highlighted by the existing literature, the current chapter, to the best of my knowledge, is the first to empirically investigate how outsourcing affects the responsiveness of the relative demand for skilled workers with respect to factor prices. I define this second-order effect of outsourcing as the "rotating" effects henceforth. The implication of rotating effects of outsourcing on the relative demand for skilled workers is that the increases in skilled wage inequality might stem not only from the shift effects of outsourcing, but also from the changes in the competitiveness of the labor market. If, say, outsourcing is skill-biased and reduces elasticities of substitution between skilled and unskilled labor, the impacts of outsourcing on skilled wage inequality are magnified since the relative wage must increase considerably in order to eliminate the relative excess demand for skilled labor. The rotating effects could be determined by the elasticities of substitution between unskilled and skilled labor. By using parameter estimates from equation (77) and (78) and the fitted variable factor shares, the Hicks-Allen partial elasticities of substitution between two variable inputs i and j for general dual cost function G can be measured as:

$$\sigma_{ij} = \frac{G \cdot G_{ij}}{G_i G_j} \tag{79}$$

where the i, $j = L$, H, and M subscripts denote the first and second partial derivatives of the dual cost function in equation (73) with respect to input price, w_i and w_j, respectively. By using equations (73) and (79), it can be shown that

$$\sigma_{ij} = \begin{cases} \dfrac{\gamma_{ii}}{S_i^2} + 1 - \dfrac{1}{S_i} & ,if \quad i = j \\ \dfrac{\gamma_{ij}}{S_i S_j} + 1 & ,if \quad i \neq j \end{cases} \tag{80}$$

By differentiating equation (80) with respect to the outsourcing variable, $\ln O$, I can show that the marginal effects of outsourcing on the elasticities of substitution between variable factors *i* and *j* are:[85]

$$\frac{\partial \sigma_{ij}}{\partial \ln O} = \begin{cases} \phi_{io} \left[-\dfrac{2\gamma_{ii}}{(S_i)^3} + \dfrac{1}{(S_i)^2} \right] & ,if \quad i = j \\ -\dfrac{\gamma_{ij}}{(S_i S_j)^2} \left(\phi_{io} S_j + \phi_{jo} S_i \right) & ,if \quad i \neq j \end{cases} \tag{81}$$

Next, I will move into the discussions of the estimation technique for equations (77) and (78). Although the equation-by-equation OLS estimation might be appealing since the unskilled and skilled labor shares (77) and (78) are linear in the parameters, these demand equations are required to satisfy cross-equation symmetry and linear homogeneity constraints. Even if those constraints are satisfied asymptotically, equation-by-equation OLS estimates will not reveal such parameter restrictions. To impose the cross-equation constraints (74A-B), it is inevitable instead to employ a system of regression equations.

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[85] Note that the logarithm prevails only in the denominator of (81) in order to be consistent with the typical specification of biases. See Morrison (1988) for more details regarding the bias specification.

One possibility is to employ the Zellner's seemingly unrelated (SUR, henceforth) estimator (see Zellner, 1962). In my context, SUR is superior to equation-by-equation OLS estimators for two reasons. First, despite the absence of the cross-equation constraints, SUR can account for the fact that the disturbances across the labor share equations are contemporaneously correlated, implying that the covariance matrix Ω is non-diagonal. In this sense, equation-by-equation OLS estimates are inconsistent Second, by taking into account the cross-equation correlations of the disturbances, SUR estimators are more efficient than equation-by-equation OLS estimates at least asymptotically.

In general, the SUR estimation is carried out by two steps. In the first step, the disturbance covariance matrix Ω is obtained from equation-by-equation OLS estimations. The Generalized Least Squares (GLS), given the initial estimated Ω from the first step, are then applied on the sets of equations. I also perform the efficient estimation based on the iterative two-step SUR (ISUR) estimation in which the estimates of Ω and the Zellner's procedure are updated and iterated. This iterative procedure yields efficient estimators that are numerically equivalent to those of maximum likelihood (ML) estimators.[86] This result is particularly advantageous for my estimation results in the sense that the parameter estimates are invariant to the choices of share equations arbitrarily dropped due to the adding-up condition.[87] Fortunately, as suggested by Berndt (1991), as long as the ISUR estimation is utilized,

[86] See Oberhofer and Kmenta (1974) for a proof of this result.
[87] If this invariant property is absent, it would be problematic for my estimation results since one may choose to drop the share equations that yield the results that are the most consistent with their prior belief or judgments.

all parameter estimates and estimated covariance matrix Ω are invariant to the choices of factor share equations used in the estimation.[88]

As argued by Amiti and Wei (2006), there may also be a problem of potential endogeneity of outsourcing. Intuitively, the decisions to outsource may be affected by industry-specific factors, such as the exposure to international trade and foreign ownership. Feenstra and Hanson (1997) find the evidence in Mexico that exporters are more likely to deal with outsourcing activities. Due to the existence of incomplete contract and unverifiable firm-specific investment, an infant industry should be less likely to contract out production activities. Moreover, more productive firms may be self-selected to be engaged in outsourcing activities. Besides outsourcing indexes, the discussions of my econometric approach enumerated thus far have to do closely with a short-run cost function in which the capital stock is partially adjusted and therefore quasi-fixed. As noted by Morrison (1999), the quasi-fixed capital is likely to be correlated with industry-specific factors, thereby entailing the potential endogeneity problem in SUR and ISUR estimations.[89] To account for this problem, the quasi-fixed capital (K) and the indexes of material (OM) and service (OS) outsourcing will be instrumented by the lagged structural variables (see Pindyck and Rotemberg, 1983), the indexes representing foreign ownership ($FHOLD$) and exposure to international trade ($EXPORT$). I will relegate the measurement of these IVs to next section. The first-stage regression can be portrayed as follows.[90]

$$\underset{}{\ln K_{it}} = \underset{(.8601)}{22.6837^{***}} + \underset{(.0400)}{.0248}\ln K_{it-1} + \underset{(.2184)}{.7977^{***}} \ln FHOLD_{it} - \underset{(.2502)}{.4892^{*}} \ln EXPORT_{it}$$

[88] The invariant property of dropping share equations also holds for SUR estimation provided that the estimated Ω is estimated by the equation-by-equation OLS estimation without the symmetry conditions imposed.

[89] Amiti and Wei (2006) argue that the endogeneity problem may also exist in outsourcing variables. Nevertheless, due to the existence of the incomplete contract and firm-specific investment (see Grossman and Helpman, 2002), they, at least in short run, can be treated as exogenously given.

[90] The asterisks ***, **, and * are statistical significance at 1, 5, and 10 percent levels, respectively. The robust standard errors are reported in parentheses.

$R^2 = .0512 \quad F = 4.12^{***}$

$$\ln OM_{it} = -.7050^{***} - .0272 \ln OM_{it-1} + .1522^{***} \ln FHOLD_{it} - .0381 \ln EXPORT_{it}$$
$$(.0851) \quad (.0567) \qquad (.0547) \qquad (.0514)$$

$R^2 = .1674 \quad F = 6.56^{***}$

$$\ln OS_{it} = -4.0279^{***} - .1369^{**} \ln OS_{it-1} + .1391 \ln FHOLD_{it} - .3694^{**} \ln EXPORT_{it}$$
$$(.3279) \quad (.0570) \qquad (.1494) \qquad (.1788)$$

$R^2 = .0635 \quad F = 4.11^{***}$

The industries with high foreign ownership are characterized by high quasi-fixed capital and material outsourcing activities, and hence the index of foreign ownership may be a good IV for quasi-fixed capital and material outsourcing. Moreover, the results reveal that the industries with high exposure to the international market tend to have low quasi-fixed capital and service outsourcing. In this sense, the index of international trade exposure is strongly correlated with quasi-fixed capital and service outsourcing.

It should also be noted these firm's characteristics at least in short run should be exogenous to the firms and strongly correlated to the exposure to outsourcing activities and capital utilization. Therefore, they satisfy the general requirements of the instrumental variables. The measurement details will be elaborated in next section. Given this potential econometric problem, the three-stage least squares (3SLS) estimation will also violate the invariant property of share equation choices to be eliminated if the symmetry condition is imposed. To account for both endogeneity problem and invariant property, the iterative three-stage least squares (I3SLS) estimation will be employed. Not only does the I3SLS estimation have its asymptotic consistency, but it can also be shown that my I3SLS is asymptotically efficient if the instruments satisfy the general requirements of IV estimators.[91]

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[91] Schmidt (1976) shows that the 3SLS estimator is more efficient than the 2SLS one asymptotically.

4.4 Data Measurement

For my empirical estimations, I primarily employ the establishment-level data retrieved from the reports of the Manufacturing Industry Survey for 1999-2003,[92] provided by the National Statistical Office (NSO), Thailand. These datasets contain basic establishment-level information on manufacturing, such as the number of establishments; the number of persons engaged; the number of employees; the value of raw materials, parts, and components purchased; and the value of fixed assets, etc. In each year, there were approximately 5,000-8,000 establishments engaged in this survey.

According to the survey, the establishments engaged in manufacturing are defined as the mechanical or chemical transformation of substances into new products. The assembly of component parts of manufactured products is also considered as manufacturing. In this survey, the manufacturing industry activities are classified according to 4-digit ISIC Rev.3. With establishments as the sampling units, the survey covered the 62 types of manufacturing activities (4-digit ISIC) in 21 industries (2-digit ISIC). The description of manufacturing aggregated at 2-digit ISIC is portrayed in Table 4.1.

One major problem of my datasets is that firms' identification numbers, due probably to confidential purposes, were not reported. Therefore, the only way to pool four datasets for four years altogether is to aggregate them at 4-digit ISIC level, yielding us 62 manufacturing industries. In the estimation of factor share equations (77) and (78), 4-digit ISIC industries are classified into three sub-industries according

[92] The dataset in 2002 is absent because NSO did not conduct this survey in this year.

to their technology intensities (see Table 4.2 for details) of low, medium, and high technology industries.[93]

Table 4.1: The descriptions of industry classification (ISIC Rev.3)

Industry	Description
1	Manufacture of food products and beverages
2	Manufacture of tobacco products
3	Manufacture of textiles
4	Manufacture of wearing apparel; dressing and dyeing of fur
5	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
6	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
7	Manufacture of paper and paper products
8	Publishing, printing and reproduction of recorded media
9	Manufacture of coke, refined petroleum products and nuclear fuel
10	Manufacture of chemicals and chemical products
11	Manufacture of rubber and plastics products
12	Manufacture of other non-metallic mineral products
13	Manufacture of basic metals
14	Manufacture of fabricated metal products, except machinery and equipment
15	Manufacture of machinery and equipment n.e.c.
16	Manufacture of office, accounting and computing machinery
17	Manufacture of electrical machinery and apparatus n.e.c.
18	Manufacture of radio, television and communication equipment and apparatus
19	Manufacture of medical, precision and optical instruments, watches and clocks
20	Manufacture of motor vehicles, trailers and semi-trailers
21	Manufacture of other transport equipment
22	Manufacture of furniture; manufacturing n.e.c.
23	Recycling

[93] I group the manufacturing industries into three sub-industries, namely low-, medium-, and high-technology industries. The primary manufactures, such as food, tobacco, textile, and wood product, are regarded as low-technology industries. In contrast, more sophisticated production, such as chemical, metal, computer, machinery, electronic product, medical product, and motor vehicle, is classified as high-technology industries. The rest are defined as medium-technology industries.

Table 4.2: Technology Level Classification.

Technology Level	Industry
Low	1-6
Medium	7-9, 11-12, 22-23
High	10, 13-21

The dataset is constructed by pooling firms across four-digit ISIC level from 1999-2003. The unskilled labor share (S_L) is proxied by the ratio of the production worker wage bill to the total production cost (total wage bill plus material cost), and the skilled labor share (S_H) is likewise measured by the ratio of non-production worker wage bill to the total production cost. Except for the price of materials, the data for unskilled (w_L) and skilled (w_H) wages (i.e., production and non-production average wages) can be directly retrieved from the datasets. In addition, the capital stock (K_i) is proxied by the value of land, building and construction, and machinery and equipment at the end of each consecutive year, whereas the total output (Y_i) is approximated by the sales of goods produced.

Unlike unskilled and skilled wages, my datasets do not report the average material price (w_M). I derived the price index of raw material inputs by making use of the Annual Input-Output tables retrieved from Office of the National Economic and Social Development Board (NESDB), together with the annual producer price indexes at 2-digit ISIC level from Bank of Thailand (BOT).

There are two relevant indexes of offshore outsourcing utilized in my empirical estimation: material outsourcing (OM_i) and service outsourcing (OS_i). Following Morrison and Siegel (2001), the intensity of service outsourcing is approximated by the ratio of services purchased to total production cost. According to my dataset from NSO, there are two types of service purchases reported: cost of contract and commission work and cost of repair and maintenance work done by others. In contrast, the index of material outsourcing is defined in the same fashion as the 'wide' definition of international outsourcing (see Feenstra and Hanson, 1996).[94] Specifically,

$$OM_i = \sum_j \frac{imported \quad intermediate \quad input \quad j \quad by \quad industry \quad i}{total \quad intermediate \quad inputs \quad used \quad by \quad industry \quad i}. \qquad (82)$$

The index of technological progress (T_i) is essentially represented by the intensities of R&D activities (Anderton and Brenton, 1999). As such, this index is proxied by the ratio of research, planning, and development cost to total expense of the establishment.

In addition to variables used in the structural system of labor share equations, I also need to create proxies for instrumental variables (IV) to tackle with the potential problem of endogeneity. As discussed in the previous section, the quasi-fixed capital and outsourcing decisions are likely to be endogenously determined by, in addition to lagged values of structural variables, industry-specific factors, including the proportions of foreign owned firms and exporters. Classified by four-digit ISIC manufacturing industries, the proportion of foreign owned firms ($FHOLD$) are proxied by the number of firms with foreign share holding to the total number of firms in that industry. Likewise, the proportion of exporters ($EXPORT$) is measured by the ratio of the number of firms engaged in exporting activities to the total number of firms in that industry.

[94] In Feenstra and Hanson (1996), the index of material outsourcing is measured by combining production data with the annual input-output table to proxy the imported intermediate inputs. However, since the imported intermediate inputs can be directly extracted from my datasets, I can employ the idea of the wide measure of material outsourcing directly.

4.5 Empirical Results

4.5.1 Impacts of Outsourcing on the Demands for Unskilled and Skilled Workers

In this section, the empirical results from the translog cost function are reported. I first report the results in Tables 4.3-4.5 based on the full sample of my data.

Table 4.3: Zellner's Seemingly Unrelated Regression (SUR) Estimates, Thailand's Manufacturing, 1999-2003.

Independent Var.	**Share Equations**	
	Unskilled Share (S_L)	**Skilled Share (S_H)**
$\ln w_L$	0.0105(.0059)*	0.0099(.0052)*
$\ln w_H$	0.0099(.0052)*	-0.0454(.0098)***
$\ln w_M$	-0.0204(.0063)***	0.0354(.0112)***
$\ln K$	-0.0049(.0031)	0.0037(.0059)
$\ln Y$	-0.0023(.0034)	-0.0222(.0065)***
$\ln OM$	-0.0267(.0063)***	-0.0096(.0123)
$\ln OS$	0.0084(.0026)***	0.0397(.0051)***
$\ln T$	0.0028(.0013)**	0.0041(.0025)
Constant	0.0862(.0466)*	0.9933(.0876)***
No. of Obs.	232	232
R-squared	0.3378	0.5608
Chi-squared (p-value)	117.29(0.000)***	309.67(0.000)***
Correlation of Residual	0.3630	
Breusch-Pagan Test (p-value)	30.563(0.000)***	

Note: 1) Standard error is in parentheses. 2) * statistically significant at 10 percent. 3) ** statistically significant at 5 percent. 4) *** statistically significant at 1 percent 5) Breusch-Pagan Test is distributed as the Chi-squared distribution with one degree of freedom under the null that there is no industry- and time- specific effects jointly.

Tables 4.3 and 4.4 highlights the preliminary results based on SUR and ISUR estimations. The results from both SUR and ISUR are qualitatively the same. The Chi-squared statistics reveal that the null hypothesis that all coefficients are jointly equal to zero is rejected at 1 % level of statistical significance with R-squared equal to 0.338 and 0.561 for unskilled and skilled share equations respectively. With the correlation of residuals between two equations equal to 0.363 and 0.364 for SUR and ISUR estimations respectively, the Breusch-Pagan Test rejects the null that there are no industry- and time-specific effects, and therefore the inclusion of industry- and time-specific dummies seems justified.[95] According to both estimations, I find the following interesting results.

Table 4.4: Iterative Zellner's Seemingly Unrelated Regression (ISUR) Estimates, Thailand's Manufacturing, 1999-2003.

Independent Var.	**Share Equations**	
	Unskilled Share (S_L)	**Skilled Share (S_H)**
$\ln w_L$	0.0105(.0059)*	0.0100(.0052)*
$\ln w_H$	0.0100(.0052)*	-0.0453(.0097)***
$\ln w_M$	-0.0205(.0063)***	0.0353(.0112)***
$\ln K$	-0.0049(.0031)	0.0036(.0058)
$\ln Y$	-0.0023(.0034)	-0.0222(.0065)***
$\ln OM$	-0.0267(.0062)***	-0.0095(.0122)
$\ln OS$	0.0084(.0025)***	0.0397(.0050)***
$\ln T$	0.0027(.0013)**	0.0040(.0026)
Constant	0.0861(.0464)*	0.9932(.0878)***
No. of Obs.	232	232
R-squared	0.3378	0.5608
Chi-squared (p-value)	118.02(0.000)***	308.89(0.000)***
Correlation of Residual	0.3643	
Breusch-Pagan Test (p-value)	30.784(0.000)***	

Note: 1) Standard error is in parentheses. 2) * statistically significant at 10 percent. 3) ** statistically significant at 5 percent. 4) *** statistically significant at 1 percent 5) Breusch-Pagan Test is distributed as the Chi-squared distribution with one degree of freedom under the null that there is no industry- and time- specific effects jointly.

Firstly, both unskilled and skilled workers are substitutes since the coefficient of $\ln w_H$ (γ_{Hl}) in the unskilled share equation[96] is positive and statistically significant. Meanwhile, the price of raw materials has a positive impact on the demand for skilled workers but a negative impact for the demand for unskilled workers.[97] Secondly, the quasi-fixed capital, though statistically insignificant, is positively correlated with skilled labor, implying that the higher amount of the quasi-fixed capital induces firms

[95] I suppress the coefficients of industry- and time-specific dummies in the tables for economizing space.

[96] The linear homogeneity and symmetry restrictions (74A-B)) imply that the coefficient of $\ln w_H$ (γ_{Hl}) in the unskilled share equation must be equal to that of $\ln w_L$ in the skilled one.

[97] Since the dependent variables are the factor shares, I cannot infer whether unskilled and skilled workers are substitutes for or complementary with material inputs. As shown later, the Hicks-Allen elasticities of substitution show that material inputs are substitutes for both unskilled and skilled workers and are skill-biased.

to shift the relative demand away from unskilled labor to skilled one. Thirdly, the expansion of output (economies of scale) reduces both unskilled and skilled shares, thereby raising the raw material share. This may be explained by the presence of labor market rigidities in the short run. Intuitively, in the short run I could expect the labor market frictions that may hinder firms to fully adjust workers to meet the production demands, thereby confining firms to increase the use of material inputs when production increases. Fourthly, material outsourcing ($\ln OM$) has a negative impact on both labor demands with a more significant impact on unskilled workers.[98] As shown in Tables 4.3 and 4.4, the estimation results reveal that internationally sourcing of intermediate inputs results in a decline in both relative demands for unskilled and skilled workers, which in turn implies positive impacts on the relative demands for materials. Intuitively, according to standard Heckscher-Ohlin Theorem, the negative impacts of material outsourcing may suggest that the Thailand's manufacturing industries may import labor-intensive intermediate inputs, reducing the demands for domestically employed labor. In this sense, the estimated coefficients reveal that the effect of material outsourcing in the Thailand's manufacturing industries is analogous to those observed in industrialized countries in terms of 'exporting jobs'. Moreover, my results indicate that such negative impacts are more pronounced for unskilled workers due mainly to the imports of unskilled-intensive intermediate inputs. Fifthly, the effects of service outsourcing ($\ln OS$) shift the relative demand for both skilled and unskilled labor. However, the increase in service outsourcing tends to augment the demand for skilled labor relative to that for the

[98] The coefficients of $\ln OM$ in both equations are negative, but only the former is statistically significant at 1 percent level.

unskilled.[99] This may suggest that on the one hand contracting out service activities may enable firms to reap benefits from reallocating labor to core-competent activities, thereby entailing gains from specialization. On the other hand, service activities, such as maintenance, call operators, recruitment, etc., in general are unskilled-intensive. Therefore, outsourcing service activities is more likely to be skill-biased such that an outward shift in the relative demand for skilled workers is greater than that for unskilled ones. Lastly, technological progress is labor-augmenting in the sense that the greater intensities of R&D activities imply the greater relative demands for all types of workers.[100] It can also be observed that labor-augmenting effects of technological progress are also skill-biased in the sense that the magnitude of a shift in the relative demand for skilled workers is more enormous than that for unskilled ones. Given unchanged physical labor inputs, the labor-augmenting effects of technological progress entail increases in 'efficiency units' of labor, which in turn shift their relative demands outwards.

To account for a potential endogeneity problem in both SUR and ISUR estimations, Table 4.5 shows the Iterative Three-stage Least Squares (I3SLS) results in which the quasi-fixed capital ($\ln K$), material outsourcing ($\ln OM$), and service outsourcing ($\ln OS$) are instrumented by the lagged values of structural variables and industry-specific factors, including the intensities of foreign ownership and exporters. In light of this, Hausman specification test asserts that the null hypothesis of no endogeneity problem can be rejected with the 1 percent level of significance (as a corollary, the parameter estimates under SUR and ISUR are inconsistent).

[99] The coefficients of $\ln OS$ in the unskilled and skilled share equations are positive and statistically significant at 1 percent level.

[100] Although the coefficient of $\ln T$ in the skilled share equation is greater than that in unskilled one, only the latter is statistically significant at 5 percent level.

Table 4.5: Iterative Three-stage Least Squares (I3SLS) Estimates, Thailand's Manufacturing, 1999-2003.

Independent Var.	**Share Equations**	
	Unskilled Share (S_L)	**Skilled Share (S_H)**
$\ln w_L$	-0.0167(.0085)**	0.0115(.0073)
$\ln w_H$	0.0115(.0073)	-0.0509(.0141)***
$\ln w_M$	0.0052(.0075)	0.0395(.0150)***
$\ln K$	0.0178(.0096)*	-0.0044(.0179)
$\ln Y$	-0.0233(.0099)**	-0.0111(.0191)
$\ln OM$	-0.0435(.0224)*	-0.0035(.0490)
$\ln OS$	-0.0027(.0119)	0.0620(.0270)**
$\ln T$	0.0035(.0016)**	0.0062(.0036)*
Constant	0.1780(.0628)***	1.0452(.1283)***
No. of Obs.	158	158
R-squared	0.2998	0.5524
Chi-squared (p-value)	110.27(.000)***	199.68(.000)***
Hausman Test (p-value)	114.49(.000)***	

Note: 1) Standard error is in parentheses. 2) * statistically significant at 10 percent. 3) ** statistically significant at 5 percent. 4) *** statistically significant at 1 percent. 5) $\ln K$, $\ln OM$ and $\ln OS$ are RHS endogenous and instrumented by lagged structural variables and industry-specific variables in logarithm forms, including the ratio of foreign-owned firms to the total number of firms, and the ratio of exporters to the total number of firms. 6) Hausman Specification Test Statistic is distributed as the Chi-squared distribution with 24 degree of freedom under the null of no endogeneity problem.

In contrast with the results under SUR and ISUR discussed thus far, the parameter estimates under I3SLS yield us interesting results. Firstly, the coefficient of $\ln w_L$ in unskilled share equation (γ_{Hl}) turns out to be negative and statistically significant at 5 percent level. This ensures that the estimated translog cost function is well behaved. Secondly, the extent to which unskilled and skilled workers are substitutes still holds in I3SLS even accounting for the endogeneity in the estimation. Thirdly, the new results indicate that material inputs are substitutes for both unskilled and skilled labor. This suggests that an increase in material prices ($\ln w_M$) results in outward shifts of relative demands for both types of labor. Thirdly, the effects of the quasi-fixed capital on the relative demand for unskilled and skilled workers are reversed in the sense that it is complementary with unskilled workers but substitutable for skilled ones. This result is consistent with Helg and Tajoli (2005) who studied the labor market effects of international outsourcing, proxied by outward processing trade, based on Italy and German data during 1990s. They find that capital stock has negative impacts for demands for skilled workers. Lastly, the impact of service outsourcing on the relative demand for unskilled workers is negative, though statistically insignificant. This result strongly supports the fact that service activities are unskilled-intensive, and therefore firms sourcing those activities at arm's length prone to demand less unskilled workers. Meanwhile, gains from specializing in core-competent activities are reaped by skilled labor, thereby raising their relative demands.

Despite some differences, my main findings concerned with the impacts of international material outsourcing on the relative demands for unskilled and skilled workers remain qualitatively unchanged with I3SLS. Specifically, the negative impacts of material outsourcing on both labor demands are still observed. Therefore, the fear of job losses in most industrialized economies is also observable for the developing countries. Furthermore, the fact that technological progress is in terms of skilled- and unskilled-augmenting effects is still observed, and technological improvement will augment the physical labor, thereby increasing their efficiency units and shifting their relative demands. Further, the results from I3SLS reveals that the factor-augmenting effects of service outsourcing seem more pronounced for skilled workers.

Interestingly, as shown in Table 4.5, my empirical results are also consistent with the literature concerned with outsourcing and wage inequality in such a way that the coefficients of materials ($\ln OM$) and services ($\ln OS$) in the skilled share equation are always greater than those in the unskilled one. Given this, the prevalence of outsourcing activities will give rise to the widened gap between skilled and unskilled income. This result is particularly consistent with a number of literatures in relation to industrialized economies (see Feenstra and Hanson, 1996, 1999, Anderton and Brenton, 1999, and Geishecker, 2002 among others).

I further divide the data by levels of technology of the industries to analyze the impacts of outsourcing on the relative demands for unskilled and skilled labor. Given the possibilities that outsourcing may affect those demands according to industry-specific characteristics, it may be desirable to carry out the analogous econometric methodology on an individual industry. Since Hausman specification test reported in Table 4.5 portrays that the SUR and ISUR results may in fact suffer from the endogeneity problem and hence results in inconsistent parameter estimates, I will focus on deriving the results corresponding to I3SLS. In so doing, I will segregate the Thailand's manufacturing sector into three sub-sectors based on their technology levels, i.e., low-, medium-, and high-technology industries. The details of this classification are shown in Table 4.2.

Table 4.6: Iterative Three-stage Least Squares (I3SLS) Estimates by Thailand's Manufacturing industries, 1999-2003.

Independent Var.	**Low Technology Industries**		**Medium Technology Industries**		**High Technology Industries**	
	Unskilled Share (S_L)	**Skilled Share (S_H)**	**Unskilled Share (S_L)**	**Skilled Share (S_H)**	**Unskilled Share (S_L)**	**Skilled Share (S_H)**
$\ln w_L$	0.0073(.009)	0.0302(.014)**	-0.0239(.013)*	0.0133(.014)	-0.0217(.01)***	0.0103(.007)
$\ln w_H$	0.0303(.014)**	0.0463(.053)	0.0133(.014)	-0.124(.030)***	0.0102(.007)	-0.0332(.019)*
$\ln w_M$	-0.0376(.02)**	-0.0765(.065)	0.0107(.019)	0.1107(.036)***	0.0114(.008)	0.0229(.022)
$\ln K$	0.0278(.008)***	0.0978(.031)***	0.0227(.014)	0.0256(.026)	-0.0072(.008)	-0.0313(.023)
$\ln Y$	-0.0309(.01)***	-0.114(.033)***	-0.038(.014)***	-0.0430(.025)*	0.0067(.009)	0.0152(.026)
$\ln OM$	0.0640(.026)**	0.2206(.102)**	-0.0162(.020)	-0.0212(.040)	-0.0421(.021)**	-0.0153(.062)
$\ln OS$	0.0150(.011)	0.0689(.042)*	0.0051(.013)	0.0646(.026)**	0.0170(.005)***	0.0601(.016)***
$\ln T$	0.0078(.003)**	0.0191(.013)	0.0088(.003)***	0.0047(.006)	0.0015(.001)	0.0073(.004)**
Constant	0.0302(.123)	0.6344(.461)	0.5222(.165)***	1.6009(.329)***	0.1465(.040)***	0.8892(.115)***
No. of Obs.	31	31	51	51	76	76
R-squared	0.2023	0.2593	0.4549	0.5663	0.4648	0.6337
Chi-squared (p-value)	22.78(.012)**	32.01(.000)***	55.54(.000)***	65.64(.000)***	80.44(.000)***	161.18(.000)***
Hausman Test (p-value)	32.61(.027)**		7.76(0.9889)		25.12(0.1565)	

Note: 1) Standard error is in parentheses. 2) * statistically significant at 10 percent. 3) ** statistically significant at 5 percent. 4) *** statistically significant at 1 percent. 5) $\ln K$, $\ln OM$ and $\ln OS$ are RHS endogenous and instrumented by the lagged structural variables and industry-specific variables in logarithm forms, including the ratio of foreign-owned firms to the total number of firms, and the ratio of exporters to the total number of firms. 6) Hausman Specification Test Statistic is distributed as the Chi-squared distribution with 20 degree of freedom under the null of no endogeneity problem.

As shown in Table 4.6, when the overall manufacturing industries are disaggregated according to their skill intensities, the null hypothesis of no endogeneity problem cannot be rejected except for unskilled-intensive industries. Essentially, the main findings from Table 4.6 can be summarized as follows. First, unskilled and skilled workers are substitutes for all industries, and the degree of their substitution seems to be the strongest in low technology industries. Second, material inputs are substitutes for workers employed only in medium and high technology industries whereas an increase in material prices will cause a decrease in the relative demands for those employed in low technology industries.[101] Third, the quasi-fixed capital ($\ln K$) seems to be complementary with those employed in low technology industries. In addition, albeit statistically insignificant, my results show that capital and labor are complementary in medium technology industries but are substitutes in high technology industries. Fourth, short-run rigidities of labor and capital adjustments may account for the fact that expansion of final output production requires higher relative demands for material inputs, in turn entailing a significant decline in the relative demands for unskilled and skilled labor. These negative impacts of output expansions ($\ln Y$) prevail only in low and medium technology industries. In high technology industries, the impacts of output expansion on the relative demands for both types of labor, though statistically insignificant, are positive. Fifth, the separation of the manufacturing sector into three sub-sectors implies that labor employed in different industries may be affected differently by material outsourcing. More specifically, the results that material outsourcing ($\ln OM$) leads to a decline in the relative demands for unskilled and skilled workers prevail solely in

[101] As portrayed in Table 4.6, in low technology industries, the effects of $\ln w_M$ are significant only for the unskilled share; in medium technology industries, merely skilled workers are significantly affected by material prices; and, neither unskilled nor skilled shares is significantly affected in high technology industries.

medium and high technology industries. However, a statistically significant and positive relationship between material outsourcing and the relative labor demands does characterize low technology industries. Intuitively, these may be interpreted as the fact that manufactures in medium and high technology industries internationally source labor-intensive intermediate inputs, while those in low technology industries may choose to contract out capital-intensive ones. Sixth, with regard to the impacts of service outsourcing ($\ln OS$) on the relative labor demands, I find that, unlike those of SUR and ISUR, service outsourcing entails a positive effects on the relative demands for both unskilled and skilled workers, and the effects are particularly significant in high technology industries. It is also noteworthy that, as explained earlier, service outsourcing is skill-biased since service activities contracted out are in general unskilled-intensive, and therefore the positive impacts on skilled labor demand are more pronounced. Lastly, my results of labor-augmenting technological progress ($\ln T$) are rather robust in the sense that it does shift the demands for both types of labor outwards across all sub-sectors as their productivity, in terms of efficiency units, increases.

Furthermore, with regard to the role of outsourcing as an explanatory for rising wage inequality, increases in material and service outsourcing can enlarge the wage differential across skilled groups in low technology and high technology industries. In other words, since the coefficients of $\ln OM$ and $\ln OS$ are greater in the skilled share equation in those industries, material and service outsourcing is skill-biased and thus brings about larger wage inequalities. Nevertheless, I can only observe such effects for service outsourcing in medium technology industries.

4.5.2 Impacts of Outsourcing on Factors Substitution

As elaborated in Section 4.3, my next step is to utilize the estimation results from the previous sub-section to study the impacts of outsourcing on (variable) factors substitution as proxied by their Hicks-Allen partial elasticities of substitution. To figure out elasticities of substitution, I employ parameter estimates based on I3SLS so as to account for invariance of parameter estimates with respect to the share equation dropped and the potential endogeneity problem, and all calculations are evaluated at the fitted means of factor shares.

By using parameter estimates of I3SLS in Table 4.5, the Hicks-Allen elasticities of substitution as in (80) can be represented in matrix form as follows.

$$\begin{bmatrix} \sigma_{LL} & \sigma_{LH} & \sigma_{LM} \\ & \sigma_{HH} & \sigma_{HM} \\ & & \sigma_{MM} \end{bmatrix} = \begin{bmatrix} -33.58 & 3.27 & 1.15 \\ & -10.38 & 1.38 \\ & & -0.26 \end{bmatrix} \tag{83}$$

As shown in (83), the diagonal elements, representing own price elasticities, are all negative, which implies that the translog cost function estimated is well behaved. Furthermore, it can also be seen that the demand for unskilled labor is the most elastic, and thus they are the most vulnerable to a change in their wages. In contrast, raw materials are the least sensitive to changes in their prices. The off-diagonal elements in (83) portray the elasticities of substitution between two variable factors. Apparently, all variable factors, unskilled labor, skilled labor, and raw materials are substitutes.

Next, I calculate the marginal effects of material and service outsourcing by using (81). The impacts of material outsourcing on substitutions among variable factors of production are given in (84).

$$\begin{bmatrix} \partial\sigma_{LL}/\partial\ln OM & \partial\sigma_{LH}/\partial\ln OM & \partial\sigma_{LM}/\partial\ln OM \\ & \partial\sigma_{HH}/\partial\ln OM & \partial\sigma_{HM}/\partial\ln OM \\ & & \partial\sigma_{MM}/\partial\ln OM \end{bmatrix} = \begin{bmatrix} -47.64 & 2.49 & 0.155 \\ & -0.41 & -0.011 \\ & & 0.075 \end{bmatrix} \tag{84}$$

As shown in (84), material outsourcing increases the own price elasticities of the unskilled and skilled labor demands in the sense that when firms become more specialized in some particular core-competent activities, the existing workers are prone to be more vulnerable to changes in their own returns.[102] This suggests that the notion of material outsourcing not only shifts the relative demands for unskilled and skilled workers, but also increases the responsiveness of their demands. Intuitively, as material outsourcing opportunities become more feasible, firms' labor demands are more responsive to changes in their wages. Unlike those of unskilled and skilled workers, the elasticities of raw materials seem to be negatively correlated with material outsourcing; that is, when firms decide to internationally source intermediate inputs, the demands for raw material become more inelastic. This may be explained by the fact that material outsourcing requires firms to customize their raw materials used to be perfectly compatible with intermediate inputs produced at arm's length, thereby making them less sensitive to their price changes.

Regarding the substitution between variable factors of production, material outsourcing tends to have a positive impacts on the substitution between unskilled and skilled workers and between unskilled and raw materials, but negative, though negligible, impacts on the substitution between skilled workers and raw materials. This suggests that material outsourcing makes unskilled workers more substitutable by skilled workers and raw materials, but the substitutions between skilled workers and raw materials are reduced.

Likewise, the impacts of service outsourcing on substitution among variable factors of production are given in (85).

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[102] Recall that the well behaved cost function requires that own price elasticities are always negative.

$$\begin{bmatrix} \partial\sigma_{LL}/\partial\ln OS & \partial\sigma_{LH}/\partial\ln OS & \partial\sigma_{LM}/\partial\ln OS \\ & \partial\sigma_{HH}/\partial\ln OS & \partial\sigma_{HM}/\partial\ln OS \\ & & \partial\sigma_{MM}/\partial\ln OS \end{bmatrix} = \begin{bmatrix} -2.93 & -0.9 & -0.0047 \\ & 7.35 & -0.164 \\ & & -.094 \end{bmatrix} \quad (85)$$

According to (85), service outsourcing makes the demands for unskilled and raw materials more elastic and those for skilled workers less elastic. This may provide clearer insights on the skill-biased effect of service outsourcing in the sense that Thailand’s manufactures contracting out service activities, which are by definition less skill-intensive, and therefore become more specialized in more skill-intensive activities performed in-house. The fact that the remaining production activities become more skilled-intensive is also characterized by more elastic demands for unskilled workers and raw materials and less elastic demands for skilled workers.

Unlike material outsourcing, service outsourcing identically brings about lower elasticities of substitution among all factors of production. A decline in substitutability of factors of production may stem from the fact that service outsourcing, as discussed earlier, enables the remaining factors of production to be more specialized in core-competent activities, thereby reducing their substitutability.

4.6 Conclusion

In this chapter, I employ a non-homothetic translog function to empirically investigate the impacts of outsourcing on the demands for unskilled and skilled labor in the Thailand’s manufacturing sector during 1999-2003.

My empirical results reveal that material outsourcing has negative impacts on the relative demands for unskilled and skilled workers and is skill-biased. Explained by the standard H-O Theorem, Thailand’s manufacturing industries in general may outsource labor-intensive intermediate inputs, thereby reducing their relative demands domestically. My results support the observation of job losses due to ‘exporting jobs’ effect of material outsourcing in developing countries as observed in most industrialized economies. Moreover, service outsourcing is also found to have negative impacts on unskilled workers and positive impacts on skilled workers. This can be explained by the fact that service activities are in general unskilled-intensive and the decisions to contract out those activities will undermine the relative demand for unskilled workers, whereas gains from specialization can be reaped by skilled workers employed in house. Like material outsourcing, service outsourcing is therefore skill-biased. By combining these effects of material and service outsourcing, I can also infer that the skill bias of outsourcing could explain the rising wage inequality within industries.

I also extend my empirical results to uncover the impacts of outsourcing on own-price and cross-price elasticities of substitution among variable factors of production by calculating Hicks-Allen partial elasticities of substitution. Evaluated at fitted values of factor shares, my results indicate that unskilled labor, skilled labor, and raw materials are substitutes. I find that material outsourcing makes both skilled and unskilled labor more susceptible to changes in their own wages whereas it results in more inelastic demands for raw materials. Besides, it makes unskilled labor more substitutable by skilled labor and raw materials but reduces the substitution between skilled labor and materials. In contrast, service outsourcing is found to entail more elastic demands for unskilled labor and raw materials and more inelastic demand for skilled workers. Unlike material outsourcing, service outsourcing reduces substitutability among all variable factors of production.

My results shed further light on the impacts of outsourcing on the labor market in the Thailand’s manufacturing sector. The results show that outsourcing decisions by local manufacturers may not be always undesirable for domestic workers, depending on their types. In the case of Thailand, material outsourcing is found to have a negative impact on domestic employment, whereas the service outsourcing, though skill-biased, may be beneficial for domestic workers. Thus, in designing labor market policies for developing countries, it is important for policymakers to understand the different impacts of material and service outsourcing on the labor market.

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