Task Offshoring and Organizational Form: Evidence from China*

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Abstract

This paper develops a simple model that incorporates different organizational forms into a task trading framework. The model is used to study how falling offshoring costs affect home welfare and the relative prevalence of different organizational forms. It identifies an important source of productivity effect: a fall of offshoring cost could lead to lower efficiency wages paid by foreign-owned firms due to their segmented labor market, and the lower efficiency wages consequently induce a larger productivity gain. It also predicts that falling offshoring costs favor intrafirm offshoring if the offshoring cost function is steep enough or if intrafirm offshoring is sufficiently more efficient in communication than armslength offshoring. The prediction is tested using export processing trade data in China and is strongly supported.

JEL: F11, F14, F15, F16, F23

Keywords: Task Offshoring, Heterogeneous Offshoring Cost, Organizational Form, Export Processing Zones

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1 Introduction

Growth of offshoring[1] has been a dominant feature of the international economy. Feenstra and Hanson (1996) find that the share of imported intermediates increased from 5.3% of total U.S. intermediate purchases in 1972 to 11.6% in 1990. Hummels, Ishii, and Yi (2001) also show that the share of imported inputs embodied in goods that are exported increased from 16.5% in 1970 to 21% in 1990 in 14 countries. Feenstra and Hanson (2005) find that China's export processing[2] accounted for 55.6% of the country's total exports over the period of 1997 to 2002.

Offshoring takes two possible organizational forms: intrafirm offshoring and armslength offshoring. If a firm chooses to be vertically integrated and produces intermediate inputs by a foreign subsidiary, it engages in intrafirm offshoring. If it buys customized components from an armslength supplier abroad, it engages in armslength offshoring. However, the relative importance of intrafirm offshoring compared with armslength offshoring remains largely unknown, partly due to data restrictions. Moreover, empirical analysis of how falling costs of offshoring affect organizational forms is unavailable at this point in time.

In recent work, trade theorists bring modern theories of the firm into trade models to study choices of organizational form. Building on Grossman and Helpman (2002), Antràs (2003) uses the property-rights theory to study the choice of organizational form. Antràs and Helpman (2004) further incorporate heterogeneous firms and study the impact of productivity on organizational form choice. They show that a fall in offshoring cost or a decline in the labor cost in offshoring destination country induces a reorganization that favors armslength offshoring.

Similarly, Grossman and Helpman (2004) apply the incentive-systems framework to managerial compensation in global production. Firms are sorted into different organizational forms according to their productivity. The effect of a fall in offshoring cost on the relative prevalence of different organizational forms is ambiguous. If most firms that conduct armslength offshoring are those with highest productivity, then trade liberalization tends to favor

[1] Follwoing Grossman and Rossi-Hansberg (2008), "offshoring" means the performance of tasks in a country different from where a firm's headquarter is located.

[2] Export processing is an arrangement that a processing factory converts intermediate inputs into finished goods and then exports the final output. The intermediate inputs might be purchased by the factory itself or provided by the foreign partner of the processing factory.

intrafirm offshoring. In contrast, if most firms that conduct armslength offshoring have the lowest productivity, trade liberalization favors armslength offshoring.[3]

Despite the rich insights shed by these studies, they assume away the task heterogeneity. Some tasks are easier to offshore than others. "Routineness" identified in Autor, Levy, and Murnane (2003), "codifiability" identified in Leamer and Storper (2001), and "impersonality" identified in Blinder (2006) all might affect the offshoring costs of tasks. Tasks thus are performed at home or in foreign countries depending on their offshoring costs. Moreover, firms are constantly offshoring more and more tasks to developing countries. Figure 1 shows that the value-added share of processing export in China is continuously increasing over the period of 1992 to 2008, especially for foreign-invested firms. Blonigen and Ma (2007) also provide evidence that over time foreign firms are locating increasingly more sophisticated products in China. Grossman and Rossi-Hansberg (2008) provide the first trade model that recognizes the heterogeneous offshoring costs and studies the welfare implications of task offshoring.

Similarly, if tasks are offshored, firms might choose different organizational forms for different tasks. Figure 2 shows that, over the period of 1997 to 2008, intrafirm offshoring increased much faster than armslength offshoring in China. What contributes to the surprisingly fast growing intrafirm offshoring?

In order to study the organizational form choice of offshoring, in this paper, I build a simple model of task offshoring, incorporating different organizational forms. Based on Grossman and Rossi-Hansberg (2008), I assume that a continuum of tasks need to be performed to produce goods. Firms are motivated to offshore tasks and choose the organizational form for each offshored task by the prospect of factor-cost savings. They might choose to offshore some tasks simply because they can be performed remotely more easily than others. When it comes to choosing organizational form firms face a trade-off. Intrafirm offshoring saves communication costs but requires the payment of efficiency wages, which are higher than the wage paid by armslength suppliers. On the other hand, armslength offshoring saves wage costs while higher communication costs are associated. The sets of tasks performed in different locations and in different organizational forms are determined endogenously so that the cost

[3] Arguably, China's export processing trade is closer to the later case in the sense that armslength suppliers typically have lower productivity than multinational corporations(Blonigen and Ma 2007).

of the marginal tasks is equalized across locations or across organizational forms.

The essential trade-off involves communication costs versus efficiency wages. Communication costs are related to the complexity levels of tasks and the organizational forms. Workers encounter a larger range of problems when they perform a more complex task. In order to solve these problems, they need to consult with headquarters. Communication in intrafirm offshoring is less costly than armslength offshoring.

Efficiency wages stem from imperfect international monitoring. The ability to monitor workers' effort is assumed to depend on proximity (Grossman and Helpman 2004). For intrafirm offshoring, shirking can only be partly detected due to remote monitoring. However, monitoring of armslength suppliers is perfect due to onsite monitoring by their owners. Thus higher efficiency wages are paid by firms in order to prevent workers from shirking if they choose intrafirm offshoring.[4]

My model sheds light on the impact of offshoring organizational form on the welfare implication of a fall of offshoring cost. I show that the productivity effect identified in Grossman and Rossi-Hansberg (2008) can be decomposed into three subeffects. First, a fall of offshoring cost directly contributes to the productivity effect as in Grossman and Rossi-Hansberg (2008). Second, it decreases the offshoring cost of intrafirm offshoring by inducing lower efficiency wages and consequently contributes further to the productivity effect. Third, since the consequent expansions of home production and the range of offshored tasks increase efficiency wages, the productivity effects achieved by the first two subeffects are partially offset.

The model thus identifies another important source of productivity effect, suggested by the second subeffect. Since foreign-owned firms typically have a segmented labor market, they often pay higher wages than domestic firms.[5] When there is a fall of offshoring cost, the labor demand of foreign-owned firms tends to fall and consequently the premium paid by them becomes lower. This is equivalent to an extra saving of offshoring cost for foreign-owned

[4]Imperfect monitoring leads to higher efficiency wage is widely known. See, for example, Matusz (1996) and Blanchard and Fischer (1989). There is also plenty of empirical evidence showing that foreign invested firms pay higher wages than domestic firms, such as Aitken, Harrison, and Lipsey (1996). It is also shown that workers moving from a domestic to a foreign firm experience an increase in wages in Andrews, Bellmann, Schank, and Upward (2007).

[5]The OECD Employment Outlook (2008, p289) states that "labour markets may be segmented between foreign and domestic firms because foreign-owned firms tend to provide better working conditions, in order to limit worker turnover or because of institutional differences such as compliance with labour laws or bargaining strength vis-a-vis trade unions."

firms. Thus even though the original fall of offshoring cost is equal to both intrafirm offshoring and armslength offshoring, it might lead to a larger cost saving for intrafirm offshoring due to lower efficiency wages. This extra saving of offshoring cost consequently induces a larger productivity effect.

The model also enables us to analyze the effect of falling offshoring costs on the relative prevalence of different organizational forms. I show that the prevalence depends on the curvature of the offshoring cost function and the relative communication efficiency in different organizational forms. For sectors where the offshoring cost function is steep, lower offshoring cost favors intrafirm offshoring. If the difference in communication efficiency between intrafirm offshoring and armslength offshoring is large, lower offshoring cost also leads to larger share of intrafirm offshoring.

The intuition is straightforward. If the offshoring cost function is steep, a big fall of offshoring cost causes a small range of tasks that originally performed at home to be offshored in the form of intrafirm offshoring. The big fall of offshoring cost leads a large drop of labor demand and the newly offshored tasks lead to a small increase of labor demand. The net effect on labor demand of intrafirm offshoring is negative, causing lower efficiency wages and making intrafirm offshoring more attractive relative to armslength offshoring. Consequently intrafirm offshoring becomes more common.

Similarly, if armslength offshoring involves too high communication cost than intrafirm offshoring, trasferring tasks from intrafirm offshoring to armslength offshoring is difficult. Thus although falling offshoring cost causes some tasks that are originally performed at home to be offshored in the form of intrafirm offshoring, far fewer tasks are shifted from intrafirm offshoring to armslength offshoring. This again makes intrafirm offshoring more common.

The prediction that falling offshoring costs might favor intrafirm offshoring is opposite to the predictions by some existing literatures, particularly by Antràs and Helpman (2004). The key factor leading to this difference is that my model allows firms to choose different organizational forms for different tasks. The prevalence of different organizational forms is determined by the range of tasks performed by each type of organizational form by the *same* firm. However, previous work typically assumes that only *one* intermediate inputs is to be offshored. Firms make decisions of whether to offshore the production of this input, and if yes in what organizational form. The prevalence of different organizational forms is then determined by the number of firms choosing different forms.

The model's predictions are highly consistent with offshoring experience in China. A simple cross-section correlation analysis suggests that lower offshoring costs are associated with larger shares of intrafirm offshoring. Figure 3 shows that in special policy zones, lower offshoring costs are associated with larger shares of export processing by foreign-owned firms.[6]

To test the theory more formally, the empirical analysis in this paper tests the hypothesis that a fall of offshoring cost leads to a larger share of intrafirm offshoring. The data follow China's export processing for the period of 1997-2007. Information on special policy zones is used to provide exogenous shocks of offshoring costs. Setting up a special policy zone is assumed to lead to a fall of offshoring cost. Previewing the empirical results, I find that setting up special policy zones has highly significant positive impact on the intrafirm offshoring share. In my benchmark results, setting up an export processing zone (one type of special policy zone) in a city increases the intrafirm offshoring share in that city by 1.51 percentage points. Another indicator of offshoring cost, a proxy of transporation infrastructure, is also included. Here the results show that improvement of transportation infrastructure leads to significant increase of intrafirm offshoring share. These results are very robust to different specifications and different measures.

Thirdly, sectors in which the intrafirm offshoring grew fastest are those presumebly have steep offshoring cost functions. Table 1 shows that export processing by foreign-owned firms increases fastest in sectors such as office machine, telecommunication, electric machinery and scientfic instruments sectors.

My findings are relevant to several bodies of literature. Despite intense theoretical interest in offshoring organizational form there is little empirical work on it. Feenstra and Hanson (2005) study factory ownership and input control in China's export processing trade, but their main focus is on whether the ownership and input control should be split to different parties. My work focus only on the ownership and study its relation with offshoring costs.[7] A

[6] The special policy zones in the figure are Economic and Technology Development Areas in China in 2007. The offshoring cost index is constructed by the sum of indexes of the cumulative investment in infrastructure, the capability of water, steam and gas supply, whether the administrative institution passes $ISO9001$ certification, whether the zone has authorities to approve provincial level foreign investment projects, whether the administrative management is efficient, and whether the zone has patent protection offices.

[7] Antràs, Garicano, and Rossi-Hansberg (2008) also discuss the relation between communication cost and

second body of literature to which my work relates is the view of offshoring as "task trading". Among others, Grossman and Rossi-Hansberg (2008) propose this "new paradigm"; Costinot, Oldenski, and Rauch (2009) show that complex tasks tend to be offshored in the form of intrafirm offshoring; Keller and Yeaple (2008) study the location choices of task trading. I extend the literature by studying organizational form choices of task trading. Moreover, this paper provides a more concrete and endogenous model of offshoring cost based on Cremer, Garicano, and Prat (2007).

The remainder of this paper is organized as follows. Section 2 constructs a model introducing different organizational forms and studies the effects of a fall of offshoring cost on factor prices and the relative prevalence of different organizational forms. Section 3 tests the hypothesis that a fall of offshoring cost leads to a larger share of intrafirm offshoring in China. Section 4 concludes.

2 The Model

Following Grossman and Rossi-Hansberg (2008), there are two countries, home and foreign. Each country has two industries, X and Y. The production of one unit of either good involves a continuum of L-tasks, which only use low-skilled labor, and a continuum of H-tasks, which only use high-skilled labor. The measure of tasks are normalized such that to produce one unit of each good, each task must be performed once. It is further assumed that to produce a good at home, completion of tasks within each type require the same amount of factor.

The industries may differ in their factor intensities, which means, for example, that a typical L-task in one industry may use a greater input of domestic low-skilled labor than an L-task in the other industry. Without loss of generality, industry X is assumed to be relatively more skill intensive. If for industry j, $j \in \{X, Y\}$, a_{Lj} units of low-skilled labor and a_{Hj} units of high-skilled labor are used to perform L-tasks and H-tasks to produce one unit of output j, the assumption indicates that $a_{Hx}/a_{Lx} > a_{Hy}/a_{Ly}$. The production technology is constant return to scale.

Firms can undertake tasks at home or abroad. Tasks can be performed offshore either within or beyond the boundaries of the firm. If the tasks are performed in firms' foreign sub-

offshoring. However, they do not discuss different organizational forms.

sidiaries, it is called intrafirm offshoring and the foreign subsidiaries are called multinational corporations or MNCs.[8] If the tasks are performed in foreign indigenous firms, it is called armslength offshoring and the foreign firms are called armslength suppliers. For simplicity, I assume firms only offshore L-tasks.[9]

Intrafirm offshoring differs from armslength offshoring in two ways. First, intrafirm offshoring has lower communication costs than armslength offshoring. Second, MNCs pay higher efficiency wages than armslength suppliers. The trade-off between communication costs and wage costs shapes firms' equilibrium organizational form choices for each task.

2.1 Communication Cost

Tasks differ in complexity level. Workers encounter a larger range of problems when they perform more complicated tasks. Tasks are indexed by i, $i \in [0, 1]$, indicating the complexity levels, and more specifically, the range of problems workers might encounter. A task with index i means that workers would encounter problems that are drawn from a uniform distribution with support $[0, i]$.

The only type of offshoring cost, communication cost, arises when problems need to be solved abroad. Communication is not costless. To solve the problem encountered, workers in foreign country must communicate with home headquarters. Due to bounded rationality, workers can only incompletely describe the problem using a limited number, K, of "words".[10] After hearing a word, the engineer in the headquarter knows that the problem is in an interval defined by that word and she needs to diagnosis the exact problem in that interval. The diagnosis cost is assumed to be a function, $t(z)$, of the length of the interval, z. $t(z)$ is continuously differentiable and satisfies that $t(0) = 1$, $t'(z) > 0$ and $t''(z) > 0$.[11]

The number of words that can be used in communication is exogenous.[12] However, how to code these words to refer to intervals is an optimal choice. Such an optimal code system, i.e. a system defining the mapping of words into intervals, is to divide the range of potential problems into equal-length intervals (proved in Cremer, Garicano, and Prat (2007) appendix B).

[8] Without causing confusion, I use MNC and intrafirm offshoring interchangeably.

[9] Offshoring of H-tasks delivers similar results.

[10] I call it "words" following Cremer, Garicano, and Prat (2007).

[11] Some further assumptions about $t(z)$ would be speficied later.

[12] The number of words could potentially be endogenized by assuming that words are expensive to obtain.

The communication cost for using a K-word code system to solve problems related to a task indexed by i is endogenously determined. For task i, the optimal length of each interval is i/K and there are K such intervals. The expected communication cost for the task i is then,

$$\Sigma_{k=1}^{K}\frac{1}{K}\beta t\left(\frac{i}{K}\right)=\beta t\left(\frac{i}{K}\right),$$

where $\beta > 1$ represents the communication technology.[13]

After the engineer in the headquarters diagnoses the problem and returns the solution, the worker can perform the task with no further problems. Assuming the production technology, a_{Lj}, is perfectly transferable to foreign partners regardless of the organizational form,[14] a firm that chooses a_{Lj} for L-tasks at home needs to employ $\beta t\left(\frac{i}{K}\right)a_{Lj}$ units of foreign labor to perform the same task offshore, for a given number of words, K.[15]

Intrafirm offshoring and armslength offshoring differ in communication efficiency.[16] Intrafirm communication can use a larger number of words than interfirm communication. I.e. $\delta K_m = K_a$, where K_m and K_a are the number of words used by MNCs and armslength suppliers respectively.[17] δ is less than one, representing the inferiority of communication in armslength offshoring. The intuition is that the larger the number of words is, the more precise the communication is and the less the diagnosis cost is. To make sure that it is impossible to offshore all tasks to foreign country, the offshoring cost of the most complicated task is assumed to be infinite even through intrafirm offshoring, i.e. $t\left(i/K_m\right)\to\infty$ if $i\to 1$.

In sum, there are three different factors that affect the communication costs. The first is the communication technology, β, capturing factors that affect both intrafirm offshoring and

[13]It is worth noting that β includes all factors that affect the costs of intrafirm offshoring and armslength offshoring equally. Particularly, for example, a drop of β can represents a fall of offshoring cost due to setting up special policy zones.

[14]The assumption of perfect transferability of production technology might be relaxed. It can be instead assumed that intrafirm offshoring has an offshoring cost of $\beta t\left(\frac{i}{K}\right)a_{Lj}$ while armslength offshoring has an offshoring cost of $\beta t\left(\frac{i}{K}\right)A^{*}a_{Lj}$, where A^{*} is the technological inferiority of the foreign firms. As long as A^{*} is assumed to be constant, the relaxation of the assumption does not change the results.

[15]This offshoring cost function can be seen as a more concrete form of that in Grossman and Rossi-Hansberg (2008).

[16]In reality, compared to armslength suppliers, MNCs are either better in training workers to identify the problems so to save the diagnosis costs or are easier to organize synchronous communication channels, such as net meeting and video conferencing.

[17]It is implicitly assumed that tasks performed at home do not have any communication cost, i.e. $K_d\to\infty$ and $\beta_d = 1$, because nothing gets "lost in translation" and communication can be conducted face-to-face. When the firm's headquarter is not in the country where the tasks are performed, K is finite because problem-solving technology is not perfectly transferable to outside of the headquarter; and $\beta > 1$ because face-to-face communication is no longer available.

armslength offshoring equally. The second is the complexity level of the task, determining the range of problems that workers encounter. The last is the number of words, representing the efficiency of the communication in different organizational forms. Without taking into account wages, the offshoring costs are then, $\beta t\left(\frac{i}{K_m}\right)a_{Lj}$ and $\beta t\left(\frac{i}{\delta K_m}\right)a_{Lj}$ for intrafirm and armslength offshoring respectively.

2.2 Efficiency Wage

Foreign workers are hired by three different types of employers, MNCs, armslength suppliers and foreign indigenous firms.[18] Labor is free to move between armslength suppliers and foreign indigenous firms. The wages paid by these two types of firms are thus the same, denoted as w^*. The wage paid by MNCs, w_m, is larger than w^*. This is because international monitoring is imperfect and MNCs can only partly detect shirking. In order to prevent workers from shirking, MNCs must pay a higher wage. In contrast, workers working in armslength suppliers do not shirk because the detection rate of shirking is 100% in these firms due to onsite monitoring.

The efficiency wage, w_m, is determined by the oppotunity costs of shirking. Workers hired in MNCs have a natural exogenous quit rate $b > 0$. Detection rate $q > 0$ denotes the rate at which shirking is detected in MNCs. Quited or fired workers from MNCs are automatically hired by either armslength suppliers or foreign indigenous firms. Workers working in these firms tend to search for employment in MNCs because MNCs offer higher wages (efficiency wages). e is the accession rate at which new MNC jobs are aquired by non-MNC workers. Define V_{mn}, V_{ms} and V_a respectively as the expected lifetime utility of non-shirking MNC employees, shirking MNC employees, and the non-MNC workers. Assuming risk neutrality, the asset value equations applicable to the three groups of agents are

$$\rho V_{mn} = w_m - d + b\left(V_a - V_{mn}\right), \quad (1)$$

$$\rho V_{ms} = w_m + (b+q)\left(V_a - V_{ms}\right), \quad (2)$$

$$\rho V_a = w^* + e\left(V_{mn} - V_a\right), \quad (3)$$

where $\rho > 0$ is the discount rate and d is the disutility of not shirking. To prevent workers from shirking, MNCs must set w_m high enough so that $V_{mn} \geq V_{ms}$. However, they will only

[18] Armslength suppliers are different from foreign indigenous firms in that they perform tasks for home firms while foreign indigenous firms produce finished goods.

provide the lowest possible wage as long as workers do not shirk. I.e. MNCs set w_m such that $V_{mn} = V_{ms}$. This indicates

$$w_m = \rho V_a + \frac{\rho + b + q}{q} d. \tag{4}$$

Solving V_a from equation (1) and (3),

$$V_a = \frac{e\left(w_m - d\right) + \left(\rho + b\right) w^*}{\rho\left(\rho + e + b\right)},$$

and substituting in equation (4), the efficiency wage is determined by

$$w_m = w^* + \frac{\rho + b + q + e}{q} d.$$

In steady state, the number of workers flowing into MNCs must equal to the number of workers quiting or fired from MNCs. This implies that

$$e\left(L - L_m\right) = bL_m,$$

where L^* is the population in foreign country and L_m is the employment in MNCs. The "No Shirking Constraint" follows:

$$w_m\left(w^*, L^*, L_m\right) = w^* + \frac{\rho + q + b\left(\frac{L^*}{L^* - L_m}\right)}{q} d. \tag{5}$$

Equation (5) actually gives the labor supply function for MNCs. It is clear the efficiency wage is an increasing function of the MNCs' employment, L_m. The intuition is that when employment in MNCs increases, the opportunity cost of shirking decreases due to the fact that the expected time spent in non-MNC firms is less. The incentive for shirking becomes stronger and MNCs must adjust to a higher efficency wage to offset it. The relation between efficiency wage and MNC employment is shown by the supply curve in Figure 4. The position of the labor supply curve is determined by parameters such as the foreign wage and foreign population. Decreasing w^* or increasing L^* makes shirking more costly and thus drives down the efficiency wage level.

2.3 Organizational Forms

Based on the offshoring costs of different organizational forms, home firms decide whether to offshore each task, and if yes, whether to use the form of intrafirm offshoring or the form of armslength offshoring.

To produce good j, $j = \{X, Y\}$, the unit cost of performing task i at home is home wage times unit labor requirment, wa_{Lj}. Similarly, the cost of performing the same task in foreign country in the form of intrafirm offshoring is $\beta t\left(\frac{i}{K_m}\right) a_{Lj} w_m$, and $\beta t\left(\frac{i}{K_a}\right) a_{Lj} w^*$ in the form of armslength offshoring. The marginal task performed at home has an index I_o such that the cost of performing it at home is the same as that if it is offshored, or

$$w = \min\left\{\beta t\left(\frac{I_o}{K_m}\right) w_m, \beta t\left(\frac{I_o}{K_a}\right) w^*\right\}.$$

The marginal task performed in the form of intrafirm offshoring has an index, I_m, such that the offshoring costs in different organizational forms are equalized, or

$$t\left(\frac{I_m}{K_m}\right) w_m = t\left(\frac{I_m}{K_a}\right) w^*. \tag{6}$$

There are only two possible outcomes, as shown in Figure 5: either all tasks are offshored in the form of armslength offshoring, i.e. $I_m \geq I_o$, or simplest tasks are offshored in the form of armslength offshoring and more complex tasks are offshored in the form of intrafirm offshoring, i.e. $I_m < I_o < 1$.[19]

Only the latter case is of interest given the presence of intrafirm offshoring in reality. Then I_o is determined by

$$w = \beta t\left(\frac{I_o}{K_m}\right) w_m. \tag{7}$$

Equations (6) and (7) together imply that

$$w = \beta t\left(\frac{I_o}{K_m}\right) \frac{t\left(\frac{I_m}{K_a}\right)}{t\left(\frac{I_m}{K_m}\right)} w^*. \tag{8}$$

I define $\varepsilon(z)$ as the elasticity of t function, i.e. $\varepsilon(z) \equiv \frac{t'(z)z}{t(z)}$, and assume that it is an increasing function.[20] Then $\frac{\partial I_m}{\partial w_m} = \frac{I_m t\left(\frac{I_m}{K_m}\right)}{w^* \bar{\varepsilon} t\left(\frac{I_m}{K_a}\right)} > 0$, where $\bar{\varepsilon} \equiv \varepsilon\left(\frac{I_m}{K_a}\right) - \varepsilon\left(\frac{I_m}{K_m}\right)$. This

[19] The simplest tasks would always be offshored in the form of armslength offshoring, if they are offshored. This is because $\beta t\left(\frac{0}{K_m}\right) w_m > \beta t\left(\frac{0}{K_a}\right) w^*$ always holds. This is in turn a result of $t(0) = 1$ and $w_m > w^*$. Then if there are both intrafirm offshoring and armslength offshoring, it must be that simplest tasks are offshored in the form of armslength offshoring and more complicated tasks are offshored in the form of intrafirm offshoring. This pattern of offshoring is supported in Costinot, Oldenski, and Rauch (2009).

[20] This is not a very strong assumption. Examples includes exponential function $t(z) = e^z$, among others. Actually a sufficient condition for this assumption to hold is that for any integer n, the n^{th} derivative of t function is greater or equal to zero. Mathematically, for any such functions, the Taylor expansion at point zero is $t(z) = 1 + \sum_{j=1}^{\infty} a_j z^j$ where $a_j \geq 0$. It can be easily shown that the elasticity function, $\varepsilon(z) = \frac{\sum_{j=1}^{\infty} j a_j z^j}{1+\sum_{j=1}^{\infty} a_j z^j} = \frac{1}{\frac{1}{\sum_{j=1}^{\infty} j a_j z^j} + \frac{\sum_{j=1}^{\infty} a_j z^j}{\sum_{j=1}^{\infty} j a_j z^j}}$, is increasing in z. The second term in the denominator is decreasing in z since $\sum_{i=1}^{\infty} i a_i z^{i-1} \sum_{j=1}^{\infty} j a_j z^j < \sum_{i=1}^{\infty} a_i z^i \sum_{j=1}^{\infty} j^2 a_j z^{j-1}$ due to $2ij\left(a_i z^{i-1} a_j z^j\right) \leq \left(i^2 + j^2\right)\left(a_i z^{i-1} a_j z^j\right)$.

assumption suggests that given w^*, lower efficiency wage causes intrafirm offshoring more attractive and less tasks are performed in armslength suppliers.

2.4 Equilibrium

2.4.1 Home

In a competitive economy, the price of any good is less than or equal to the unit cost of production, with equality whenever a positive quantity of the good is produced. Assuming imperfect specialization, i.e. both countries produce both goods, then the prices are equal to the unit costs and profits are zero

$$p_j = wa_{Lj}\left(1-I_o\right) + w^* a_{Lj}\int_0^{I_m}\beta t\left(\frac{i}{K_a}\right)di + w_m a_{Lj}\int_{I_m}^{I_o}\beta t\left(\frac{i}{K_m}\right)di + sa_{Hj},\ j\in\{X,Y\},$$

where s denotes the high-skilled labor wage.

Substituting for w^* and w_m using equation (6) and (7) and taking good X as numeraire, the zero profit condition can be rewritten as

$$\begin{aligned} 1 &= \Omega\left(I_o, I_m\right) wa_{Lx} + sa_{Hx} \\ p &= \Omega\left(I_o, I_m\right) wa_{Ly} + sa_{Hy} \end{aligned}$$

where

$$\Omega\left(I_o, I_m\right) \equiv \left(1-I_o\right) + \frac{1}{t\left(\frac{I_o}{K_m}\right)}\frac{t\left(\frac{I_m}{K_m}\right)}{t\left(\frac{I_m}{K_a}\right)}\int_0^{I_m} t\left(\frac{i}{K_a}\right)di + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di}{t\left(\frac{I_o}{K_m}\right)}.$$

It is easy to show that Ω is a decreasing function of I_o and I_m, given that $\varepsilon\left(z\right)$ is increasing in z and $I_o > 0$. I.e.

$$\frac{\partial\Omega}{\partial I_o} = -\frac{\varepsilon\left(\frac{I_o}{K_m}\right)}{I_o t\left(\frac{I_o}{K_m}\right)}\left(\frac{t\left(\frac{I_m}{K_m}\right)}{t\left(\frac{I_m}{K_a}\right)}\int_0^{I_m} t\left(\frac{i}{K_a}\right)di + \int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di\right) < 0, \tag{9}$$

$$\frac{\partial\Omega}{\partial I_m} = -\frac{\int_0^{I_m} t\left(\frac{i}{K_a}\right)di}{t\left(\frac{I_o}{K_m}\right)}\frac{t\left(\frac{I_m}{K_m}\right)}{t\left(\frac{I_m}{K_a}\right)I_m}\bar{\varepsilon} < 0. \tag{10}$$

The intuition for $\frac{\partial\Omega}{\partial I_o} < 0$ is straightfoward. Increasing I_o indicates that offshoring cost falls. The cost savings are much the same as would result from an economy-wide increase in the productivity of the low-skilled labor, i.e. a fall of Ω. The intuition of $\frac{\partial\Omega}{\partial I_m} < 0$ is similar. Increasing I_m indicates lower offshoring costs in armslength offshoring. The cost savings are again the same as would result from an economy-wide productivity improvement for the lower-skilled labor, or a fall of Ω.

Finally, the home factor market clearing conditions are

$$\begin{aligned} a_{Lx}(\cdot)\,x + a_{Ly}(\cdot)\,y &= \frac{L}{1-I_o}, \\ a_{Hx}(\cdot)\,x + a_{Hy}(\cdot)\,y &= H. \end{aligned}$$

2.4.2 Foreign Country

Let $A^* > 1$ denote the Hicks-neutral technological inferiority of foreign firms in both industries. The zero profit conditions and factor market clearing conditions are respectively

$$\begin{aligned} 1 &= A^* w^* a_{Lx} + A^* s^* a_{Hx}, \\ p &= A^* w^* a_{Ly} + A^* s^* a_{Hy}, \end{aligned}$$

and

$$\begin{aligned} A^* a_{Lx} x^* + A^* a_{Ly} y^* + \beta \left(\int_0^{I_m} t\left(\frac{i}{K_a}\right) di + \int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di \right) (a_{Lx} x + a_{Ly} y) &= L^*, \\ A^* a_{Hx} x^* + A^* a_{Hy} y^* &= H^*. \end{aligned}$$

The total foreign labor demanded by intrafirm offshoring is

$$\begin{aligned} L_m &= (a_{Lx} x + a_{Ly} y)\,\beta \int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di \\ &= \frac{L\beta}{1-I_o} \int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di, \end{aligned} \tag{11}$$

where the second equality comes from home factor market clearing conditions. The intrafirm offshoring employment is determined by the task range performed by MNCs, $[I_m, I_o]$, and the communication technology (β). The impacts of I_o on L_m are both marginal and inframarginal. Increasing I_o causes more tasks to be offshored to MNCs. More importantly, it also causes an expansion of home production ($\frac{L}{1-I_o}$ increases). Such an expansion requires more units of each offshored task to be performed and thus increases MNC employment. Communication technology, β, affects the amount of labor demanded to perform each unit of task offshored.

Equation (6), (7) and (11) together provide labor demand function for intrafirm offshoring, given w and w^*. This is shown by the demand curve in Figure 4. It is downward sloping since lower w_m increases L_m. The intuition is that if the efficiency wage, w_m, falls and if

w, w^* and β are fixed, then the range of tasks offshored in the form of intrafirm offshoring increases. Consequently the labor demanded by MNCs increases. The position of the labor demand curve is affected by w, w^* and β. Increasing w, increasing w^*, or increasing β all would increase the labor demanded by MNCs.

Finally, the model is closed with consumer goods demand. I assume that households have identical and homothetic preferences around the globe. Equilibrium in the goods market requires

$$\frac{y + y^*}{x + x^*} = D(p),$$

where $D(p)$ is the (homothetic) world relative demand for good Y and $D^{'}(p) < 0$. If the home country is small in relation to the size of world markets, the relative price p can be treated as exogenous to the home economy. If the home country is large, the relative price is determined by an equation of world relative demand and world relative supply.

2.5 Effects of Falling Offshoring Costs

This model allows us to study the effects of a rich array of events. In this section, I study the effects of a fall in offshoring costs on factor prices at home and on the relative prevalence of different offshoring organizational forms. Paticularly, I assume that there is an improvement in the communication technology such that β drops and all other exogenous variables remain fixed. Moreover, for simplicity, I assume that home country is relatively small compared with foreign country. This implies that the goods prices are not affected by improvements in communication technology. Due to well-known "factor price insensitivity" in Heckscher-Ohlin models, w^*, s^*, s and $w\Omega$ are then fixed, or

$$\hat{w} + \hat{\Omega} = 0, \tag{12}$$

where $\hat{w}$ and $\hat{\Omega}$ are the log changes of w and Ω respectively. Only the low-skilled labor wage at home is affected.[21]

Equation (5), (6), (7), (11) and (12) together provide the equilibrium solution, solving all endogenous variables w, w_m, L_m, I_m and I_o.

[21] Because home low-skilled labor wage is the only one that changes, without causing confusion, "home wage" hereafter refers to "home low-skilled labor wage" unless otherwise noted.

Substituting equation (6) and (11) into (5) gives

$$\frac{t\left(\frac{I_m}{K_a}\right)}{t\left(\frac{I_m}{K_m}\right)} = 1 + \frac{d}{w^*}\left(1 + \frac{\rho}{q} + \frac{b}{q}\left(\frac{L^*}{L^* - \frac{L\beta}{1-I_o}\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di}\right)\right). \tag{13}$$

This suggests that I_m is an implicit function of I_o and β. The effects of changes in I_o and β on I_m are given by

$$\frac{\partial I_m}{\partial I_o} = \frac{\frac{L^* bdL\beta}{w^* q\left(L^* - \frac{L\beta}{1-I_o}\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di\right)^2}\left(\frac{t\left(\frac{I_o}{K_m}\right)}{1-I_o} + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di}{(1-I_o)^2}\right)}{\frac{t\left(\frac{I_m}{K_a}\right)\bar{\varepsilon}}{t\left(\frac{I_m}{K_m}\right)I_m} + \frac{L^* bdL\beta}{w^* q\left(L^* - \frac{L\beta}{1-I_o}\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di\right)^2}\frac{t\left(\frac{I_m}{K_m}\right)}{1-I_o}}, \tag{14}$$

$$\frac{\partial I_m}{\partial \beta} = \frac{\frac{L^* bdL}{w^* q\left(L^* - \frac{L\beta}{1-I_o}\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di\right)^2}\frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di}{1-I_o}}{\frac{t\left(\frac{I_m}{K_a}\right)\bar{\varepsilon}}{t\left(\frac{I_m}{K_m}\right)I_m} + \frac{L^* bdL\beta}{w^* q\left(L^* - \frac{L\beta}{1-I_o}\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di\right)^2}\frac{t\left(\frac{I_m}{K_m}\right)}{1-I_o}}. \tag{15}$$

Both are positive given that $\varepsilon(\cdot)$ is an increasing function.

These two equations are important because they show the channels of how the presence of different organizational forms affect the gains from trade. As shown by equation (10), increasing I_m leads to lower Ω, and equation (12) shows the negative relation between Ω and the home wage. Thus, impacts of falling offshoring costs on the range of tasks performed in armslength offshoring will consequently affect the home wage.

The intuition of $\frac{\partial I_m}{\partial I_o} > 0$ is as follows. When I_o increases, employment in MNCs increases due to both inframarginal and marginal expansion of intrafirm offshoring. Increasing labor demand by MNCs makes shirking less costly since it becomes easier to get rehired in MNCs. To offset stronger incentives for shirking, MNCs must increase the efficiency wage, w_m. However, higher efficiency wages paid by MNCs make armslength offshoring relatively cheaper. Firms will then shift some tasks from intrafirm offshoring to armslength offshoring, i.e. I_m increases. The effect that expansions in MNC labor demand lead to more tasks offshored in the form of armslength offshoring is referred as the "MNC expansion effect".

The intuition of $\frac{\partial I_m}{\partial \beta} > 0$ is similar. When there is a fall of β, the labor demanded to perform each unit of task is lower due to more efficient communication. This causes lower employment in MNCs which in turn makes shirking more costly. MNCs can accordingly offer a lower efficiency wage and save in offshoring costs. Moreover, this extra saving in MNCs makes intrafirm offshoring relatively cheaper and thus induces transfer of tasks from armslength offshoring to intrafirm offshoring. I.e. I_m would decrease accordingly. The effect that falling offshoring costs lead to lower efficiency wages in MNCs due to lower employment in MNCs is referred as the "indirect cost saving effect".

These two effects affect I_m in opposite directions. Later I will show that in equilibrium a fall of offshoring cost, β, leads to larger range of tasks offshored. The MNC expansion effect then drives up I_m and the indirect cost saving effect drives it down. The overall effect on I_m depends on the relative magnitudes of these two effects. If a fall of β leads to a large change of I_o, then the MNC expansion effect would dominate and I_m would increase. Otherwise the indirect cost saving effect dominates and I_m decreases. The relative magnitudes of these two effects in turn depend on the functional form of the offshoring cost function and the relative communication efficiency in different organizational forms. I will discuss this in detail later.

Equations (8), (12) and (13) then solve the three unknowns, w, I_o and I_m(for details, see appendix A):

$$\hat{w} = \frac{-\frac{\partial\Omega}{\partial I_o} + \frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial\beta}\beta\frac{\varepsilon\left(\frac{I_o}{K_m}\right)}{I_o t\left(\frac{I_o}{K_m}\right)}\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di - \frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial I_o}}{\frac{1-I_o}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right) + \left(1 - I_o + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di}{t\left(\frac{I_o}{K_m}\right)}\right)\frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial I_o}}\left(-\hat{\beta}\right) \tag{16}$$

$$dI_o = \frac{\Omega + \left(1 - I_o + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di}{t\left(\frac{I_o}{K_m}\right)}\right)\frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial\beta}\beta}{\frac{1-I_o}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right) + \left(1 - I_o + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di}{t\left(\frac{I_o}{K_m}\right)}\right)\frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial I_o}}\left(-\hat{\beta}\right) \tag{17}$$

$$dI_m = \left(\frac{\Omega\frac{\partial I_m}{\partial I_o} - \frac{1-I_o}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right)\frac{\partial I_m}{\partial\beta}\beta}{\frac{1-I_o}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right) + \left(1 - I_o + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di}{t\left(\frac{I_o}{K_m}\right)}\right)\frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial I_o}}\right)\left(-\hat{\beta}\right) \tag{18}$$

It is obvious that a fall of offshoring cost, β, always induces a larger range of tasks to be offshored and a higher home wage, i.e. $\hat{w} > 0$ and $dI_o > 0$ if $\hat{\beta} < 0$.

2.5.1 Decomposing Effects on Home Wage

The effect of a fall in offshoring costs on home low-skilled labor wage in the small open economy case is called the "productivity effect" in Grossman and Rossi-Hansberg (2008). This is because falling offshoring costs cause lower Ω, which is similar in nature to an economy-wide increase in the productivity of the low-skilled labor. With the presence of different organizational forms, falling offshoring costs could affect the home wage through more channels besides the one identified in Grossman and Rossi-Hansberg (2008). Equation (16) shows that the productivity effect can be decomposed into three sub-effects.

The first sub-effect is the one identified in Grossman and Rossi-Hansberg (2008), shown by the term that includes $\frac{\partial \Omega}{\partial I_o}$ in equation (16). It contributes positively to the productivity effect. The intuition is that a fall of β causes both inframarginal and marginal cost savings of offshoring, regardless organizational form. These cost savings induce a higher home wage as a productivity improvement of home labor does so. Mathematically, because offshoring becomes more attractive relative to performing tasks at home, more tasks are offshored, i.e. I_o increases. Since $\frac{\partial \Omega}{\partial I_o} < 0$, increasing in I_o causes a fall of Ω, which in turn increases home wage according to equation (12). I call this the "direct cost saving effect" in the sense that falling β directly causes savings in offshoring costs.

The second sub-effect is an extra cost saving for intrafirm offshoring due to lower efficiency wages, identified above as the "indirect cost saving effect". The intuition is that falling offshoring costs reduce employment in MNCs because labor demanded to perform each unit of task is lower. This discourages shirking and allows MNCs to pay a lower efficiency wage. Mathematically, this effect is shown by the term that includes $\frac{\partial I_m}{\partial \beta}$ in equation (16). Since $\frac{\partial I_m}{\partial \beta} > 0$, this effect contribute positively to home low skilled wage.

Finally, the last sub-effect is a cost increase in intrafirm offshoring, identified by the "MNC expansion effect". Intuitively, larger I_o and smaller I_m implied by the first two channels indicate that the range of tasks performed in MNCs are larger. Moreover, home production expansion demands more units of tasks to be performed in MNCs. This increases the labor demand by intrafirm offshoring, encouraging shirking and forcing MNCs to offer higher efficiency wages. The higher efficiency wage offsets parts of the previous two cost savings effects, inducing a lower home wage. Mathematically, this effect is shown by the terms that include $\frac{\partial I_m}{\partial I_o}$ in equation (16). Since this effect induces higher I_m and $\frac{\partial \Omega}{\partial I_m} < 0$, it consequently leads to higher Ω and lower wage at home.

Although the influence of the last subeffect is in the opposite direction from those of the first two subeffects, the overall effect of a fall of β on home wage is positive, suggested by the positive $\hat{w}$ in equation (16). The proposition follows,

Proposition 1 *The productivity effect can be decomposed into three sub-effects: the direct cost saving effect, the indirect cost saving effect and the MNC expansion effect. The direct cost saving effect comes from decreasing offshoring costs in both organizational forms directly due to lower β. The indirect cost saving effect comes from lower efficiency wages in MNCs due to lower demand of labor in MNCs to perform each unit of tasks. The MNC expansion effect stems from higher efficiency wages in MNCs due to expansion of home production and the range of tasks performed in the form of intrafirm offshoring. Both direct and indirect cost saving effects cause higher home wage while they are partially offset by the MNC expansion effect. However, the overall productivity gain from a fall of offshoring cost is always positive.*

2.5.2 Decomposing Effects on Orgnizational Forms

Equation (17) shows that a larger range of tasks would be offshored if the offshoring cost falls. However, the relative prevalence of different offshoring organizational forms is much less clear. Equation (14) and (15) show that the range of tasks performed in the form of armslength offshoring is determined by the range of tasks offshored (I_o) and the communication technology (β). Moreover, according to equation (7), I_o is also related to equilibrium home wage (w). Thus the impact of a fall of offshoring cost on the relative prevalence of different organizational forms also works through three channels, through β, through I_o, and through w.

The labor market for intrafirm offshoring helps us to understand these three channels. This is because the prevalence of different organizational forms is determined by the range of tasks offshored in armslength offshoring, I_m. I_m is monotonically related to w_m, shown by equation (6). Finally, w_m is determined by the labor market for intrafirm offshoring. Figure 6 depicts the three channels explicitly.

First, falling β indicates that for each unit of task less foreign labor is demanded. This drives down the labor demand for intrafirm offshoring. Graphically, this effect shifts the demand curve down from position D_o to D_1 in the figure.

Second, keep the home wage, w, fixed, falling β indicates cheaper offshoring and more tasks to be offshored. I.e. I_o would increase as suggested by equation (7). As noted above, larger I_o means both inframarginal and marginal expansion of intrafirm offshoring and drives up the labor demand for intrafirm offshoring. This shifts the labor demand curve up from position D_1 to D_2 as shown in the figure.

Finally, the productivity effect increases the home wage, which in turn makes offshoring relatively cheaper. I_o increases further as indicated by equation 7, and labor demand for intrafirm offshoring increases further. It shifts the demand curve up further from position D_2 to D_3.

On the other hand the labor supply curve for intrafirm offshoring is not affected. The final position of the labor demand curve determines the overall direction of w_m change. If a fall of β causes either large change of w or large change of I_o, then the last two effects dominate and efficiency wage would increase, so does I_m. Otherwise the first effect dominates. The efficiency wage, w_m, and the range of tasks performed in armslength offshoring, I_m, both would decrease.

The proposition follows,

Proposition 2 *The effect of falling offshoring costs on the range of tasks performed in armslength offshoring (I_m) can be decomposed into three sub-effects. First, falling offshoring costs directly decrease the labor demanded to perform each unit of tasks in MNCs. This causes lower efficiency wage and lower I_m. Secondly, falling offshoring costs cause expansions of home production and a larger range of tasks offshored, which in turn increase the MNC labor demand, the efficiency wage and I_m. Finally, falling offshoring costs drives up home wage, causing more tasks offshored and larger MNC labor demand. This again increases the efficiency wage and consequently increases I_m. The overall effect is ambiguous and depends on the relative maganitude of each sub-effect.*

I now study under what situations intrafirm offshoring becomes more prevalent when β falls. Prevalence of intrafirm offshoring is defined as the range of tasks offshored in intrafirm offshoring relative to that in armslength offshoring, $(I_o - I_m)/I_m$. Since $dI_o > 0$ always holds when β drops, the sign and the magnitude of dI_m in equation (18) then determine the relative prevalence of intrafirm offshoring. I identify two situations under which intrafirm offshoring becomes relatively more prevalent. The first situation is when I_o increases while I_m decreases and the second situation is when I_m increases slower than I_o.

The first situation happens if the $t\left(\frac{i}{K_m}\right)$ function increases "fast" enough in i at point I_o. The intuition is that if this is true a large fall of β can cause a relatively small change of I_o while a large drop of labor demanded to perform each unit of tasks. Thus, it leads to a larger indirect cost saving effect and a smaller MNC expansion effect. The former tends to decrease I_m and the latter tends to increase I_m. Since the former effect dominates, the range of tasks performed in armslength offshoring falls.

Proposition 3 *The range of tasks offshored in the form of armslength offshoring would decrease with falling β if and only if the offshoring cost function $t\left(\frac{i}{K_m}\right)$ increases sufficiently fast with i at I_o such that $\varepsilon\left(\frac{I_o}{K_m}\right) > \frac{I_o}{(1-I_o)}\frac{\Omega}{(1-I_o)}\left(\frac{t\left(\frac{I_o}{K_m}\right)(1-I_o)}{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di} + 1\right)$.*

Proof. See appendix B. ■

The second situation happens when $d\left(\frac{I_o - I_m}{I_m}\right) > 0$. This would be the case if armslength offshoring is sufficiently inefficient in communication relative to intrafirm offshoring, i.e. if δ is small enough. The intuition is that if δ is sufficiently small, for a small change of I_m, the offshoring cost of armslength offshoring would increase much faster than that of intrafirm offshoring, i.e. $d\left(\frac{t\left(\frac{I_m}{\delta K_m}\right)}{t\left(\frac{I_m}{K_m}\right)}\right)/dI_m$ is large enough. It is then more difficult for firms to shift tasks from intrafirm offshoring to armslength offshoring. Thus even when firms offshore a larger range of tasks to the foreign country, the range of tasks offshored in intrafirm offshoring will not increase much.

Proposition 4 *If armslength offshoring is sufficiently inefficient in communication relative to intrafirm offshoring, i.e. if δ is sufficiently small, intrafirm offshoring becomes relatively more prevalent with falling β, i.e. $d\left(\frac{I_o - I_m}{I_m}\right) > 0$ if $d\beta < 0$.*

Proof. See appendix C. ■

3 Data and Econometrics

Proposition 3 and 4 identify two situations under which falling offshoring costs increase the intrafirm offshoring share. It is thus very likely that falling offshoring costs are responsible for the relatively fast growth of export processing by foreign firms in China shown in Figure 2. In this section, I test the hypothesis that lower offshoring cost induces larger share of intrafirm offshoring in China over the period of 1997-2007. Since offshoring costs can not be observed directly, I turn to information on special policy zones (especially Export Processing Zones) to provide exogenous shocks of offshoring costs. It is assumed that setting up a special policy zone in a city leads to a fall in offshoring costs for that city. Strong and robust empirical support is found that a fall of offshoring cost increases the prevalence of intrafirm offshoring.

In the following subsections, I first provide a brief introduction of special policy zones in China and why they cause lower offshoring costs. I then describe the dataset used in the paper, followed by the empirical specfications and estimation results. Finally, I close the section with various robustness checks.

3.1 Special Policy Zones and Offshoring Cost

Chinese cities offer a number of different special policy zones. They were set up in different periods and for different purposes. The major special policy zones are Special Economic Zones (SEZs), Economic and Technology Development Areas (ETDAs), Hi-Tech Industry Development Areas (HTIDAs) and Export Processing Zones (EPZs).[22] SEZs were setup in the early years when China adopted "Open-Door Policy". The first four SEZs were established in 1980 and another was established in 1988. SEZs typically cover a city but Hainan SEZ covers the whole province. ETDAs were established later, 14 in 1984, 18 in 1993 and another 18 after 2000. They enjoy preferential policies that were granted earlier only to SEZs but have relatively smaller size than SEZs. ETDAs policies focus on attracting investment and development of the local economy. HTIDAs were set up at the same period of ETDAs but emphasize high-technology industries. The special policy zones that most relevant to my empirical analysis are EPZs. They were all set up after 2001 and only focus on facilitating export processing. In principle EPZs are sub-areas in established ETDAs, although there are some exceptions. By 2009 there were 5 SEZs, 54 ETDAs, 56 HTIDAs and 58 EPZs in total. They are very widely distributed although provinces on the east coast have a larger portion. Each province has at least one special zone of each type excluding SEZ.[23]

Besides these special policy zones, there are other types of zones. Bonded Areas, National Border & Economic Cooperation Zones, and Taiwan Investment Zones are notable ones. Moreover, there are 1,346 *provincial* level special zones (mainly ETDAs and HTIDAs) by 2006.

[22] The term "EPZ" here is a narrower term than that used by International Labor Office (ILO). The ILO use "EPZ" to refer to all types of special policy zones in China, including SEZs, ETDAs, HTIDAs and EPZs (ILO 1998). Some studies follow ILO in studying special policy zones in China (Reinert and Rajan 2008). However, this is not accurate because special zones such as SEZs, ETDAs and HTIDAs are not exclusively designed for export processing.

[23] A brief description of special policy zones is provided by http://www.usembassy-china.org.cn/fcs/china%20pulse/regional_dftz_may.doc. Wong and Tang (2005) provide a case study.

Central government's favorable policies toward special zones do not apply in provincial level zones but local governments may provide their own favorable policies. These special zones are not included in my empirical analysis either because they are less relevant to processing trade or because provincial zones are not identified by the Chinese custom. However, excluding these special zones does not weaken the empirical conclusion since they tend to cause downward bias of the estimates.

Special zones play important roles in the growth of export processing by Wholly-Foreign-Owned firms (WFOs). Table 2 decomposes the year-by-year growth of export processing by WFOs into different types of zones.[24] It is clear that special zones contribute about half of the growth each year, within which the EPZs' share continuously increases, from 7.7% in the year 2002 to 58.5% in 2008.

Special zones provide lower offshoring cost in three ways. First, special zones provide preferential tax and management policies that reduce offshoring costs considerably. For all types of special zones, income taxes are usually fully exempted or reduced to half. Moreover, firms located in EPZs enjoy special management of export processing which other types of special zones can not provide. These special treatments include exemptions on import and export quota and licensing administration, exemptions on *Bank Deposit Account* management and *Registration Manual* management, exemptions on value-added tax and duty exemptions on all inputs and exports. Firms in EPZs also benefit from priority Customs clearance, more streamlined clearance and 24-hour Customs support.

Second, modern developed infrastructure, rich human resources and efficient management and services provided by the special zones help to decrease offshoring costs. Special zones typically have better infrastructure in transportation, informational technology, and supply of electricity, water, gas and steam. Most zones feature a one-stop severice center to help firms avoid complicated and prolonged approvements and other bureaucratic issues. Some special zones may even have "tailored policy", providing tailored service and flexible policies to large firms. A survey conducted in Weihai ETDA in 2006 suggests that government efficiency, transportation convenience and policy consistency are the most important factors that attracts

[24] In the table, Bonded Areas (BAs) are also reported. However, given that only very limited activities, such as freight classification, loading of parts, storing, packing, and branding, are allowed in BAs, they are not included in the empirical analysis.

investments to the zone.[25]

Finally, special zones trigger the formation of industrial clusters which in turn provide lower offshoring costs. Anecdotal evidence suggests that one firm moving into a special policy zone could cause related firms to locate nearby.[26] Timely input supply and zero inventory requirement provided by industrial cluster make firms more efficient in production. For instance, Kunshan ETDA in Zhejiang province has about 24 firms producing computers and network equipments while 300 local upstream suppliers are located around.[27]

3.2 Data

The dataset used to test the hypothesis is the Chinese International Trade Dataset obtained from China Customs General Administration. It includes information of products (HS 8-digit), origin city or zone, firm ownership, and Customs regime (pure-assembly or import-and-assembly) over the period 1997-2007.

The measure of intrafirm offshoring share is constructed by WFOs' share of processing export ($Intrashare$). Processing trades by other types of Foreign-Invested-Firms (FIEs), such as Equity-Joint-Ventures (EJVs) and Contractual-Joint-Ventures (CJVs), are regarded as armslength offshoring. This is because domestic partners might have larger influences on the production than foreign partners in these arrangements. Of course, processing trade by domestic firms is regarded as armslength offshoring as well.

Although direct measures of offshoring cost, β, are not readily available, I construct two types of proxies that are presumably correlated with offshoring costs. The first type of proxies is dummy variables indicating whether there are certain special policy zones in a city. Two such dummies, HT and EPZ, are constructed. The dummy variable HT equals to one if the city has any of SEZ, ETDA or HTIDA, and equals to zero otherwise. The reason that these three special zones are grouped together is that the preferential policies in these zones are very similar. Moreover, the line between ETDAs and HTIDAs is often blurred in practice and there is a trend for cities to join these zones together. Similarly, the dummy variable EPZ equals to one if cities have EPZs and equal to zero otherwise.[28] As discussed above,

[25] http://www.cadz.org.cn/news/content_news.jsp?ContentID=15554

[26] http://www.cadz.org.cn/news/content_news.jsp?ContentID=18293

[27] http://www.cadz.org.cn/news/content_news.jsp?ContentID=51475

[28] One thing should be noticed is that 19 ETDAs, 3 HTIDAs and 7 EPZs are not observed in the dataset because the codes for these special zones are not provided by the Chinese Custom. However, again, this would

special policies and management in EPZs are designed particularly to facilitate processing trade. Thus variable EPZ is the main focus of the empirical analysis.

The second type of proxy of offshoring cost is a proxy for transportation infrastructure: the ratio of passengers, taking railway or highway transportations, to the total population ($Trans$). It is constructed using a separate city level dataset, China City Statistics, obtained from the China Data Center at University of Michigan (1997-2007).

Moreover, two other city level variables are included in the empirical model: non-agriculture population (NAP) and the number of students in secondary schools (NSS). These variables identify how labor supply affects the relative prevalence of different organizational forms. According to the theory, increasing labor supply should lower the efficiency wage and consequently increase the share of intrafirm offshoring, provided that non-MNCs absorb all remaining workers.[29] Thus the estimates of these variables provide a side support of the theory if they have epected signs.

Table 3 provides some basic statistical information of these variables.

3.3 Empirical Specifications

The basic empirical model is

$$Intrashare_{ict} = \alpha_{ic} + \alpha_t + \beta_1 EPZ_{ct} + \beta_2 HT_{ct} + \beta_3 NAP_{ct} + \beta_4 NSS_{ct} + \beta_5 Trans_{ct} + \varepsilon_{ict}. \quad (19)$$

As discussed above, the dependent variable, $Intrashare_{ict}$, is the WFOs' share of processing export of product i in city c in year t. EPZ_{ct} equals to unit if city c has an EPZ in year t, and equal to zero otherwise. HT_{ct} equals to unit if city c has any SEZ, HTIDA or ETDA in year t, and equal to zero otherwise. NAP_{ct} and NSS_{ct} are respectively the number of non-agriculture population (in 10,000) and the number of students in secondary schools (in million persons) in city c in year t. $Trans_{ct}$ is the proxy of transportation infrastructure, the ratio of passengers taking railway or highway transportation to the total population in city c in year t. Finally, α_{ic} is the product-city fixed effect and α_t is the year fixed effect. The idiosyncratic effect is assumed to have a normal distribution, $\varepsilon_{ict} \sim N\left(0, \sigma_c^2\right)$.

The theory predicts that in the context of China, falling offshoring costs lead to larger share of intrafirm offshoring. Moreover, increasing in labor supply in foreign country leads to

strengthen the empirical conclusion since it causes downward bias of the estimates.

[29] The theoretical proof is not provided to save space but available upon request.

lower efficiency wages and consequently larger share of intrafirm offshoring. Since EPZ, HT, and $Trans$ measure offshoring costs, and NAP, NSS measure labor supply, the expected signs of coefficients for all these variables are positive. The estimate of β_1 is of special interest because EPZs are particularly relevant to the costs of export processing.

The consistent estimation of the basic specification depends on a strong assumption that the regressors are strictly exogenous, i.e they are not correlated with ε_{ict} in any period. However, it is possible that designation of special zones is correlated with product-city specific trends. Cities with faster growing intrafirm offshoring might have larger incentives to apply for certain special zones. To control the product-city specific trends, a "random trend" is added to the basic model[30]

$$Intrashare_{ict} = \alpha_{ic} + \alpha_t + g_{ic}t + \beta_1 EPZ_{ct} + \beta_2 HT_{ct} + \beta_3 NAP_{ct} + \beta_4 NSS_{ct} + \beta_5 Trans_{ct} + \varepsilon_{ict},$$

where g_{ic} captures product-city specific trend. To estimate this model, it is first differeced,

$$\begin{aligned} \Delta Intrashare_{ict} &= \lambda_t + g_{ic} + \beta_1 \Delta EPZ_{ct} + \beta_2 \Delta HT_{ct} \\ &\quad + \beta_3 \Delta NAP_{ct} + \beta_4 \Delta NSS_{ct} + \beta_5 \Delta Trans_{ct} + \Delta\varepsilon_{ict} \qquad (20) \end{aligned}$$

where $\lambda_t = \alpha_t - \alpha_{t-1}$ is a new set of year fixed effects. Estimating the first differenced equation (20), both product-city fixed effect, α_{ic}, and product-city specific trend, g_{ic}, are allowed to be correlated with independent variables.

Finally, it could be the intrafirm offshoring shares in previous year, rather than the product-city specific trend, that are correlated with the designation of special zones. To allow for this, the empirical model is further extended to incorporate lagged values of the dependent variable,

$$\begin{aligned} Intrashare_{ict} &= \alpha_{ic} + gt + \delta_1 Intrashare_{ict-1} + \beta_1 EPZ_{ct} + \beta_2 HT_{ct} \qquad (21) \\ &\quad + \beta_3 NAP_{ct} + \beta_4 NSS_{ct} + \beta_5 Trans_{ct} + \varepsilon_{ict}. \end{aligned}$$

Here I only include the first lag of the dependent variable ($Intrashare_{ict-1}$). Moreover, the error term, ε_{ict}, is assumed to take a first-order moving average process, i.e. $\varepsilon_{ict} = \eta_{ict} - \gamma\eta_{ict-1}$, where η_{ict} is assumed to be i.i.d. The functional form of ε_{ict} is chosen so that the estimated first differenced error term, $\Delta\varepsilon_{ict}$, satisfies $Cov(\Delta\varepsilon_{ict}, \Delta\varepsilon_{ict-k}) = 0$ for $k \geq 2$.

[30] See Wooldridge (2002) section 11.2 and Papke (1994).

This is a necessary condition for the dynamic model to be consistently estimated(Cameron and Trivedi 2008).[31]

Unfortunately, equation (21) can not be consistently estimated directly. Since the term $Intrashare_{ict-1}$ enters as a regressor, within estimates are inconsistent. This is because the mean-differenced lag variable is correlated with $\bar{\varepsilon}_{ic}$. Moreover, using lags of dependent variable as IV is not possible because any lag of $Intrashare_{ict}$ will be correlated with $\bar{\varepsilon}_{ic}$. Similarly directly estimating equation (21) by first differencing delivers inconsistent estimates since $\Delta Intrashare_{ict-1}$ is correlated with $\Delta\varepsilon_{ict}$.

Thus I estimate the dynamic model using the first-differenced equation of equation (21) using IV methods(Arellano and Bond 1991). First differencing equation (21) gives

$$\begin{aligned} \Delta Intrashare_{ict} &= g + \delta_1 \Delta Intrashare_{ict-1} + \beta_1 \Delta EPZ_{ct} + \beta_2 \Delta HT_{ct} \\ &\quad + \beta_3 \Delta NAP_{ct} + \beta_4 \Delta NSS_{ct} + \beta_5 \Delta Trans_{ct} + \Delta\varepsilon_{ict}. \end{aligned} \tag{22}$$

Given the specified MA(1) structure of ε_{ict}, $Intrashare_{ict-3}$ and $Intrashare_{ict-4}$ are not correlated with $\Delta\varepsilon_{ict}$ and can be used as instruments of $\Delta Intrashare_{ict-1}$.[32] IV estimates of equation (22) are consistent.

In sum, three types of models are estimated, the basic model (equation (19)), the random trend model (equation (20)) and the dynamic panel model (equation (22)).

3.4 Main Estimation Results

This section reports the estimation results of the above models in table 4. For the basic model, within (FE) estimates and first differencing (FD) estimates are reported in column 1 and column 2 respectively. The reported standard errors are clustered at city level to avoid the intraclass correlation and serial correlation(Angrist and Pischke 2009). All coefficients are of the expected sign except the FE estimate of EPZ. I suspect that the negative sign of EPZ in within estimation might be due to bias caused by omitted variables such as product-city specific trends.

[31] This condition is tested to be satisfied after the model is estimated.

[32] Potentially further lags could be added in as instruments. However, too many IVs would lead to poor performance of asymptotic results(Cameron and Trivedi 2008). Moreover, since average number of years observed for product-city pair is about 4, using too many lags would decrease the number of observations significantly.

Column 3 to 6 report the estimates of the random trend model. Column 3 and 4 respectively report the FE estimates, without or with year fixed effects (λ_t). Similarly, Column 5 and 6 respectively report the FD estimates, without or with year fixed effects. There is no significant difference across all these estimates. All coefficients are now positive. Particularly, the coefficients of EPZ, NAP and $Trans$ are highly significant. The results show that setting up an EPZ in a city increases the share of intrafirm offshoring by 1.33 to 1.46 percentage points. A one million increase of nonagriculture population increases the share of intrafirm offshoring by 3.8 to 4.4 percentage points. A one unit change of $Trans$ is associated with 0.1 percentage point increase in intrafirm offshoring share. The HT Dummy is not statistically signifiant. The student number in secondary schools also has no significant impact on the intrafirm offshoring share, probably because it is not a good measure of the current labor supply. I take these estimates as the benchmark estimates.

These results are confirmed by the estimates of the dynamic panel model, reported in columns 7 and 8. Column 7 uses 2SLS methods while column 8 uses GMM methods to conduct IV estimation. GMM estimation is more efficient when the model is overidentified. Again, EPZ, NAP and $Trans$ are all highly significant. Moreover, the HT Dummy is now estimated to have a highly significant impact on the intrafirm offshoring share. It is not surprising that the estimated coefficients in the dynamic panel models are typically smaller than those from random trend models since the coefficient estimates in dynamic models are the short run effects. In the short run, setting up an EPZ increases the intrafirm offshoring share in processing trade by 0.54 percentage point. An increase of nonagriculture population by one million would increases the intrafirm offshoring share by 1.6 percentage points. A one unit increase in $Trans$ is associated with 0.03 percentage point increase in intrafirm offshoring share. The estimated impact of HT Dummy is particularly large, 3.3 percentage points increase in intrafirm offshoring share would occur if either SEZ, ETDA or HTIDA is set up.

In order to compare the estimates across models, the long run effects for dynamic panel models are calculated using the formula $\beta^* = \frac{\beta}{1-\delta_1}$(Blien, Suedekum, and Wolf 2006). The long run effects of EPZ, NAP and $Trans$ are 1.32, 3.8, and 0.087 respectively, very close to the estimates of the random trend models.

Finally, to make sure that the estimates of the dynamic panel model are consistent, the assumption that $Cov(\Delta\varepsilon_{ict}, \Delta\varepsilon_{ict-k}) = 0$ for $k \geq 2$ is tested using Arellano-Bond test(Arellano and Bond 1991). The assumption fails to be rejected at 1% significant level, indicating the specification of the dynamic model is valid.

In sum, across different specifications, setting up EPZs in cities is estimated to have a significant positive impact on the intrafirm offshoring share. Since EPZs provide considerable cost savings for export processing, it is safe to conclude that falling offshoring costs induce a larger share of intrafirm offshoring in China. Other measures of offshoring cost deliver similar results. Moreover, increasing labor supply is found to have significant positive impact on the intrafirm offshoring share too.

3.5 Robustness Check

One might worry that some other reasons, other than falling offshoring costs, might explain why setting up special policy zones leads to larger share of intrafirm offshoring. Two explanations are plausible. The first is the possibility that discriminatory policies against domestic firms are applied in the special zones, thus inducing faster growth of export processing by WFOs. The second is that special zones prefer foreign firms to domestic firms when they consider granting access. This section addresses these alternative explanations. Moreover, some other considerations of the empirical strategy are also considered in the end of this section.

There are two ways to rule out the first alternative explanation. First, different responses by different types of foreign firms can be used. As discussed above, there are three types of foreign invested firms, WFOs, EJVs and CJVs. The pereferential policies towards foreign firms apply equally to all types of FIEs. If difference in responses to special policy zones by different types of foreign firms are observed, then preferential policies towards FIEs can be ruled out as the sole explanation of increasing share of intrafirm offshoring.

In order to test whether there are different responses to special zones by different types of foreign firms, the dependent variables in the above specifications are replaced by the WFOs' share of export processing by all types of FIEs ($IntrashareFIE_{ict}$). All the specifications are estimated again and the results are shown in table 5. The results are very similar to the previous results. The only difference is that the coefficients of HT dummy is highly significant in most specifications. These results indicate that different types of foreign invested firms respond differently to special zones and that discriminatory policies against domestic firms can not solely explain the faster growth of WFOs' processing export.

The second way to rule out discrimination policies against domestic firms as the sole explanation is to make use of firms' responses to EPZs in cities where other types of special zones have already been established. The rationale is that discrimination policies are the similar in all types of special zones and EPZs differ from other special zones mainly in providing extra policies that faciliate export processing. More importantly, these extra policies in EPZs do not discriminate by firm types. Thus if WFOs respond to EPZs differently from other types of firms in cities where other types of special zones have already been established, then it must be due to the extra policies provided by EPZs and not by the discriminatory policies against domestic firms. Differential setup timing for special zones allows us to do this. EPZs are typically set up later than ETDAs. More importantly they are generally established within the confines of existing special zones, usually ETDAs.

The sample is thus restricted to a subsample that contains observations where cities already have some SEZs, ETDAs or HTIDAs. All specifications are estimated again. Since the HT dummy is now time invariant it is excluded from the models. The coefficient for $EPZs$, β_1, now only captures the effects of falling offshoring cost brought by the extra policies of EPZs. The results are shown in table 6. Similar to previous results, the coefficients of EPZ are highly significant and in most specifications the coefficients are larger than the counterparts in the table 4. One notable difference is that the $Trans$ variable is not significant now in most models.

Similarly, the second alternative explanation can be ruled out using the externalities generated by special zones. The rationale of the second alternative explanation is that special zones might prefer to select foreign firms and this preference can not be controlled for by other observable variables.[33] However, presumbly special zones can not select the types of firms located outside the zones. On the other hand, special zones might generate externalities that lower offshoring cost in nearby regions through industrial clusters. Thus if responses to special zones by different types of firms which are located outside the special zones are different, it can not be explained by zones selection of foreign firms.

[33] This is different from the first alternative explanation since for the first one HT dummy provides some control.

The dependent variables in the specifications are then replaced by the intrafirm offshoring share outside any special zones ($Intrashareoutzone_{ict}$) and all specifications are re-estimated. The coefficients of EPZ and HT then capture the externalities created by special zones on intrafirm offshoring share. The results are reported in table 7. Again, they are very similar to the benchmark results. EPZ dummy is positive and highly signifiant, although compared to the benchmark results, the estimated coefficients are a little bit smaller. This indicates that setting up EPZs do have strong impacts on the relative prevalence of intrafirm offshoring even for the areas outside the EPZs.

Finally, because the estimations of the above models are essentially difference-in-difference estimations, one may worry that pooling all observations of all provinces introduces risks of comparing non-comparable locations. For example, using cities in Tibet as a control group for a city in Guangdong province may not be valid, since these two provinces are so different in every regard. More formally, this problem would be important if there exists a province-year fixed effect, α_{pt}, where p stands for province, and if this fixed effect is correlated with the regressors.

This province-year fixed effect can be potentially included in and identified by the previous models, if a full set of province-year dummies are included. However, this would introduce 341 new dummies (31 provinces and 11 years) which might lead to too large degree of freedom. Without including the full set dummies, in previous estimations, the random trend model and the dynamic panel model partially control this fixed effect by including either product-city specific trend or the lag values of the dependent variable. Moreover, since about 92% of all observations of the sample are coming from the east region of China, where cities can be thought relatively homogeneous, this problem should not have big influences on the estimates.

To further check how big this problem is, a subsample that only includes provinces in east region is used to re-estimate all the models.[34] The estimate results, as shown in table 8, are very similar to previous results. The only noticable difference is that the HT dummy is highly signifiant in most specifications. This indicates that the province-year fixed effect does not matter too much and the benchmark results are reliable.

[34] The division of cities into different regions is according to the official criteria, see http://www.stats.gov.cn/was40/gjtjj_detail.jsp?searchword=%B6%AB%B2%BF&channelid=7565&record=1.

4 Conclusion

I have developed a general equilibrium framework to study task trading and organizational forms. In my model, firms are motivated to offshore heterogeneous tasks and choose organizational forms based on cost considerations. The prohibitively high communication costs associated with the most complicated tasks cause these tasks performed at home. When making offshoring form decisions for less complicated tasks, firms trade off the benefits of lower communication costs in intrafirm offshoring against the higher efficiency wages. These tradeoffs induce firms to offshore the least complex tasks in the form of armslength offshoring and other tasks in the form of intrafirm offshoring.

The model is used to study the effects of a fall of offshoring cost on factor prices and on the relative prevalence of different organizational forms. A key result is that the presence of different organizational forms has important implications on the productivity effect identified in Grossman and Rossi-Hansberg (2008). A fall of offshoring cost causes lower labor demand for each unit of tasks performed in MNCs and consequent lower efficiency wages. This provides another source of the productivity effect. On the other hand, expansion of home production demands larger employment in MNCs and increases the efficiency wages. This would partially offset the productivity gains.

Another key result is that falling offshoring costs may cause relatively more intrafirm offshoring. For sectors where the offshoring cost functions are steep enough, or if the difference in communication efficiency between intrafirm offshoring and armslength offshoring is large enough, falling offshoring costs would lead to larger share of intrafirm offshoring.

This prediction is tested in the context of processing trade in China. Using special policy zones as indicators of falling offshoring costs, I show robust empirical evidence that falling offshoring costs contribute significantly to the relative faster growth of processing trade by Wholly-Foreign-Owned firms in China. Given the growing importance of China as a destination of offshoring, my work helps to understand the task trading patterns and their welfare implications.

The model can also be used to study effects of other intersting events. For example, one particularly important question is how technological catching up by developing countries would affect the relative prevalence of different organizational forms and the wages in developed countries. It also provides rich predictions about task trading. It should help in designing other empirical studies of the fast evolving world trading system. For example, empirical studies of the relative communication efficiency of different organizational forms could be future topics.

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Appendix

A Solving the Equilibrium

Rewrite equation (12) as

$$\begin{aligned}\hat{w}+\hat{\Omega} &= \hat{w}+\frac{1}{\Omega}\left(\frac{\partial\Omega}{\partial I_m}\left(\frac{\partial I_m}{\partial I_o}dI_o+\frac{\partial I_m}{\partial\beta}d\beta\right)+\frac{\partial\Omega}{\partial I_o}dI_o\right)\\ &= \hat{w}+\frac{1}{\Omega}\left(\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial I_o}+\frac{\partial\Omega}{\partial I_o}\right)dI_o+\frac{\beta}{\Omega}\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial\beta}\hat{\beta}=0. \qquad (23)\end{aligned}$$

Equation (8) suggests that, given w^* unchanged,

$$\begin{aligned}\hat{w} &= \hat{\beta}+\hat{t}\left(\frac{I_o}{K_m}\right)+\hat{t}\left(\frac{I_m}{K_a}\right)-\hat{t}\left(\frac{I_m}{K_m}\right)\\ &= \hat{\beta}+\frac{t'\left(\frac{I_o}{K_m}\right)}{t\left(\frac{I_o}{K_m}\right)K_m}dI_o+\frac{t'\left(\frac{I_m}{K_a}\right)}{t\left(\frac{I_m}{K_a}\right)K_a}dI_m-\frac{t'\left(\frac{I_m}{K_m}\right)}{t\left(\frac{I_m}{K_m}\right)K_m}dI_m\\ &= \hat{\beta}+\varepsilon\left(\frac{I_o}{K_m}\right)\frac{dI_o}{I_o}+\bar{\varepsilon}\frac{dI_m}{I_m}\\ &= \hat{\beta}+\varepsilon\left(\frac{I_o}{K_m}\right)\frac{dI_o}{I_o}+\frac{\bar{\varepsilon}}{I_m}\left(\frac{\partial I_m}{\partial I_o}dI_o+\beta\frac{\partial I_m}{\partial\beta}\hat{\beta}\right)\\ &= \left(1+\frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial\beta}\beta\right)\hat{\beta}+\left(\frac{1}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right)+\frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial I_o}\right)dI_o \qquad (24)\\ &= A\hat{\beta}+BdI_o,\end{aligned}$$

where $A\equiv 1+\frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial\beta}\beta>0$, and $B\equiv\frac{1}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right)+\frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial I_o}>0$.

Equation (23) and (24) then slove the two unknowns dI_o and $\hat{w}$,

$$\begin{aligned}\hat{w} &= \frac{B\beta\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial\beta}-A\left(\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial I_o}+\frac{\partial\Omega}{\partial I_o}\right)}{\Omega B+\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial I_o}+\frac{\partial\Omega}{\partial I_o}}\left(-\hat{\beta}\right), \qquad (25)\\ dI_o &= \frac{A\Omega+\beta\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial\beta}}{\Omega B+\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial I_o}+\frac{\partial\Omega}{\partial I_o}}\left(-\hat{\beta}\right). \qquad (26)\end{aligned}$$

To simplify the solutions, using the facts that

$$\begin{aligned}\frac{1}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right)\Omega+\frac{\partial\Omega}{\partial I_o} &= \frac{1-I_o}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right),\\ \frac{\bar{\varepsilon}}{I_m}\Omega+\frac{\partial\Omega}{\partial I_m} &= \frac{\bar{\varepsilon}}{I_m}\left(1-I_o+\frac{\int_{I_m}^{I_o}t\left(\frac{i}{K_m}\right)di}{t\left(\frac{I_o}{K_m}\right)}\right),\\ \frac{1}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right)\frac{\partial\Omega}{\partial I_m}-\frac{\bar{\varepsilon}}{I_m}\frac{\partial\Omega}{\partial I_o} &= \frac{\bar{\varepsilon}}{I_m}\frac{\varepsilon\left(\frac{I_o}{K_m}\right)}{I_o t\left(\frac{I_o}{K_m}\right)}\int_{I_m}^{I_o}t\left(\frac{i}{K_m}\right)di.\end{aligned}$$

I have

$$
\begin{aligned}
& B\beta\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial\beta} - A\left(\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial I_o} + \frac{\partial\Omega}{\partial I_o}\right) \\
= & \left(\frac{1}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right) + \frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial I_o}\right)\beta\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial\beta} - A\left(\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial I_o} + \frac{\partial\Omega}{\partial I_o}\right) \\
= & \left(\frac{1}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right)\beta\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial\beta} - A\frac{\partial\Omega}{\partial I_o}\right) + \left(\frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial I_o}\beta\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial\beta} - A\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial I_o}\right) \\
= & \left(\frac{1}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right)\frac{\partial\Omega}{\partial I_m} - \frac{\bar{\varepsilon}}{I_m}\frac{\partial\Omega}{\partial I_o}\right)\frac{\partial I_m}{\partial\beta}\beta - \frac{\partial\Omega}{\partial I_o} + \left(\frac{\bar{\varepsilon}}{I_m}\beta\frac{\partial I_m}{\partial\beta} - A\right)\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial I_o} \\
= & \frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial\beta}\beta\frac{\varepsilon\left(\frac{I_o}{K_m}\right)}{I_o t\left(\frac{I_o}{K_m}\right)}\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di - \frac{\partial\Omega}{\partial I_o} - \frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial I_o},
\end{aligned}
$$

$$
\begin{aligned}
& B\Omega + \frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial I_o} + \frac{\partial\Omega}{\partial I_o} \\
= & \left(\frac{1}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right)\Omega + \frac{\partial\Omega}{\partial I_o}\right) + \left(\frac{\bar{\varepsilon}}{I_m}\Omega + \frac{\partial\Omega}{\partial I_m}\right)\frac{\partial I_m}{\partial I_o} \\
= & \frac{1-I_o}{I_o}\varepsilon\left(\frac{I_o}{K_m}\right) + \frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial I_o}\left(1 - I_o + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di}{t\left(\frac{I_o}{K_m}\right)}\right),
\end{aligned}
$$

and

$$
\begin{aligned}
& A\Omega + \beta\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial\beta} \\
= & \left(1 + \frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial\beta}\beta\right)\Omega + \beta\frac{\partial\Omega}{\partial I_m}\frac{\partial I_m}{\partial\beta} \\
= & \Omega + \left(\frac{\bar{\varepsilon}}{I_m}\Omega + \frac{\partial\Omega}{\partial I_m}\right)\frac{\partial I_m}{\partial\beta}\beta \\
= & \Omega + \frac{\bar{\varepsilon}}{I_m}\frac{\partial I_m}{\partial\beta}\beta\left(1 - I_o + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right)di}{t\left(\frac{I_o}{K_m}\right)}\right).
\end{aligned}
$$

Then the equilibrium solution (16) and (17) are derived.

The change of I_m can then be solved,

$$
\begin{aligned}
dI_m &= \frac{\partial I_m}{\partial I_o} dI_o + \frac{\partial I_m}{\partial \beta} d\beta \\
&= \frac{\Omega + \left(1 - I_o + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di}{t\left(\frac{I_o}{K_m}\right)}\right) \frac{\bar{\varepsilon}}{I_m} \frac{\partial I_m}{\partial \beta} \beta}{\frac{1-I_o}{I_o} \varepsilon \left(\frac{I_o}{K_m}\right) + \left(1 - I_o + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di}{t\left(\frac{I_o}{K_m}\right)}\right) \frac{\bar{\varepsilon}}{I_m} \frac{\partial I_m}{\partial I_o}} \left(-\hat{\beta}\right) \frac{\partial I_m}{\partial I_o} + \beta \frac{\partial I_m}{\partial \beta} \hat{\beta} \\
&= \left(\frac{\Omega \frac{\partial I_m}{\partial I_o} - \frac{1-I_o}{I_o} \varepsilon \left(\frac{I_o}{K_m}\right) \beta \frac{\partial I_m}{\partial \beta}}{\frac{1-I_o}{I_o} \varepsilon \left(\frac{I_o}{K_m}\right) + \left(1 - I_o + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di}{t\left(\frac{I_o}{K_m}\right)}\right) \frac{\bar{\varepsilon}}{I_m} \frac{\partial I_m}{\partial I_o}} \right) \left(-\hat{\beta}\right).
\end{aligned}
$$

B Proof of Proposition 3

The range of tasks performed in armslength offshoring (I_m) would decrease if and only if

$$
\begin{aligned}
& dI_m < 0 \\
\Leftrightarrow\ & \Omega \frac{\partial I_m}{\partial I_o} < \frac{1 - I_o}{I_o} \varepsilon \left(\frac{I_o}{K_m}\right) \beta \frac{\partial I_m}{\partial \beta} \\
\Leftrightarrow\ & \frac{\Omega}{\frac{1-I_o}{I_o} \varepsilon \left(\frac{I_o}{K_m}\right)} < \frac{\beta \frac{\partial I_m}{\partial \beta}}{\frac{\partial I_m}{\partial I_o}} = \frac{\beta \frac{\partial L_m}{\partial \beta}}{\frac{\partial L_m}{\partial I_o}} = \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di}{t\left(\frac{I_o}{K_m}\right) + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di}{1-I_o}} \\
\Leftrightarrow\ & \varepsilon \left(\frac{I_o}{K_m}\right) > \frac{I_o}{(1 - I_o)} \frac{\Omega}{(1 - I_o)} \left(\frac{t\left(\frac{I_o}{K_m}\right)(1 - I_o)}{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di} + 1 \right).
\end{aligned}
$$

Notice that $\frac{\Omega}{(1-I_o)} \left(\frac{t\left(\frac{I_o}{K_m}\right)(1-I_o)}{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di} + 1 \right) > 1$ since $\Omega > 1 - I_o = \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di}{\frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di}{1-I_o}} > \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di}{t\left(\frac{I_o}{K_m}\right) + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di}{1-I_o}}$.

C Proof of Proposition 4

The intrafirm offshoring becomes more prevalent if and only if

$$
\begin{aligned}
& d\left(\frac{I_o - I_m}{I_m}\right) > 0 \\
\Leftrightarrow\ & I_m dI_o - I_o dI_m > 0 \\
\Leftrightarrow\ & \frac{dI_m}{dI_o} = \frac{\partial I_m}{\partial I_o} + \frac{\partial I_m}{\partial \beta} \frac{d\beta}{dI_o} < \frac{I_m}{I_o} < 1.
\end{aligned}
$$

Given that $\frac{\partial I_m}{\partial I_o} > 0$ and $\frac{\partial I_m}{\partial \beta} \frac{d\beta}{dI_o} < 0$, then it would be satisfied as long as $\frac{\partial I_m}{\partial I_o}$ is sufficiently small. Recall that $K_a = \delta K_m$, $\frac{d\left(\frac{t\left(\frac{I_m}{K_a}\right)\bar{\varepsilon}}{t\left(\frac{I_m}{K_m}\right) I_m}\right)}{d\delta} < 0$, and $\frac{t\left(\frac{I_m}{K_a}\right)\bar{\varepsilon}}{t\left(\frac{I_m}{K_m}\right) I_m} \to \infty$ if $\delta \to 0$, then if δ is sufficiently small, $\frac{t\left(\frac{I_m}{K_a}\right)\bar{\varepsilon}}{t\left(\frac{I_m}{K_m}\right)I_m}$ would be sufficiently large and $\frac{\partial I_m}{\partial I_o}$ is sufficiently small according to equation (14).

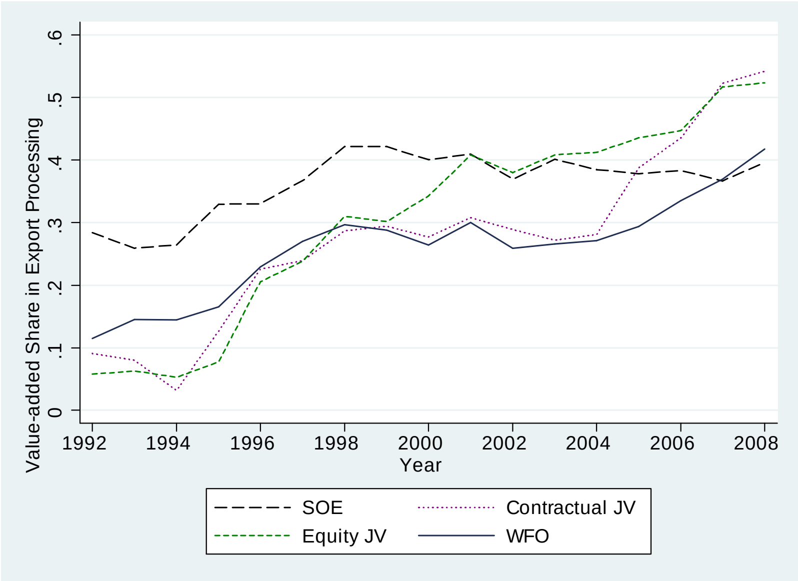

Figure 1: Value-added Share in Processing Export

Notes:

1. Firms' types are: SOE (State Owned Enterprise), Contractual JV (Contractual Joint Venture), Equity JV (Equity Joint Venture) and WFO (Wholly Foreign Owned firms).

2. Source: Author's calculation from the dataset.

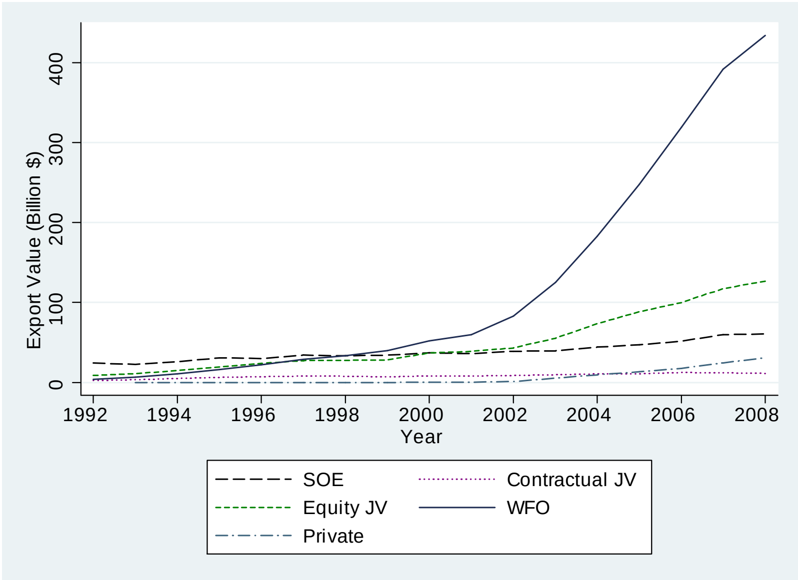

Figure 2: Export Processing Values of Different Types of Firms

Notes:

1. Firms' types are: SOE (State Owned Enterprise), Contractual JV (Contractual Joint Venture), Equity JV (Equity Joint Venture), WFO (Wholly Foreign Owned firms), and Private (Private owned firms).

2. Source: Author's calculation from the dataset.

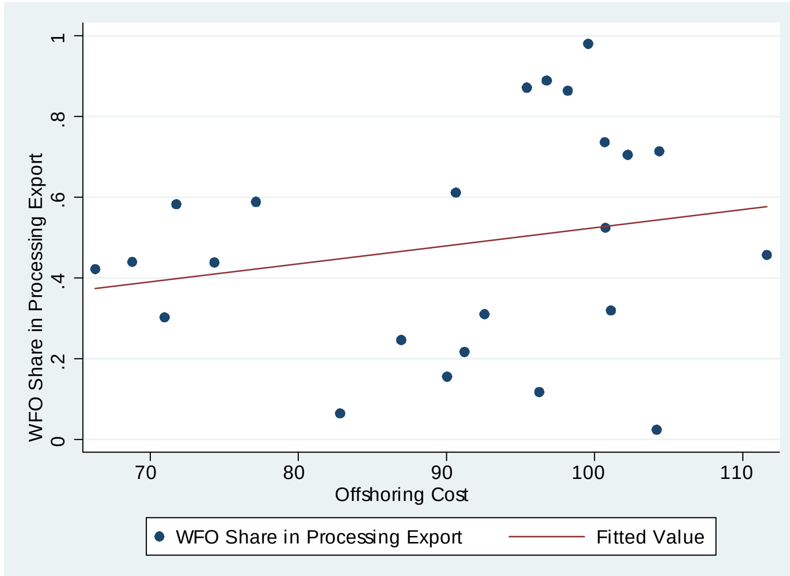

Figure 3: Offshoring Cost and WFO Share In Processing Trade

Notes:

1. Data are for 50 Economic and Technology Development Areas in China in 2007. The offshoring cost index is constructed by the sum of indexes of the cumulative investment in infrastructure, the capability of water, steam and gas supply, whether the administrative institution passes $ISO9001$ certification, whether the zone has authorities to approve provincial level foreign investment projects, whether the administrative management is efficient, and whether the zone has patent protection offices. WFO stands for Wholly-Foreign-Owned firms.

2. Source: Author's calculation based on China Development Zones Yearbook, 2007.

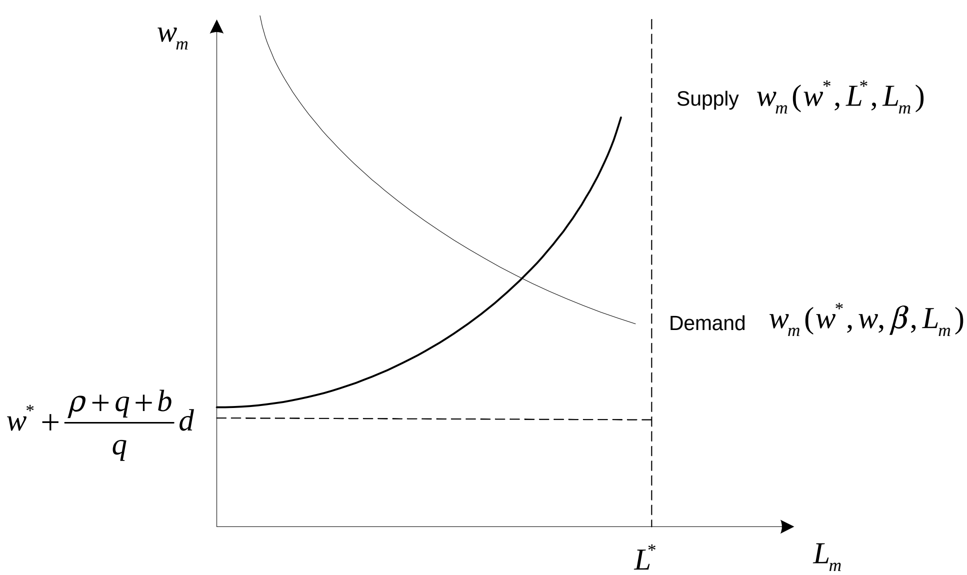

Figure 4: MNCs' Labor Market

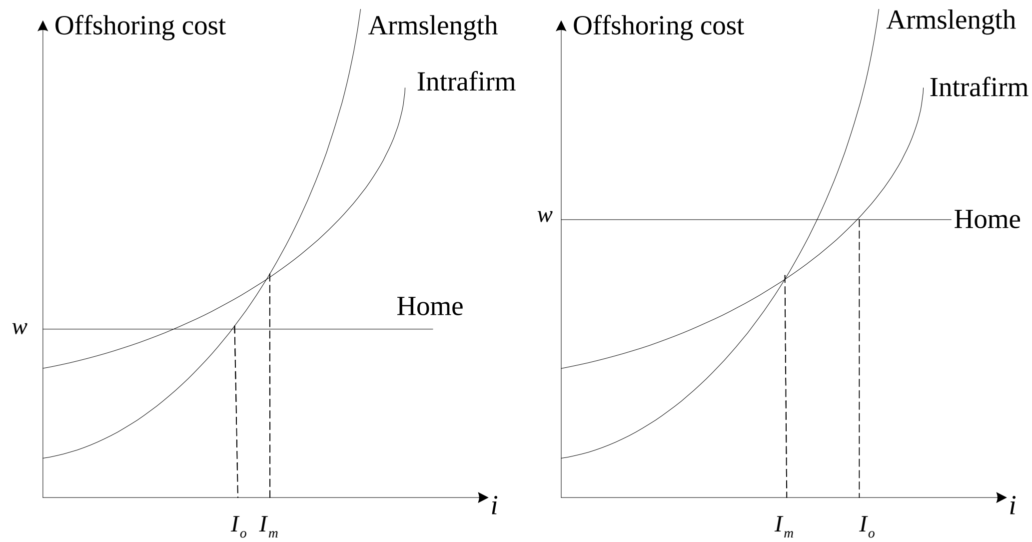

Figure 5: Task Offshoring in Different Organizational Forms

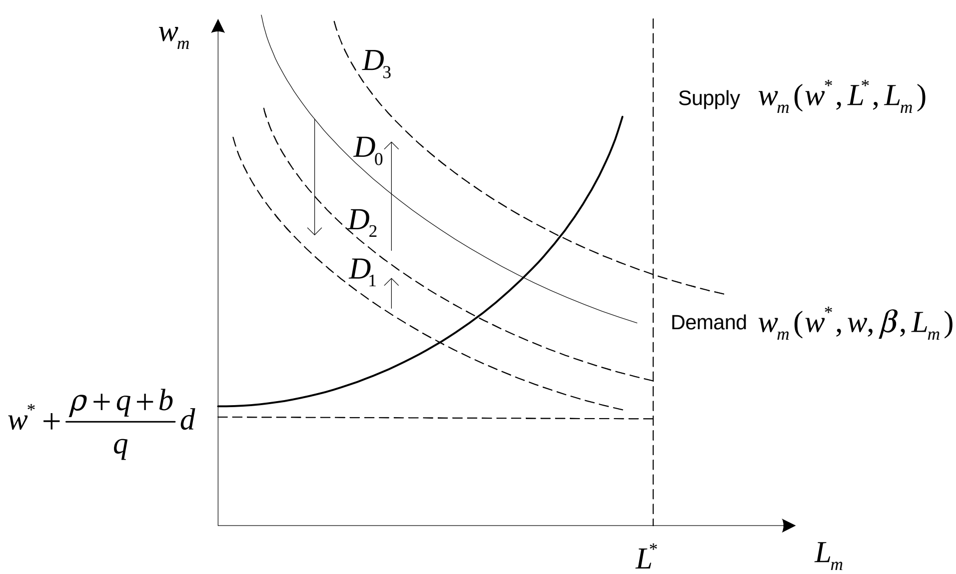

Figure 6: Effects of a Fall of Offshoring Cost on MNC Employment

Table 1: Major Sectors' Share in Processing Export by WFO

Year	SITC65 Textiles	SITC75 Office Mach.	SITC76 Telecom	SITC77 Elec. Mach.	SITC84 Apparel	SITC85 Footwear	SITC87 Sci. Ins.	SITC88 Photo. Equ.	SITC89 Misc. Man
1997	0.044	0.142	0.108	0.143	0.113	0.072	0.012	0.032	0.135
1998	0.042	0.168	0.101	0.152	0.098	0.064	0.013	0.030	0.135
1999	0.040	0.185	0.096	0.179	0.091	0.058	0.016	0.025	0.116
2000	0.033	0.208	0.113	0.178	0.080	0.048	0.019	0.024	0.104
2001	0.029	0.244	0.120	0.163	0.074	0.047	0.015	0.019	0.101
2002	0.023	0.296	0.128	0.156	0.059	0.034	0.015	0.013	0.103
2003	0.018	0.363	0.134	0.141	0.048	0.026	0.028	0.011	0.081
2004	0.016	0.352	0.167	0.143	0.040	0.021	0.037	0.010	0.068
2005	0.015	0.346	0.189	0.140	0.034	0.018	0.041	0.010	0.069
2006	0.015	0.343	0.194	0.152	0.032	0.016	0.039	0.009	0.066
2007	0.014	0.318	0.210	0.154	0.030	0.015	0.046	0.009	0.071
2008	0.013	0.312	0.203	0.155	0.029	0.015	0.049	0.009	0.075

Note 1: Sectors are defined as 2-digit SITC sectors according to SITC Rev.3. The orginal dataset is aggregated to HS 6-digits codes and then converted to SITC Rev.3 5-digit code.

Note 2: Major sectors are defined as sectors that have a share of processing export by WFOs more than 3% in any year between 1997-2008. The total share of these major sectors is more than 80% of all processing export by WFOs.

Note 3: The shares are calculated by deviding the processing export value of each sector by the total processing export value in each year.

Note 4: Sector names: SITC65: Textiles; SITC75, Office machines; SITC76, Telecommunications; SITC77, Electrical machineries; SITC84, Apparels; SITC85, Footwears; SITC87, Scientific instruments; SITC88, Photographic equipments; SITC89, Miscellaneous manufactured articles.

Note 5: Source: Author's calculation from the dataset.

Table 2: Decomposing the Change of Processing Trade by WFO into Zones

Year	Export Change (Billion $)	Share of Export Change						Import Change (Billion $)	Share of Import Change					
		SEZ	ETDA	HTIDA	BA	EPZ	Non-zone		SEZ	ETDA	HTIDA	BA	EPZ	Non-zone
1998	4.89	-0.005	0.077	0.179	0.130		0.619	2.67	-0.012	0.174	0.290	0.185		0.363
1999	5.94	0.030	0.142	0.060	0.208		0.561	4.53	0.017	0.226	0.037	0.182		0.538
2000	12.6	0.093	0.121	0.107	0.067		0.611	10.2	0.087	0.179	0.138	0.071		0.525
2001	7.72	0.192	0.072	0.099	0.027		0.564	3.51	0.316	-0.031	0.085	0.014		0.506
2002	22.9	0.002	0.119	0.156	0.073	0.077	0.574	19.5	-0.001	0.076	0.154	0.130	0.089	0.552
2003	42.6	0.017	0.119	0.173	0.059	0.181	0.450	30.7	0.003	0.152	0.147	0.068	0.164	0.467
2004	57.2	0.021	0.187	0.100	0.050	0.184	0.459	40.9	0.025	0.227	0.083	0.029	0.142	0.494
2005	64.8	0.034	0.155	0.077	0.046	0.206	0.483	41.7	0.029	0.158	0.075	0.042	0.167	0.529
2006	71.7	0.044	0.091	0.021	0.081	0.262	0.501	37.6	0.026	0.122	0.000	0.062	0.201	0.589
2007	72.8	0.032	0.066	0.087	0.025	0.275	0.515	34.8	0.032	0.153	-0.008	0.001	0.171	0.650
2008	42.2	0.012	0.099	-0.253	-0.081	0.585	0.637	5.68	0.028	0.528	-0.812	-0.208	0.881	0.578

Note 1: Export change is culculated by processing export value in the current year minus that in the previous year. Similar for Import change. All values are nominal.

Note 2: Shares of the zones are culculated by the change of processing export(or import) value in the zone devided by the overall change of processing export(or import) in the same year.

Note 3: SEZ: Special Economic Zone; ETDA: Economic and Technology Development Area; HTIDA: Hi-Technology Industry Development Area; BA: Bonded Area; EPZ: Export Processing Zone; Non-zone: none of above area.

Note 4: Source: author's calculation from the dataset.

Table 3: Basic Statistics for Key Variables

Variables	Obs.	Mean	Std.Dev.	Min	Max
WFO share of processing export*100 ($Intrashare$)	431281	37.465	44.602	0.000	100.000
WFO share of processing export by FIEs*100 ($IntrashareFIE$)	328265	57.359	46.072	0.000	100.000
WFO share of processing export outside special policy zones*100 ($Intrashareoutzone$)	384758	34.702	43.833	0.000	100.000
EPZ Dummy	431281	0.275	0.447	0.000	1.000
HT Dummy	431281	0.672	0.469	0.000	1.000
Non-agriculture population in million persons (NAP)	427741	2.592	2.561	0.120	11.969
Number of secondary school students in million persons (NSS)	425427	0.323	0.206	0.000	2.305
Proxy of transportation Infrastructure (Passenger number/population, $Trans$)	429889	34.527	41.898	1.890	285.830

Table 4: Main Estimation Results, *Intrashare* as Dependent Variable

Models	Basic Model		Random Trend Model				Dynamic Panel Model	
Estimation Method	FE	FD	FE		FD		2SLS	GMM
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPZ Dummy (EPZ)	-2.995**	1.317**	1.338***	1.337***	1.324***	1.466***	0.544**	0.542**
	(1.226)	(0.536)	(0.476)	(0.421)	(0.414)	(0.418)	(0.257)	(0.257)
HT Dummy (HT)	2.468	2.509*	2.022	2.463*	2.160	2.470	3.371***	3.326***
	(1.506)	(1.382)	(1.399)	(1.313)	(2.123)	(2.103)	(0.993)	(0.995)
Nonagriculture population (NAP)	2.123**	4.629***	3.989***	3.803***	4.345***	4.437***	1.632***	1.600***
	(0.983)	(0.743)	(0.812)	(0.750)	(0.740)	(0.736)	(0.193)	(0.193)
Secondary school student (NSS)	13.92*	13.08	7.023	7.883	1.790	2.798	1.803	1.739
	(8.405)	(8.395)	(6.685)	(6.770)	(5.387)	(5.509)	(1.559)	(1.557)
Transportaion Infrastructure ($Trans$)	0.0400*	0.104***	0.0861***	0.0833***	0.102***	0.104***	0.0366***	0.0359***
	(0.0213)	(0.0178)	(0.0191)	(0.0179)	(0.0184)	(0.0182)	(0.00535)	(0.00535)
LagIntrashare							0.574***	0.588***
							(0.0282)	(0.0280)
Prod-City fixed effect	Yes	Yes	Yes	Yes	Yes	Yes		
Year fixed effect	Yes	Yes	No	Yes	No	Yes		
Prod-City trend	No	No	Yes	Yes	Yes	Yes		
Constant	36.38***		1.862***	0.438			9.368***	8.996***
	(5.639)		(0.125)	(0.338)			(1.248)	(1.242)
Observations	422098	316012	316012	316012	245514	245514	289675	289675
R-squared	0.081	0.014	0.002	0.003	0.002	0.002		
Product-City pairs	103278		70491	70491			65964	65964

Note 1: Cluster robust standard errors at city level are reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Note 2: Dependent variable: Intrashare, calculated by WFOs' processing exports devided by overall processing exports, then times 100.

Note 3: Regressors are export processing zone dummy(EPZ), other special zone dummy (HT), nonaggreculture population in million persons (NAP), number of students in secondary school in million persons (NSS) and transportaion infrastructure ($Trans$, calculated as the ratio of passenger number to population).

Note 4: Estimation methods: FE: Fixed effect panel estimation; FD: First Differencing panel estimation; 2SLS, Two-stage least square estimation; GMM, Generalized method of moments estimation.

Table 5: Intrafirm Offshoring Share of Export Processing by FIEs, $IntrashareFIE$ as Dependent Variable

Models	Basic Model		Random Trend Model				Dynamic Panel Model	
Estimation Method	FE	FD	FE		FD		2SLS	GMM
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPZ Dummy (EPZ)	-3.263**	1.546***	1.430***	1.467***	1.077**	1.200***	0.601**	0.603**
	(1.603)	(0.513)	(0.382)	(0.374)	(0.469)	(0.450)	(0.296)	(0.294)
HT Dummy (HT)	6.143***	4.883***	4.195***	4.518***	4.367***	4.750***	4.333***	4.398***
	(1.823)	(0.638)	(0.358)	(0.386)	(0.757)	(0.716)	(1.245)	(1.249)
Nonagriculture population (NAP)	2.649*	4.396***	3.264***	3.332***	3.551***	3.766***	1.440***	1.334***
	(1.357)	(0.930)	(0.812)	(0.775)	(0.760)	(0.749)	(0.206)	(0.205)
Secondary school student (NSS)	11.27	9.015	4.577	4.200	0.0490	0.433	0.894	0.673
	(9.330)	(7.121)	(4.922)	(4.761)	(4.409)	(4.451)	(1.778)	(1.774)
Transportaion Infrastructure ($Trans$)	0.0639**	0.100***	0.0713***	0.0733***	0.0824***	0.0856***	0.0297***	0.0278***
	(0.0262)	(0.0226)	(0.0198)	(0.0189)	(0.0191)	(0.0186)	(0.00572)	(0.00563)
LagIntrashareFIE							0.600***	0.622***
							(0.0359)	(0.0355)
Prod-City fixed effect	Yes	Yes	Yes	Yes	Yes	Yes		
Year fixed effect	Yes	Yes	No	Yes	No	Yes		
Prod-City trend	No	No	Yes	Yes	Yes	Yes		
Constant	27.52***		2.099***	1.942***			16.66***	15.76***
	(5.067)		(0.131)	(0.275)			(1.985)	(1.974)
Observations	321177	235056	235056	235056	180015	180015	222915	222915
Production-City pairs	77444		52670	52670			50378	50378
R-squared	0.100	0.014	0.001	0.002	0.001	0.002		

Note 1: Cluster robust standard errors at city level are reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Note 2: Dependent variable: Intrashare, calculated by WFOs' processing exports devided by total processing exports by FIEs, then times 100.

Note 3: Regressors are export processing zone dummy(EPZ), other special zone dummy (HT), nonaggreculture population in million persons (NAP), number of students in secondary school in million persons (NSS) and transportaion infrastructure ($Trans$, calculated as the ratio of passenger number to population).

Note 4: Estimation methods: FE: Fixed effect panel estimation; FD: First Differencing panel estimation; 2SLS, Two-stage least square estimation; GMM, Generalized method of moments estimation.

Table 6: Intrafirm Offshoring Share in Cities with Other Special Zones, *Intrashare* as Dependent Variable

Models	Basic Model		Random Trend Model				Dynamic Panel Model	
Estimation Method	FE	FD	FE		FD		2SLS	GMM
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPZ Dummy (EPZ)	-1.987	1.784***	1.439***	1.447***	1.334***	1.530***	0.781***	0.784***
	(1.294)	(0.579)	(0.488)	(0.461)	(0.445)	(0.462)	(0.263)	(0.263)
Nonagriculture population (NAP)	1.540	4.930***	4.863***	4.789***	5.307***	5.386***	1.426***	1.330***
	(1.453)	(1.279)	(1.443)	(1.447)	(1.279)	(1.283)	(0.256)	(0.256)
Secondary school student (NSS)	6.282	6.888	5.887	5.122	0.569	0.956	1.196	1.377
	(9.824)	(6.796)	(4.922)	(5.440)	(3.923)	(4.259)	(1.713)	(1.713)
Transportaion Infrastructure ($Trans$)	0.170*	0.106	0.0165	0.0428	0.0552	0.0743	0.0207	0.0199
	(0.0992)	(0.0769)	(0.0582)	(0.0663)	(0.0560)	(0.0610)	(0.0199)	(0.0199)
LagIntrashare							0.586***	0.606***
							(0.0308)	(0.0305)
Prod-City fixed effect	Yes	Yes	Yes	Yes	Yes	Yes		
Year fixed effect	Yes	Yes	No	Yes	No	Yes		
Prod-City trend	No	No	Yes	Yes	Yes	Yes		
Constant	36.80***		1.543***	1.490***			11.86***	11.31***
	(8.565)		(0.199)	(0.362)			(1.286)	(1.276)
Observations	284459	218852	218852	218852	173281	173281	199657	199657
R-squared	0.071	0.012	0.002	0.003	0.002	0.002		
Product-City Pairs	65537		46377	46377			43314	43314

Note 1: Cluster robust standard errors at city level are reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Note 2: Dependent variable: Intrashare, calculated by WFOs' processing exports devided by overall processing exports, then times 100.

Note 3: Regressors are export processing zone dummy(EPZ), nonaggreculture population in million persons (NAP), number of students in secondary school in million persons (NSS) and transportaion infrastructure ($Trans$, calculated as the ratio of passenger number to population).

Note 4: Estimation methods: FE: Fixed effect panel estimation; FD: First Differencing panel estimation; 2SLS, Two-stage least square estimation; GMM, Generalized method of moments estimation.

Table 7: Intrafirm Offshoring Share in Outside of Zones, *Intrashareoutzone* as Dependent Variable

Models	Basic Model		Random Trend Model				Dynamic Panel Model	
Estimation Method	FE	FD	FE		FD		2SLS	GMM
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPZ Dummy (EPZ)	-3.605***	0.514	0.994**	0.937**	0.780**	0.919**	0.662**	0.626**
	(1.312)	(0.451)	(0.426)	(0.390)	(0.372)	(0.371)	(0.281)	(0.281)
HT Dummy (HT)	1.553	1.891	1.217	1.672	1.663	1.979	2.759***	2.652***
	(1.777)	(1.463)	(1.611)	(1.493)	(2.363)	(2.345)	(0.939)	(0.940)
Nonagriculture population (NAP)	2.038**	3.824***	3.251***	3.034***	3.346***	3.441***	1.746***	1.740***
	(0.964)	(0.582)	(0.627)	(0.533)	(0.611)	(0.620)	(0.230)	(0.231)
Secondary school student (NSS)	12.75	13.69*	7.275	8.537	2.836	4.040	3.349**	2.819*
	(7.730)	(7.773)	(6.137)	(6.251)	(4.804)	(4.920)	(1.645)	(1.641)
Transportaion Infrastructure ($Trans$)	0.0370*	0.0849***	0.0681***	0.0647***	0.0776***	0.0794***	0.0387***	0.0388***
	(0.0189)	(0.0146)	(0.0149)	(0.0130)	(0.0155)	(0.0156)	(0.00614)	(0.00616)
LagIntrashareoutzone							0.549***	0.561***
							(0.0361)	(0.0357)
Prod-City fixed effect	Yes	Yes	Yes	Yes	Yes	Yes		
Year fixed effect	Yes	Yes	No	Yes	No	Yes		
Prod-City trend	No	No	Yes	Yes	Yes	Yes		
Constant	13.37***		1.878***	0.447			8.726***	8.523***
	(3.484)		(0.111)	(0.327)			(1.273)	(1.261)
Observations	376307	276476	276476	276476	211998	211998	255816	255816
Product-City pairs	94095		63291	63291			59405	59405
R-squared	0.081	0.012	0.001	0.002	0.001	0.001		

Note 1: Cluster robust standard errors at city level are reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Note 2: Dependent variable: Intrashareoutzone, calculated by, excluding special policy zones, WFOs' processing exports devided by total processing exports, then times 100.

Note 3: Regressors are export processing zone dummy(EPZ), other special zone dummy (HT), nonaggreculture population in million persons (NAP), number of students in secondary school in million persons (NSS) and transportaion infrastructure ($Trans$, calculated as the ratio of passenger number to population).

Note 4: Estimation methods: FE: Fixed effect panel estimation; FD: First Differencing panel estimation; 2SLS, Two-stage least square estimation; GMM, Generalized method of moments estimation.

Table 8: Intrafirm Offshoring Share in East Region, *Intrashare* as Dependent Variable

Models	Basic Model		Random Trend Model				Dynamic Panel Model	
Estimation Method	FE	FD	FE		FD		2SLS	GMM
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPZ Dummy (EPZ)	-3.401***	1.343**	1.394***	1.395***	1.376***	1.524***	0.545**	0.543**
	(1.250)	(0.553)	(0.491)	(0.432)	(0.427)	(0.433)	(0.258)	(0.259)
HT Dummy (HT)	2.690	3.844***	3.391***	3.806***	4.006***	4.325***	4.422***	4.368***
	(1.732)	(0.736)	(0.457)	(0.499)	(1.278)	(1.313)	(1.171)	(1.171)
Nonagriculture population (NAP)	1.663	4.539***	3.950***	3.752***	4.306***	4.418***	1.691***	1.658***
	(1.006)	(0.756)	(0.822)	(0.753)	(0.751)	(0.750)	(0.194)	(0.195)
Secondary school student (NSS)	15.54*	13.75	6.821	7.883	1.583	2.652	1.697	1.602
	(8.905)	(9.043)	(6.929)	(7.091)	(5.487)	(5.701)	(1.599)	(1.598)
Transportaion Infrastructure ($Trans$)	0.0299	0.102***	0.0851***	0.0818***	0.101***	0.103***	0.0380***	0.0373***
	(0.0213)	(0.0182)	(0.0194)	(0.0180)	(0.0187)	(0.0185)	(0.00537)	(0.00537)
LagIntrashare							0.559***	0.573***
							(0.0286)	(0.0284)
Prod-City fixed effect	Yes	Yes	Yes	Yes	Yes	Yes		
Year fixed effect	Yes	Yes	No	Yes	No	Yes		
Prod-City trend	No	No	Yes	Yes	Yes	Yes		
Constant	16.21***		1.945***	1.707***			9.471***	9.086***
	(4.156)		(0.130)	(0.314)			(1.348)	(1.341)
Observations	389248	295190	295190	295190	231463	231463	271423	271423
Product-City Pairs	91250		63720	63720			59752	59752
R-squared	0.084	0.014	0.002	0.003	0.002	0.002		

Note 1: Cluster robust standard errors at city level are reported in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Note 2: Dependent variable: Intrashareoutzone, calculated by WFOs' processing exports devided by total processing exports, then times 100.

Note 3: Regressors are export processing zone dummy(EPZ), other special zone dummy (HT), nonaggreculture population in million persons (NAP), number of students in secondary school in million persons (NSS) and transportaion infrastructure ($Trans$, calculated as the ratio of passenger number to population).

Note 4: Estimation methods: FE: Fixed effect panel estimation; FD: First Differencing panel estimation; 2SLS, Two-stage least square estimation; GMM, Generalized method of moments estimation.

Appendix Table A: Main Notation for the Paper

Symbol	Definition
	Panel A: Theoretical Framework
a_{Lj}, a_{Hj}	Units of low-skilled (high-skilled) labor used to perform L-tasks (H-tasks) to produce one unit of output j
i	Complexity level of task indexed by i
K_m, K_a	Number of words used in communication by MNCs and armslength suppliers
$t(z)$	Diagnosis cost for a word referring to an interval of length z
β	Communication technology
δ	The inferiority of communication in armslength offshoring
w, w^*, w_m	Home and foreign low-skilled labor wage, and low-skilled wage paid by MNCs
b	Natural exogenous quit rate from MNCs
q	The rate at which shirking is detected in MNCs
e	The accession rate of non-MNC workers aquiring MNC jobs
V_{mn}, V_{ms}, V_a	The expected lifetime utility of non-shirking MNC employees, shirking MNC employees, and non-MNC workers
ρ	The discount rate
d	Disutility of not shirking
L, L^*, L_m	Home and foreign low-skilled labor, and low-skilled labor hired by MNCs
I_o	The marginal offshored task
I_m	The marginal offshored task in the form of intrafirm offshoring
$\varepsilon(z)$	The elasticity function of t function
$\bar{\varepsilon}$	$\bar{\varepsilon}$ is defined as by $\bar{\varepsilon} \equiv \varepsilon\left(\frac{I_m}{K_a}\right) - \varepsilon\left(\frac{I_m}{K_m}\right)$
p	Price of good Y when good X is numeraire
$\Omega(I_o, I_m)$	$\Omega(I_o, I_m) \equiv (1 - I_o) + \frac{1}{t\left(\frac{I_o}{K_m}\right)} \frac{t\left(\frac{I_m}{K_m}\right)}{t\left(\frac{I_m}{K_a}\right)} \int_0^{I_m} t\left(\frac{i}{K_a}\right) di + \frac{\int_{I_m}^{I_o} t\left(\frac{i}{K_m}\right) di}{t\left(\frac{I_o}{K_m}\right)}$
x, y	Quantity of good X and Y
s, s^*	Home and foreign high-skilled labor wage
H, H^*	Home and foreign high-skilled labor
A^*	Hicks-neutral technological inferiority of foreign firms
$D(p)$	The (homothetic) world relative demand for good Y
A, B	$A \equiv 1 + \frac{\bar{\varepsilon}}{I_m} \frac{\partial I_m}{\partial \beta} \beta > 0$, and $B \equiv \frac{1}{I_o} \varepsilon\left(\frac{I_o}{K_m}\right) + \frac{\bar{\varepsilon}}{I_m} \frac{\partial I_m}{\partial I_o}$
	Panel B: Empirical Specification
ε_{ict}	Idiosyncratic error term, $\varepsilon_{ict} \sim N\left(0, \sigma_c^2\right)$
η_{ict}	In dynamic panel specification, $\varepsilon_{ict} = \eta_{ict} - \gamma\eta_{ict-1}$ and η_{ict} is *iid*.
α_{ic}	Product-city fixed effect
α_t	Year fixed effect
g_{ic}	Product-city specific trend
λ_t	Year fixed effect, equal to $\alpha_t - \alpha_{t-1}$