Offshoring and Wage Inequality: Theory and Evidence from China†

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Abstract

We develop a model to study the ownership structure of offshoring and its implications for skill demand and wage inequality in developing countries. With the presence of contractual frictions in the South, multinational companies have incentives to choose FDI offshoring for skill intensive production, but prefer arm's length transactions for low-skill activities. Therefore, FDI offshoring contributes more prominently than arm's length arrangements to technology upgrading and skill premium in developing countries. By incorporating these results into an augmented Mincer earnings regression, we test the model based on a natural experiment in which China lifts its restrictions on foreign ownership upon its accession to the WTO. Empirical findings using detailed Urban Household Surveys and trade data from Chinese customs provide strong support to the proposed theory, thus shedding light on the changes in firm ownership structures, the skill content of exports, and the evolution of wage inequality for the period of 1992-2008 in China.

Key words: offshoring, ownership structure, processing trade, wage inequality, China

JEL classification: F16, J31, D23

1 Introduction

Globalization has changed the nature of international trade. For centuries, conventional trade primarily involved the exchange of final goods across countries. Over the last several decades, trade in intermediate inputs - offshoring through both foreign direct investment (FDI) and arm's length outsourcing – have gained prominence in the global economy. Now roughly two-thirds of world trade is trade in intermediate inputs, and approximately half of that is within the boundaries of multinational companies.[1] The rise in offshoring and corresponding changes in organizational structures raise important questions on the distributional effects on factor prices. How does offshoring influence wage inequality? Do FDI offshoring and arm's length offshoring affect skill demand differently in developing countries?

Extensive studies have investigated the effect of globalization on wage inequality over the last two decades. The classical Heckscher-Ohlin model suggests that opening to trade should help low-skilled workers in developing countries because such countries export low skill-intensive products. However, there is overwhelming evidence that globalization has increased the income of skilled workers relative to that of less skilled in these countries (Goldberg and Pavcnik, 2007). The seminal paper by Feenstra and Hanson (1996a) and subsequent studies have shown that offshoring from the North to the South could increase skill premium in both economies,[2] but recent development implies that the effect of offshoring on wage inequality is more complex as it depends on whether low-skill tasks or high-skill tasks are offshored (Grossman and Rossi-Hansberg, 2008; Acemoglu and Autor, 2011). Thus far, the literature has mainly focused on the effect of aggregate offshoring size on wage inequality without making a distinction between FDI and arm's length offshoring. This approach neglects the extensive evidence that multinationals are more likely to offshore more

[1]See Johnson and Noguera (2011). According to UNCTAD (1999, p.232), approximately one-third of world trade was intermediate inputs traded within firm boundaries in 1996. Thus, FDI offshoring contributes approximately half of total offshoring.

[2]See, for example, Feenstra and Hanson (1996b, 1997, 1999) and Hsieh and Woo (2005). Those studies find that offshoring contributes modestly to the rising wage inequality in U.S. in 1980s and 1990s, however, there is no systematic evidence from developing countries as the impact of offshoring on wage inequality in those countries has so far been examined only for Mexico and Hong Kong (Goldberg and Pavcnik, 2007).

sophisticated and thus more skill intensive activities through their foreign affiliates.[3] To bridge this gap, this paper develops an integrated framework to analyze the ownership structure of offshoring in shaping skill demand and wage inequality in developing countries, and provides empirical evidence by using recent data from China, a fast-growing large developing economy. Consistent with the model, our empirical analysis shows that the ownership structure of offshoring plays a key role in understanding skill upgrading and widening wage inequality for the period of 1992-2008 in China.

The main theoretical innovation of this paper is to introduce ownership choices into the offshoring framework of wage determination (Feenstra and Hanson, 1996a). The model disentangles the role of comparative advantage and contractual frictions in shaping the pattern of offshoring. It retains the main implication of comparative advantage in the sense that more skill-intensive products are produced in the North because of its abundant endowment in skilled labor, whereas the less skill-intensive goods are offshored to the South (Dornbusch et al., 1980). The model also keeps the key ingredient of the Property Right Theory (Grossman and Hart, 1986), as it shows that multinational companies have an incentive to choose FDI offshoring for skill-intensive production, but prefer arm's length transactions for sourcing low-skill activities. Therefore, FDI offshoring contributes more prominently to the skill upgrading in developing countries. The model also shows that ownership liberalization for foreign investments can attract more skill-intensive production and thus raise the skill premium in the South. Given the prevalent ownership restrictions on the operation of multinational companies in many developing countries (Kalinova et al., 2010; UNCTAD, 2006), this paper forges a new but potentially important linkage between globalization and wage inequality. One additional innovation in this paper is to develop an augmented Mincer wage regression based on the implication of the model on skill demand, which provides a useful empirical specification to test the model predictions by using the detailed household survey data and trade data.

[3] See, for example, Grossman and Helpman (2002, 2005), Antràs (2003, 2005), Antràs and Helpman (2004), Feenstra and Hanson (2005), Nunn and Trefler (2008), Costinot et al. (2011), and Fernandes and Tang (2012). Please see Helpman (2006) for a comprehensive review of trade, FDI and firm organizations.

China provides an intriguing natural experiment to test the major implications of our model. In the 1980s and 1990s, the Chinese government encouraged joint ventures, but restricted (wholly) foreign ownership for strategic purposes. Upon its accession to the World Trade Organization (WTO) in 2001, China was forced to undertake major legal reforms to remove the ownership restrictions, together with other trade liberalization reform in manufacturing sector. The accession to WTO has successfully transformed China from a negligible player in international markets to the world's largest exporter and the largest recipient of FDI among developing countries. These policy reforms, induced largely by external factors, present an unusual opportunity to investigate the effects of structural changes in offshoring on skill demand and wage inequality.[4]

Figure 1 presents two striking empirical patterns that are consistent with the main implications of our model. First, as shown in panel (a), FDI processing exports, which are defined as processing exports by wholly foreign-owned enterprises, accelerated to a considerably much steeper trajectory of growth shortly after China's accession to the WTO in 2001. By contrast, arm's length processing exports, which are defined as processing exports by joint ventures and Chinese domestic firms, was outpaced by FDI processing exports soon after the critical event despite maintaining its growth over time. We use processing exports as a measure of offshoring because it involves a foreign firm that either works with its own affiliates or contracts with local firms to assemble imported inputs with local factors, and re-exports the products to foreign markets. In other words, processing exports are the offshored production from foreign countries.[5] Meanwhile, as illustrated in panel (b), the college wage premium in the Chinese manufacturing sector remained flat before China's accession to the WTO, but increased dramatically thereafter. The college wage premium is computed based on the national representative sample of Chinese Urban Household Surveys (UHS), to which we

[4]Ownership liberalization on foreign investment in China has resulted in a remarkable compositional change between wholly foreign-owned firms and joint ventures in the inflow of foreign investment. Prior to 2001, joint ventures played a dominant role, but since then the investment made by wholly foreign-owned firms increased rapidly and outpaced that of joint ventures.

[5]See the detailed explanation of processing exports in Feenstra and Hanson (2005). Processing exports play a major role in China's international trade, accounting for an average of 53 percent of the country's total exports from 1992 to 2008. The processing exports by wholly foreign-owned firms exhibited steady growth in the 1990s, reaching 52 billion USD in 2000. Since then, the growth has exploded, reaching 434 billion USD in 2008, which accounts for 64 percent of China's processing exports.

have unique access. The average earnings gap between those with and without college education was approximately 30 percent throughout the 1990s, but this skill premium rose to 55 percent by 2006. These two empirical observations indicate a close positive association between FDI offshoring and college wage premium in China.

We proceed to test the main implications of the model using two comprehensive data sources: the Urban Household Surveys (UHS 1992-2006) and the Chinese customs trade data (1992-2008), which contain detailed ownership and product-level information. Both data sets cover all Chinese provinces such that we can test our theory by taking advantage of the rich spatial variations in trade exposure through three stages. First, we find cross-industry evidence that FDI processing exports are more skill intensive than arm's length processing exports, which is the key implication of the model. More specifically, both the average skill intensity and the first-order stochastic dominance test for distribution differences show that the gap in skill intensity between two types of processing exports has been widening after China's accession to the WTO.

Second, we test the implication of the model that ownership and trade liberalization increases FDI offshoring more than arm's length offshoring. we construct a unique measure of ownership liberalization based on official regulations whether FOEs were "encouraged" or "restricted/prohibited," an index that varies across industries and over time. In addition, we use an infrastructure variable, that is, density of highways and railways as a measure of trade cost reduction. We find that a high degree of ownership liberalization and reduction in trade cost increase FDI processing exports more than arm's length processing exports.

Third, to examine the predicted differential impacts of the two types of offshoring on skill premium, we develop an augmented Mincer earnings regression as implied by our model. The augmented Mincer regression is particularly useful because it not only provides a specification to estimate the skill premium using individual data, but also incorporates demand and supply factors in regional labor markets. Our model implies that regions with more offshoring and a higher share of FDI offshoring have higher college premium. We find that both the ratio of processing exports to industrial output and the share of FDI processing exports are important determinants of college wage premium across the Chinese provinces. This results is robust to the inclusion of various control variables, including the ratio of capital to output and the ratio of R&D to output, which are used to capture capital-skill complementarity and skill-biased technological change, respectively. We also use the predicted values of processing exports and the share of FDI processing export from the first-step regressions as instruments to control for the geographic selection of offshoring destinations. However, the IV estimates are not significantly different from the OLS estimates, which indicates an insignificant endogeneity problem. Quantitatively, the size of processing exports and the share of FDI processing exports can account for 68 percent of the total increase in college wage premium in Chinese manufacturing between 2000 and 2006. FDI processing exports alone can explain approximately 60 percent of the rising college premium during this period.

This paper contributes to the literature on the organizational forms of multinationals in global production. Previous studies mainly focus on the determinants of organizational forms (see footnote 3), while largely ignoring their differential effect on factor prices. To the best of our knowledge, this study is the first to distinguish the ownership structures of offshoring and analyze the effects of ownership liberalization and trade cost reduction on labor market outcomes in developing countries. Understanding the linkage between ownership structure in offshoring and wage inequality also has important policy significance because restrictions on foreign ownership are major barriers to inward FDI. Despite efforts to relax FDI regulations in many developing countries over the last three decades(Kalinova et al., 2010), the effect of ownership liberalization on trade structure and factor prices remains largely unknown. Our empirical findings, which are based on the Chinese experience, shed light on this neglected area.

This paper also contributes to the literature on the relationship between globalization and wage inequality in two ways. First, most recent studies exploring the contribution of firm heterogeneity to the rising demand for high-skilled labor are based on the sorting mechanism of Melitz (2003)[6], whereas our approach focuses on the heterogeneous organizational forms of offshoring. This ap-

[6]See, for example, Bustos (2011) who discusses the channel through firms' choice of skill-biased technology adoption. Verhoogen (2008) explores the quality upgrading channel. Helpman et al. (2010) provides a tractable model to explore the determinants of wage distributions that emphasize within-industry reallocation, labor market frictions, and differences in workforce composition across firms

proach points to a new mechanism and has strong policy implications for developing countries. Secondly, limited research has been conducted on the effect of globalization on income distribution in China (Goldberg and Pavcnik, 2007), with the exception of Han et al. (2011).[7] Such limitation is a serious void in the literature because of China's emerging role as the "world factory"and the profound changes in income distribution in recent decades. Our empirical findings contribute to the understanding of the effect of recent globalization on income inequality because of China's significance among developing countries.

The reminder of this paper is organized as follows: Section 2 develops the theoretical framework and presents an augmented Mincer earnings equation, as well as the identification strategy. Section 3 briefly describes China's globalization process, the natural experiment of policy changes, and the data used for empirical analysis. Section 4 presents the empirical findings. The final section presents our tentative and incomplete concluding remarks with relevant policy discussions.

2 Offshoring, Ownership Structure and Skill Premium

This section develops a model introducing ownership structure into the offshoring framework in a two-country setting, and shows how multinational firms jointly decide on offshoring, ownership structure and skill demand subject to trade and contractual frictions. The model not only presents a theoretical framework to analyze the impact of ownership and trade liberalization on the offshoring structure and aggregate wage inequality in developing countries, but also provides guidance for empirical analysis.

2.1 Setup

The world consists of two countries, the North and the South. There are two types of labor: high- and low-skilled labors, denoted by h and l respectively. Their wages in country c are denoted

[7]Han et al. (2011) also find rising wage inequality in China by using a part of CUHS data that covers five Chinese provinces. Their study is empirical and does not provide a theoretical framework to explain the sources of wage inequality.

by q^c and w^c, respectively, where $c \in \{N, S\}$. The North has more abundant high-skilled labor than the South. We assume that the North produces both the final good Y and intermediate goods, while the South only produces intermediate goods.

The production of the intermediate good $y(z)$ is given by

$$y(z) = \xi_z x_h^z x_l^{1-z} \text{ and } 0 \leq z \leq 1 \tag{1}$$

where $\xi_z = z^{-z}(1-z)^{-(1-z)}$. x_h is the high-tech input and x_l is the low-tech input. A higher z indicates more intensive use of high tech in production. The model is closely related to Antràs (2005), but it makes two crucial differences. Firstly, there is only one type of labor in Antràs (2005), while this model has two types of labor so that we can explore the impact of offshoring on factor prices. For simplicity, we assume that one unit of high-tech (low-tech) input requires one unit of high-skilled (low-skilled, l) labor (h).[8] Secondly, we assume that the production for each intermediate good $y(z)$ is not fragmentable, i.e., the two inputs have to be produced at the same location for manufacturing the good z.[9]

For any intermediate good z, only the Northern innovator has the technology (blueprint) to produce the high-tech input, but she has to find a low-tech input supplier in the North or South. Two parties' investments are assumed to be relation specific. The supplier also needs to pay her a lump-sum transfer T and this transfer would make the supplier break even. If the Northern innovator sources the low-tech inputs from domestic suppliers, the contract is assumed to be complete. However, if she offshores the inputs then she faces the incomplete contracts as the legal environment in the South is poor. However, the Northern innovators can choose the ownership of their joint production; she can either set up a foreign affiliate ($O = F$), or outsource to the Southern suppliers ($O = D$). After production the firm ships the intermediate good z and sells it to the final

[8] This assumption can be easily relaxed to have different labor productivities in different countries.

[9] We follow the approach of Feenstra and Hanson (1996a, 1997) to offshoring, where intermediate goods can be offshored, but the production of intermediate goods is not fragmentable. In contrast, Grossman and Rossi-Hansberg (2008) and Antràs (2005) assume fragmentable production, i.e., the North can offshore the high or low input production to the South separately. Please see Feenstra (2010) for a discussion of these two approaches and their implications of offshoring and wage inequality.

good producer in the North.

The demand for good $y(z)$ is:

$$y(z) = \lambda p(z)^{-1/(1-\alpha)}, \quad 0 < \alpha < 1 \tag{2}$$

where λ is a function of total expenditure and an aggregate price index.[10] Hence, $p(z) = (\lambda/y(z))^{1-\alpha}$ and the revenue is $R(z) = \lambda^{1-\alpha}y(z)^{\alpha}$.The Southern firms must send $t \geq 1$ units of goods for one unit to arrive for sale in the North due to the iceberg trade cost.

In this simple framework, the Northern innovator makes the joint decision of offshoring, ownership structure and skill demand, given the behavior of other producers. Next we focus on the optimization problem of the Northern innovator producing good z.

2.2 Production

Consider a Northern innovator who locates her production in the North. Because the contract is complete in the North, the Northern innovator chooses the low-tech x_l, and high-tech x_h, to maximize $\pi = R(z) - q^N h^N - w^N l^N$. This yields the following profit:

$$\pi^N(z) = (1-\alpha)\lambda[\alpha(1/q^N)^z(1/w^N)^{(1-z)}]^{\alpha/(1-\alpha)} \tag{3}$$

If the Northern innovator chooses to offshore, because of the incomplete contracts the Northern innovator and the Southern supplier will bargain over the surplus from their relation-specific investment after production. This ex post bargaining is modeled as a symmetric Nash bargaining game in which the innovator obtains a fraction $\beta \in [0, 1]$ of the ex post revenue, where the value of β depends on the ownership structure, as we will discuss below. Thus, the supplier sets l^S to maximize $(1-\beta)R(z) - w^S l^S$, and the innovator sets h^S to maximize $\beta R(z) - q^S h^S$, where $R(z) = \lambda^{1-\alpha}y^{\alpha}/t^{\alpha}$. Setting T so as to make the low-tech supplier break even leads to the following

[10] This demand function can be derived from an CES type of production for the final good, i.e., $Y = \log(\int_0^1 y^{\alpha}(z)dz)^{1/\alpha}$, which is a pure assembly of intermediate goods.

expression for the Northern innovator's ex ante profits:

$$\pi^S(z,\beta) = \lambda(\frac{1}{t})^{\alpha/(1-\alpha)}[\alpha(\beta/q^S)^z((1-\beta)/w^S)^{(1-z)}]^{\alpha/(1-\alpha)}[1-\alpha\beta z-\alpha(1-\beta)(1-z)] \quad (4)$$

where $\alpha \in (0,1)$ and β, $z \in [0,1]$.

Ownership gives the owner of the firm the residual rights and thus changes the two parties' ex post outside values. If the Northern innovator owns the firm ($O = F$), once they did not achieve agreement on the bargaining, the innovator can fire the low-tech supplier, who will be left nothing. But she can still obtain δ fraction of the output where $0 < \delta < 1$, which in turn generates sale revenue of $\delta^\alpha R$. The quasi-rent of this relationship is $(1-\delta^\alpha)R$. Symmetric Nash Bargaining leaves each party with its outside option plus one-half of the quasi-rent. Thus, the ex post revenue share of the Northern innovator is $\beta^F = \frac{1}{2}(1+\delta^\alpha)$. By contract, if the Southern supplier owns the firm ($O = D$), the innovator's share in revenue is $\beta^D = \frac{1}{2}(1-\delta^\alpha)$. Clearly we have $0 < \beta^D < 1/2 < \beta^F < 1$.[11]

2.3 Location and ownership choice

The Northern innovator's ex ante expected profit is

$$\pi(z) = \max\{\pi^N(z), \pi^S(z,\beta^F), \pi^S(z,\beta^D)\} \quad (5)$$

Comparing to the North, the South has abundant cheap low-skilled labor, but it has the iceberg trade cost and efficiency loss due to the incomplete contracts. To separate the effect of comparative advantage and trade costs from the effect of incomplete contracts on offshoring, we introduce a hypothetical case where the South also has complete contracts. The procedure to derive the profit for a given intermediate good z under the complete contracts in the South, denoted as $\pi^S(z)$, is similar to the case of production in the North, thus it is easy to show $\pi^S(z) =$

[11] In the previous working paper, we also consider the joint venture with $\beta = 1/2$, indicating that both parties have the veto power. The qualitative results hold without joint ventures, but it simplifies technical proof significantly.

$(1-\alpha)\lambda[\alpha(1/q^s)^z(1/w^s)^{(1-z)}]^{\alpha/(1-\alpha)}(1/t)^{\alpha/(1-\alpha)}$.

We first consider an artificial case in which both the North and the South have complete contracts. One important difference is that the ownership choice is irrelevant if the contract is complete in the South. This artificial case provides a useful comparison for the case where the South has incomplete contracts.

Let $N(z)$ denote the "log profit ratio" of the Northern production relative to the Southern production both with complete contracts:

$$N(z) \equiv \frac{1-\alpha}{\alpha}\ln(\pi^N(z)/\pi^S(z)) = z\ln(\omega_l/\omega_h) - \ln\omega_l + \ln t \tag{6}$$

where $\omega_h = q^N/q^S$, and $\omega_l = w^N/w^S$. Because the North has more abundant high-skilled labor, it is reasonable to assume $\omega_h < \omega_l$. To rule out the extreme case that all products are produced in one location, we assume the following assumption.

Assumption 1 $\omega_h < t < \omega_l$.

Clearly $N(z)$ increases in z, and there exists an unique interior solution $z^*(t) \in (0,1)$ such that $N(z^*(t)) = 0$. Thus, we can show the following lemma:

Lemma 1 *Assuming that both countries have the complete contracts and Assumption 1 holds, we have a unique cutoff $z^*(t) \in (0,1)$, and for any $z > z^*(t)$, $\pi^N(z) > \pi^S(z)$ and for any $z < z^*(t)$, $\pi^N(z) < \pi^S(z)$. Thus, more skill-intensive intermediate goods are produced in the North, and less skill-intensive intermediate goods are offshored to the South. Moreover, $z^*(t)$ increases as the trade cost decreases.*

In this artificial case, our model is the same as in Feenstra and Hanson (1997) where comparative advantage plays a crucial role in the allocation of global production sharing. Moreover, the trade cost dampens the comparative advantage of the South, and thus a reduction in trade costs help to attract more skill-intensive products to relocate to the South.

Next we characterize the global production sharing when the contracts are incomplete in the South. In this case, the Northern innovator needs to choose the optimal organizational form when she decides to offshore. We also define the "log profit ratio" of the Southern production under different ownership choices, relative to the Southern production with the complete contracts as follows:

$$\begin{aligned} S(z,\beta) &\equiv \frac{1-\alpha}{\alpha}\ln(\pi^S(z,\beta)/\pi^S(z)) \\ &= z\ln\frac{\beta}{1-\beta} + \ln(1-\beta) + \frac{1-\alpha}{\alpha}[\ln(1-\alpha\beta z-\alpha(1-\beta)(1-z)) - \ln(1-\alpha)] \end{aligned} \tag{7}$$

for $\beta \in (0,1)$. This normalization procedure peels off most of common factors in the profit function of $\pi^S(z,\beta)$, such as demand shifter λ, factor prices and trade costs, but highlights the key factors for ownership choice. This implies that ownership choice is independent of factor prices, trade costs and demand shifters, instead only depends on the skill intensity of the product. The next lemma shows an important feature of $S(z,\beta)$.

Lemma 2 *$S(z,\beta)$ is supermodular in (z,β), concave in z, and strictly concave in β. For a given value of z, there is a unique maximizer $\beta^*(z) \in [0,1]$, and $\beta^*(z)$ increases in z.*

Proof appears in Appendix A. Supermodularity implies that the Northern innovator's bargaining power is complementary to the skill intensity of the intermediate goods z. This is also the core spirit of the PRT of firms (Grossman and Hart, 1986; Hart and Moore, 1990), which argues that the optimal ownership structure should give the residual rights to the party whose investment is more crucial to the relation-specific investment. In Appendix (Lemma 3) we show that for the more skill-intensive intermediate goods produced in the South, it would be optimal if the Northern innovator owns the firm ($O = F$) since she has control over the high-tech input. While for the less skill-intensive intermediate goods, it would be optimal for the Southern supplier owns the firm ($O = D$) since his low-tech input is more important.

Now we are ready to discuss the joint decision of the Northern innovator on location and ownership choices. Note her optimization problem in Equation (5) is equivalent to the comparison between the log profit ratios of the Northern and the Southern productions with ownership choices ($N(z)$ and $S(z, \beta^O)$ for $O = F, D$). Figure 2 plots these curves, and the properties of those curves have been discussed in Lemma 1 and Appendix (Lemma 3). Clearly, the optimal choice of the Northern innovator is the upper contour of these three log profit ratios. To formally characterize this pattern of global production and ownership structure, we make a minor revision on Assumption 1.

Assumption 2 *(1) $\omega_h < t$; (2) $\omega_l > \frac{t}{1-\beta^F}[\frac{1-\alpha}{1-\alpha(1-\beta^F)}]^{\frac{1-\alpha}{\alpha}}$.*

This revised assumption is essentially the same as Assumption 1 in the sense of ruling out the extreme case that all products are produced in one location. The first part guarantees that the most skill-intensive product $z = 1$ is produced in the North, and the second part guarantees that the least skill-intensive product $z = 0$ is produced in the South.[12] Based on this assumption, we can show our main proposition:

Proposition 1 *If Assumption 2 holds and three production modes coexist, then there exists two unique cutoffs $(z^*_{FN}(t), z^*_{DF})$, such that the more skill-intensive intermediate goods are produced in the North ($z > z^*_{FN}(t)$), the middle range skill-intensive goods are through FDI offshoring ($z^*_{FN}(t) > z > z^*_{DF}$), and the less skill intensive goods are outsourced to Southern-owned firms ($z < z^*_{DF}$). Moreover, as the trade cost t decreases, $z^*_{FN}(t)$ increases.*

Proof appears in Appendix C.[13] Figure 2 is also useful to disentangle the role of comparative advantage and incomplete contracts on global production sharing in the integrated framework. Note the horizontal axis presents the log profit ratio of the South production with complete contracts, thus the curve $N(z)$ and the horizontal axis characterize the global production sharing with

[12]This imposes an up-bound for β^F, i.e., $\beta^F < \widetilde{\beta} \equiv f^{-1}(\omega_l/t)$, where $f(\beta) = \frac{1}{(1-\beta)}[\frac{1-\alpha}{1-\alpha(1-\beta)}]^{\frac{1-\alpha}{\alpha}}$. The intuition for this upper bound for the Northern innovator's revenue share is that the South supplier will have little incentive to invest in low-tech input if his revenue share $(1 - \beta)$ is close to 0. Note $f(\beta)$ is an increasing function, thus if β^F satisfies this inequality, it also holds for β^D. Note the upbound depends on ω_l and t,thus this assumption is more likely to hold if trade cost is low, given ω_l.

[13]Note this proposition only shows the pattern when three production modes coexist, however, under certain conditions, FDI offshoring may not exist. Figure 2 is sufficient for us to do general analysis, as we will show later.

the North-South cutoff $z^*(t)$ in the contractual frictionless world of Feenstra and Hanson (1997), in which the South specialized in less skill-intensive products due to the comparative advantage.

By contract, the upper contour of these curves $N(z)$, $S(z, \beta^D)$ and $S(z, \beta^F)$ depicts the global production sharing for the world with incomplete contracts in the South. The comparative advantage still plays its role but the incomplete contracts incur to the South both the intensive and extensive margins of efficiency loss; it makes the South's production less profitable and less products are offshored to the South. The North-South cutoff moves to $z^*_{FN}(t)$ and the product range between $z^*_{FN}(t)$ and $z^*(t)$ reflects the extensive margin of the efficiency loss. More importantly, those potential offshorable products are relatively more skill-intensive, and thus this would affect high-skilled labor more. Moreover, note both $S(z, \beta^D)$ and $S(z, \beta^F)$ are below the horizontal axis, this implies that the allocation of property rights can not recover the efficiency loss due to the incomplete contracts. This is also the fundamental feature of PRT, i.e., the allocation of residual rights increases one party's incentive but decreases the others (Grossman and Hart, 1986). Thus, the area between the upper contour of $S(z, \beta^D)$, $S(z, \beta^F)$ and the horizontal axis reflects the intensive margin of the efficiency loss due to the incomplete contracts.

Next we analyze the impact of trade and ownership liberalization, and improvement in contract environment on the pattern of global production pattern.

2.3.1 Trade and ownership liberalization

The effect of trade liberalization can be captured by shifting down the curve of $N(z)$ in Figure 3. If the trade cost initially is very high, intuitively it is only profitable for the Northern innovator to outsource less skill-intensive products through arms' length contracting because the trade cost dampens the comparative advantage of the South. Therefore, no FDI offshoring exists even if foreign ownership is legally allowed. As the trade cost declines it becomes profitable to offshore more skill-intensive products to the South through FDI, because the Northern innovators require more control over their production in the South. In this case, restriction of foreign ownership becomes an important trade barrier. Moreover, with ownership liberalization a reduction in trade costs is likely to have a stronger effect on FDI offshoring than on arm's length offshoring. The proof appears in Appendix D, but the intuition is simple: Equation (D.1) shows that the revenue elasticities of the trade cost is $-\frac{\alpha}{1-\alpha}$, irrespective of firm ownership types. Thus, a decline in trade costs increases the intensive margin of each types of firms proportionally. However, for the extensive margin, it depends on the location of $N(z)$. If FDI offshoring exists (as depicted in Figure 2), a reduction in trade costs increases the extensive margin of FDI offshoring but not for arm's length offshoring. Thus, the export share of FDI offshoring increases.

Governments in developing countries often indeed impose restrictions on foreign ownership for reasons including reducing competition with indigenous firms, promoting technology transfer through joint ventures, and protecting strategic sectors (e.g., Kobrin 1987; Gomes-Casseres 1990). Our model provides a framework to analyze the impact of ownership restrictions of foreign capital on the South's export structure. Figure 4 presents the effect of the ownership liberalization with the case where the Southern government removes the prohibition policy for foreign ownership. If the foreign ownership is not allowed, then the cutoff between North-South production is given by z^*_{DN}. If the trade cost is very high, this ownership restriction policy does not matter since the Northern innovators only outsource their less skill-intensive products. However, if the trade cost is sufficient low and FDI offshoring is more profitable for relatively more skill intensive products, the South can benefit substantially from relaxing the ownership control for foreign capital. First, many more skill-intensive products will migrate to the South since the cutoff between North-South production moves up to z^*_{FN}. Thus, it helps the South to achieve skill-upgrading in exports. Second, there is an efficiency gain from the ownership change from Southern ownership to foreign ownership for those products within $[z^*_{DF}, z^*_{DN}]$ because firms' profits increase.

The next proposition shows the impact of trade cost reduction and ownership liberalization on the size and structure of the offshoring.

Proposition 2 *If the trade cost is relatively low, ownership liberalization and further reduction in trade cost both increase the North-South production cutoff, i.e., shifting more skill-intensive products to the South through FDI offshoring, and thus the share of FDI offshoring increases.*

2.4 Skill premium

This section discusses the impact of offshoring on the skill premium in the South. The subscript S is omitted without causing any confusions in this section. We first show the property of the relative skill demand for a given intermediate good.

Proposition 3 *The relative demand for the high-skilled labor for each product z, i.e, $h(z,\beta)/l(z,\beta) = \frac{\beta z}{(1-\beta)(1-z)}\frac{w}{q}$, increases in z and β but decreases in the relative wage of the high-skilled labor.*

This proposition reflects two channels that offshoring increases skill demand in the South. First, skill demand increases if more skill-intensive intermediate goods (increase in z) are offshored to the South through the extensive margin. Second, for given product z, ownership liberalization in foreign capital (increase in β) itself also increases firms' demand for high-skilled labor. This is consistent with the PRT in the sense that the Northern innovator hires more high-skilled workers when she owns the firm.

Next we define the aggregate skill demand in the South as follows:

$$D(q/w,t,\Psi) = \frac{\sum\limits_{\beta^O \in \Psi} \int_{\Omega_\Psi} h(z,\beta^O)dz}{\sum\limits_{\beta^O \in \Psi} \int_{\Omega_\Psi} l(z,\beta^O)dz} \tag{8}$$

where Ψ denotes the ownership choice set, i.e., $\Psi = \{\{\beta^D\},\{\beta^D,\beta^F\}\}$. $\Omega_\Psi = [0, z^*_{DN}]$ if $\Psi = \{\beta^D\}$ and $\Omega_\Psi = \Omega_D \cup \Omega_F = [0, z^*_{DF}] \cup [z^*_{DF}, z^*_{FN}]$ if $\Psi = \{\beta^D,\beta^F\}$. Let $\overline{z}$ denote the cutoff between North-South production. We can show the following proposition:

Proposition 4 *(1) The aggregate skill demand in the South increases in $\overline{z}$, i.e., $\frac{\partial D(q/w,\overline{z})}{\partial \overline{z}} > 0$. Thus, the aggregate skill demand increases as the trade cost declines.*

(2) If trade cost is relatively low and $0 < \alpha \leq 1/2$, ownership liberalization in foreign capital increases the aggregate skill demand in the South.

(3) Based on (1) and (2), ownership liberalization and further reduction in trade cost increase the skill premium.

Proof appears in Appendix E. The increasing aggregate skill demand in the South due to the extensive margin growth is similar to the mechanism of Feenstra and Hanson (1996a), because more skill intensive products are offshored to the South. As discussed in Proposition 2, a reduction in trade cost increases the North-South production cutoff, and attracts more skill-intensive products to the South, thus in turn increases the aggregate skill demand. Note this holds even with FDI ownership restrictions. However, as the trade cost becomes low, it turns out to be more and more difficult to attract more skill intensive new products if only arm's length offshoring is allowed, because Northern innovators would like to offshore more skill intensive products through their own affiliates. In this case, once the ownership restriction is removed, the FDI offshoring increases and more skill intensive products are shifted to the South, and this will have a significant effect on skill upgrading in exports as well as on the skill demand in the South.

In the second part of the proposition we compare the aggregate skill demand before and after ownership liberalization, when the trade cost is relatively low. It shows that ownership liberalization on foreign capital can increase the skill demand in the South through two channels: more skill intensive products will migrate to the South through FDI offshoring, and the skill demand increases for firms switching from arm's length offshoring to FDI offshoring.

It is easy to show the aggregate skill demand has a downward slope given $0 < \alpha \leq 1/2$, and thus if the the relative labor supply is inelastic (as we assumed) or positively sloping, then the skill premium rises as the aggregate skill demand shifts up due to the ownership liberalization or further trade cost reduction. Thus, Proposition 4 (3) is naturally followed.

2.5 The Augmented Mincer Wage Equation

Because the relative labor supply is assumed to be exogenously given, the skill premium will be determined by the relative skill demand. Thus, the following analysis focuses on the demand side. First we obtain the inverse skill demand function from the equation (8) as

$$ln(q/w) = lnD^{-1}(\overline{z}(t, \Psi), \Psi) \tag{9}$$

The inverse skill demand depends on trade cost t and ownership set Ψ as we have shown that trade cost reduction and ownership liberalization increase the skill premium under general conditions in Proposition (4). Next we show that this inverse skill demand function can be integrated into the augmented Mincer wage equation.

Let us define workers with college degree and above as high-skilled workers, and workers without college degree as low-skilled workers. Then the classical Mincer wage equation can be written as

$$\ln wage = \alpha_0 + \alpha_1 college + \epsilon \tag{10}$$

where $college$ is an indicator variable for workers with college degree and above. Notice $\alpha_1 = E(\ln wage|college = 1) - E(\ln wage|college = 0) = lnq - \ln w$. The last equality holds because lnq and $\ln w$ are the market equilibrium (log) wage for college workers and non-college workers. From the inverse skill demand we can see that the college premium α_1 is a function of trade cost and ownership liberalization. Thus, we obtain the augmented mincer wage equation as follows

$$\ln wage = \alpha_0 + \alpha_1(t, \Psi) college + \epsilon \tag{11}$$

This augmented Mincer wage regression provides a direct empirical specification to test our theory. However, there are two challenges if we estimate the above Equation (11) directly by interacting measures of trade cost reduction and ownership liberalization with the college indicator. First, it is a reduced form regression without telling us how the effect of trade cost reduction and ownership liberalization on skill premium through their effect on offshoring and changes in offshoring organizational forms. More importantly, it can't distinguish the differential effect of two types of offshoring on skill premium. Second, if we only use annual national level data of trade and ownership liberalization, the variation is small as it is only from annual frequency. To solve these two issues, we propose a two-stage identification strategy based on the local-labor market approach. Next we discuss the identification strategy in detail.

2.6 Identification Strategy

Our identification strategy follows the local-labor-market approach that maps trade shocks to labor market outcomes, in particular the skill premium. We use the rich spatial variations in regional exposure to FDI offshoring and arm's length offshoring along the trade and ownership liberalization in the last two decades in China. More specifically, our identification strategy consists of two stages. In the first stage, we estimate the impact of trade cost reduction and ownership liberalization on regional (and industrial) distribution of FDI and arm's length offshoring:

$$lnR^O = lnR^O(t, \Psi), \text{where } O \in \{D, F\}. \tag{12}$$

In the second stage, we estimate the augmented Mincer regression with the interaction term of college indicator and regional exposure to FDI and arm's length offshoring (or equivalently, the total offshoring and the share of FDI offshoring), i.e.,

$$\ln wage = \alpha_0 + \alpha_1(R^D, R^F)college + \epsilon \tag{13}$$

This identification strategy has three advantages. First, it directly tests two main propositions (2) and (4) of our model. Second,the specification of the augmented Mincer equation in (11) is a reduced form regression, which shows the direct effect of trade and ownership liberalization on the skill premium. By contrast, our two-stage procedure is more structural. It first shows the determinants of offshoring and their differential effects on two types of offshoring, and the second stage helps us to identify which type of offshoring matters for skill premium. Moreover, one important concern in empirical estimation is the potential bias due to the selection of multinational companies. When multinational choose to set up foreign affiliates, they tend to choose regions with abundant high-quality labors. Thus, it will lead to a positive selection bias. Our two-stage procedure offers a natural approach to deal with this selection issue, because we can construct instrument variables for the endogenous variables (R^O or their transformations) by using the predicted values from the first stage regression. We will discuss this in detail later. Note an important assumption of this identification strategy is the regional labor market adjustment friction. If the labor is freely mobile across regions, it is less likely to detect significant effects of trade shocks on local labor market.

3 China's globalization

Over the last two decades China has experienced dramatic globalization along its economic reform, and has grown from a negligible player in the international market to the largest exporter in the world. As pointed out by Branstetter and Lardy (2008), China has already achieved a high degree of openness in foreign trade in manufacturing even before its accession to the WTO in 2001. The average import tariff had been lowered from about 43 percent to 15 percent in 2001. Because China also allowed duty-free importation of raw materials and parts and components used in processing exports, less than 40 percent of imports were subject to tariffs in 2000. The additional deregulation mandated under China's WTO accession agreement made China more open to the world, as the average import tariffs declined to 9.9 percent in 2007. Correspondingly, non-tariff barriers and restrictions on foreign investment were also reduced significantly (Brandt et al., 2012).

Compared with the gradual process of trade liberalization, the ownership liberalization for foreign capital in China is more dramatic, which resembles a policy regime change. As early as 1979, the Chinese government started to encourage foreign direct investment through joint ventures, which was considered as an effective way to learn management skills and technology. Wholly foreign ownership was restricted or prohibited in many manufacturing industries until the late 1990s prior to the accession to WTO. For example, washing machines, refrigerators, air conditioners were on the restricted list foreign ownership in 1995, according to the Catalogue for the Guidance of Foreign Investment Industries (CGFII) published by the National Development and Reform Commission. This ownership-biased industry policy is against the spirit of the WTO Agreement on Trade-Related Investment Measures (TRIMs), which precludes the WTO members from imposing restrictions or distortions on foreign investment. Thus, the government undertook a major legal and economic reform in foreign investment in late 1990s to remove foreign investment barriers. One major effort is to revise the CGFII to relax ownership controls gradually by increasing the encouragement coverage and decreasing the restriction coverage for foreign ownership. As documented by Sheng and Yang (2012), both the expansion of encouragement coverage and the reduction in restriction/prohibition coverage were the most significant around 2001. Brandt et al. (2012) also found that the fraction of sectors covered by various foreign investment restrictions was dropped from about 20% to 10% after China's accession to WTO in 2001. This policy regime change around 2001 has significantly changed the ownership structure of China's foreign direct investment inflow and trade pattern. Wholly foreign-owned enterprises started to dominate joint ventures in annually recorded foreign capital inflows. Because most of wholly foreign-owned enterprises are involved in processing trade, the growth of FDI processing exports has outpaced that of arm's length processing exports since 2001.

The trade liberalization and ownership liberalization on foreign capital upon China's accession to WTO made the foreign firms become an important force for China's economic growth, particularly for the industrial output and foreign trade. Foreign firms contributed about 32 percent of total industrial output and 59 percent of total exports and imports in 2006, according to the Statistics of FDI in China (2013), published by the Department of Commerce. As for the impact of foreign firms on the labor market, Hale and Long (2012, chap. 4) found that firms with higher shares of foreign ownership pay higher average wages to their engineers and managers, but not to their production workers, even after controlling for the observable quality differences. By using the same firm level data from the World bank industrial survey in 2001, they also found that the presence of foreign firms put an upward pressure on the workers' wage of neighboring domestic firms, but only for the skilled workers. Although they do not separate wholly foreign-owned firms, their results are largely consistent with our conjecture that the wholly foreign-owned firms are one of the driving forces of the rising skill premium in China.

As a summary, the ownership liberalization for foreign capital in China provides an unique opportunity to test our theory. Moreover, there is significant spatial variations of foreign capital inflow across provinces due to their initial endowment or differences in industrial structure. This feature allows us to adopt the local labor market approach to test our theory by using the identification strategy proposed above. Next we turn to our data set and empirical exercise.

3.1 Data

The primary data sources are Chinese Urban Household Surveys (CUHS 1992-2006) and the Chinese customs trade data (1992-2008). Both data sets cover mainland China's provinces except Tibet due to data missing in CUHS. The CUHS is conducted by China's National Bureau of Statistics (NBS). It records basic conditions of urban households and provides detailed information of workers' demographic characteristics (age, gender, and marital status), employment (income, educational attainment, working experience, occupation, and industry) and geographic residence (city and province). The survey includes information on about 15,000 to 56,000 workers in a year. In this paper, we focus on annual wages of manufacturing adult workers engaging in wage employment. Wage income consists of basic wage, bonus, subsidies and other labor-related income from regular jobs. We compute the real wage by deflating annual wages to the base year (2006) using province-specific urban consumption price indices.

The trade data set records both the value and quantity of export at the product level (six-digit HS code), exporter locations and destinations, firm ownership types, and types of Chinese custom regimes. The firm ownership types include Chinese-owned domestic firms, joint ventures, and wholly foreign-owned firms. We use the processing export to measure the size of offshoring, and the processing export by wholly foreign owned firms to measure FDI offshoring, and processing exports by other firms are used to measure arm's length offshoring. We also treat the high-income countries as the North country for the benchmark analysis. Our definition of high-income countries follows the World Bank's standard classification, including 66 countries.[14] China's processing exports to high-income countries contributed about 90 percent of its total processing exports. For

[14]Taiwan is not included in the World Bank's data, although it qualifies to be a high-income region. We add Taiwan into our sample because it is an important trade partner of mainland China.

robustness check we also use all China's trade partners as the North country. Most of empirical results hold for both samples.

4 Empirical Evidence

4.1 Skill Intensity

In this section, we first present evidence for the skill content difference between FDI offshoring and arm's length offshoring. Figure 5(a) presents the evolution of average skill intensity of two types of processing exports for the period 1992-2008. The average skill intensity is defined as the weighted average of industrial skill intensity, using the industrial share of processing exports as the weights.[15] The measure of skill intensity z_i for industry i is defined as the employment share of workers with college degrees or above in total industrial employment, using the employment information at the 3 digit industry level from Chinese National Industry Census 1995 (CNIC1995).[16] It clearly shows that FDI offshoring is more skill intensive than arm's length offshoring, and there has been significant skill upgrading in the processing exports since 1992.

Next, we examine the distributions in skill intensity across the two types of offshoring. Figure 5(b) presents the distributions of processing exports by firm ownership types in 1992 and 2008.[17] This figure reveals two important messages. First, the distribution of FDI processing export is more skewed toward skill-intensive sectors than that of arm's length processing exports. In other words, FDI processing exports first-order stochastically dominate those of other firms. Moreover,

[15] The average skill intensity for the firm ownership type O in year t is defined as $\widetilde{z}_t^O = \sum_i (z_i \frac{y_{i,t}^O}{\sum_i y_{i,t}^O}) = \sum_i z_i s_{i,t}^O$, where $O = F, D$. z_i denotes the skill intensity of industry i, and $y_{i,t}^O$ and $s_{i,t}^O$ denote the value and share of processing exports of industry i in year t for the firm ownership type O.

[16] We convert both the skill intensity measure at Chinese Standard Industrial Classification 1994 (CSIC1994) at 3 digits level and trade data based on 6 digits of Harmonized system into ISIC REV.3 at 4 digits level. Once we restrain ourselves to manufacturing sector, we cover 113 out of 127 classes in ISIC REV.3 at 4 digits level. Please see the concordance detail in Appendix F.2. We drop the most skill-intensive sector to avoid that our results are impacted by this sector, which is 75 percent higher than the second highest. As a robustness check, we use the skill intensity measure from the National Economic Census 2004 (NEC 2004). The results remain the same.

[17] The empirical distribution $\widehat{G}^O(z)$ for $O = F, D$ is constructed as follows: $\widehat{G}_t^O(z) = \sum_i I(z_i \leq z) s_{i,t}^O$, where $I(.)$ is the indicator function.

this feature is more significant in 2008 than 1992. Second, all distributions shift toward right from 1992 to 2008, implying significant skill upgrading in the processing exports. Note this feature is also more significant for FDI processing exports.

More formally, following Delgado et al. (2002) we adopt the non-parametric Kolmogorov-Smirnov test for the first-order stochastic dominance. We first perform a two sided Kolmogorov-Smirnov test to examine the equality of the two distributions, i.e., $G^F(z) = G^D(z)$. If the equality hypothesis is rejected, we then use a one-sided test to examine the first order stochastic dominance, i.e., $G^F(z) \leq G^D(z)$. If we fail to reject this hypothesis and given $G^F(z) \neq G^D(z)$ (obtained from the first step), we conclude that $G^F(z) < G^D(z)$.

The Kolmogorov-Smirnov test requires independent identical sample, while we have sampling data for 1992-2008 and they may have auto-correlations across years. Thus, we run the test year by year. Table 1 presents the p-value for testing results in which a small number indicates rejecting the hypotheses. The two-sided test shows that it rejects the null for years 1997-2008 at 5 percent significance level but not for earlier years, and the one-sided test does not reject the null for all years in our sample. Thus, we conclude that FDI processing exports have been more skill intensive than arm's length processing export since 1998. It is reasonable that the two-sided test fails to reject the null for years before 1997, because the trade cost was high and foreign ownership was restricted, only a few foreign-owned firms entered. Thus, the distributions are not statistically different from each other. As the trade cost declined and the restrictions on foreign ownership were gradually removed, more intermediate goods were offshored through foreign-owned firms, and their distributional differences became statistically significant.

This two-step testing procedure can be applied to testing for skill upgrading in processing exports for each type of firms. Table 2 shows the results for each five-year interval during 1992 and 2007. The two-sided test rejects the null at 5 percent significance level, but the one-sided test fails to reject the null for all firms in three time regimes. It implies that there is significant skill-upgrading in processing exports for all firms. However, recall the fact that processing exports by foreign-owned firms became more skill intensive than only after 1997. Thus, the skill upgrading must be similar for all firms initially, but later it becomes more substantial in foreign-owned firms.

In the end, we calculate the contribution of FDI processing export to the total skill content in total processing exports, as the ratio of the skill content in the FDI processing exports to the skill content of the total processing export, i.e., $skshr_t^F = \frac{\sum_i z_i y_{i,t}^F}{\sum_i z_i y_{i,t}} = \frac{\tilde{z}^F}{\tilde{z}} \frac{\sum_i y_{i,t}^F}{\sum_i y_{i,t}} = Z^F * S_t^F$ where $Z^F = \tilde{z}^O / \tilde{z}$ is the relative average skill intensity, and $S_t^F = \frac{\sum_i y_{i,t}^F}{\sum_i y_{i,t}}$ is the value share of FDI processing exports. This implies that the contribution of FDI processing exports to skill content can be decomposed into two parts: the relative average skill intensity and its share in processing exports. This exercise shows that its contribution has risen from about 12 percent to about 68 percent of total skill content of processing exports, and most of them comes from the rising size of FDI processing exports. Thus, FDI becomes the major contributor of the skill content in processing exports.[18]

The analysis above uses the industrial level trade data over the period 1992-2008, one may concern the skill intensity difference at firm level. However, the information of employment composition for Chinese manufacturing firms is only available in the first National Economic Census in 2004. Based on the economic census in 2004, Chen et al. (2011) finds that foreign invested enterprises have the highest employment share of college workers, the next is state-owned enterprises, and the other private enterprises have the lowest skill employment. If we match the economic census data with the Chinese firm level trade data, we can identify those processing firms. We find that the employment share of college graduates in wholly foreign owned enterprise is 6 percent higher than that of others. This snapshot of the skill comparison is largely consistent with the international evidence that FDI is relatively more skill and capital intensive, thus it is less likely that foreign owned firms in China are only doing the low and routine tasks.

[18]Notice this exercise only measures the "between" industrial skill upgrading, but not the "within"industrial skill upgrading.

4.2 The determinants of offshoring and its ownership structure

In this section we explore the determinants of regional and industrial distribution of processing exports. This is the first-stage regression in our two-stage identification strategy, and also directly tests the Proposition (2) derived from the model. Moreover, in the previous section, we have shown that the FDI processing exports are more skill intensive than arm's length offshoring. Thus, understanding the distribution of FDI processing exports is important to analyze the difference in regional skill demand and skill premium.

Our model shows that trade cost reduction and ownership liberalization are two important determinants for the growth of processing exports, particularly for the FDI processing exports. Following Limão and Venables (2001), we use infrastructure—the (log) density of highway and railway—to approximate trade costs reduction. One innovation of this paper is that we construct two unique measures of ownership liberalization at industrial level for various years, by using the official list from the Chinese government that specifies which industries are encouraged, restricted, or prohibited for foreign direct investment. This list, provided in the Catalogue for the Guidance of Foreign Investment Industries (NDRC, various years), was first published in 1995 and was revised subsequently in 1997, 2002, 2004, and 2007. For encouraged industries, foreign investors have more freedom in choosing their ownership structures, and they enjoy other advantages such as preferable corporate tax rates, low costs of land, and duty-free for imported inputs. In contrast, for restricted or prohibited industries, the Chinese government usually imposes stringent restrictions on ownership structures and high entry cost for foreign investors. The ownership liberalization on foreign direct investment in China was largely the consequence of China's entry into WTO. To comply with the WTO agreement on TRIMS, the Chinese government removed many investment barriers including ownership restrictions on most industries in the manufacturing sector, except those industries that were highly pollutant or dependent on Chinese traditional manufacturing techniques. The government has also expanded the encouragement coverage for foreign investment.

For regression analysis, we construct two proxies for ownership liberalization at the industry level: an encouragement policy indicator (EP_{it}), and a restriction (includes prohibited) policy indicator (RP_{it}). We assign the value of 1 for encouragement (or restriction) policy in an industry if at least one product in that industry is formally stated on the government list of encouragement (or restriction). Otherwise, we assign the value of 0 to that industry. We also assume that there are no policy changes until a formal revision is announced in the published Catalogue. These two policy indicators capture the differences in ownership regulations between industries with and without policy interventions.[19]

To develop the regression specification, we denote our dependent variable $ln(R_{oijt})$ as the log value of processing exports of organizational form o, in industry i, province j, and year t. We interact the ownership indicator variable FDI_{oijt} with the encouragement policy (EP_{it}), the restriction policy (RP_{it}), and the infrastructure ($Infra_{jt}$), obtaining the regression:

$$\begin{aligned} ln(R_{oijt}) = {} & \theta_0 + \theta_1 FDI_{oijt} + \theta_2 EP_{it} + \theta_3 FDI_{oijt} \times EP_{it} + \theta_4 RP_{it} + \theta_5 FDI_{oijt} \times RP_{it} \\ & + \theta_6 Infra_{jt} + \theta_7 FDI_{oijt} \times Infra_{jt} + \varsigma_1 Contr_i \times Inst_j + \varsigma_2 h_i H_{jt} + \varsigma_3 k_i K_{jt} \\ & + \xi_i + \xi_j + \xi_t + \epsilon_{oijt} \end{aligned} \tag{14}$$

Note the infrastructure variable differs across provinces and years, the ownership liberalization policy differs across industries and years. Following Romalis (2004) as well as Nunn (2007), this regression includes the factor endowment variables K_{jt} and L_{jt} interacted with industry-specific factor intensity h_i and k_i.[20] To control for the role of institutions, we also include the interaction term of industry-specific contract intensity $Contr_i$ and the regional contract environment $Inst_j$.[21]

[19]Please see Sheng and Yang (2012) for the details about our construction method.

[20]Skill intensity is the industry-specific college employment share,and we use the ratio of fixed asset investment to output at industrial level to proxy the capital intensity. Both variables are constructed based on the data from the Chinese National Industrial Census in 1995. The skill labor endowment is the the share of college workers in the population aged above 6, and the capital endowment is the ratio of capital to output. We are grateful to Chongen Bai for sharing this data with us.

[21]Following the idea of Nunn (2007), the industry-specific contract intensity is proxied by the inputs share of the relationship specific intermediates based on the Chinese input-output table (Feenstra et al., 2013). We are very grateful to Hong Ma for sharing this Nunn index with us. The measure of provincial contract environment is from the survey of doing business in 30 provincial capitals in China, published by World Bank (2008). Specifically, we use the “court cost” variable in their data, which is measured as the ratio of official costs of going through court procedures to the debt claim. Higher “court cost” indicates an inefficient, rent-seeking legal system, implying a lower probability of

ξ_i, ξ_j and ξ_t are used to control for industry, province and year fixed effects. To avoid the potential contemporaneous correlations between the error term and provincial variables such as infrastructure, skill labor endowment and capital stock, we use one-year lagged values. For easy interpretation, all variables except indicator variables are de-meaned before we compute the interaction term.

We begin with a simple specification in Table 3 that only includes the interaction terms of organizational form with key variables of ownership liberalization policy and the trade cost, and fixed effects for organizational form, province, industry and year.[22] The results show that the ownership policies have significant effect on the FDI processing exports but not on the arm's-length processing exports. Industries with encouragement(restriction) policy have higher (lower) FDI processing exports, compared with industries without encouragement(restriction) policies. Infrastructure has positive effects on both types of processing exports, but the magnitude is higher for the FDI processing exports, which is consistent with our theory.

One additional important policy instrument for foreign capital inflow is policy zones in China. Policy zones are contained geographic regions within a country with more liberal laws and economic policies to encourage foreign investment (Wang and Wei, 2010). China began to establish special economic zones for export in the early 1980 in coastal cities, and expanded into inland cities in 1990s .These policy zones include Economic and Technological Development Zone, High-Tech Development Area, Bonded Area, Export Processing Zone, and other types. Multinational companies in these zones enjoy various advantages, including lowered corporate tax rate of 15 percent, duty free for imported inputs, no import quotas, low costs of land, and no property tax in the first five years. There are also additional benefits for foreign firms if they export most of their products.[23] Broadly speaking, those policy zones reduced investment barriers and trade costs for

upholding contracts between firms. For convenience of interpretation, we construct a court efficiency measure, which equals 0.5 minus the ratio of court cost.

[22]Because our theory does not model the entry decision of multinational firms, and the Proposition (2) is also conditional on the moderate trade cost such that some arm's length and FDI processing exports exist. In particular, these ownership policies are invalid in regions without exports due to the extremely high trade costs. Thus, our sample covers all industries and regions with a positive value of processing exports.

[23]The data reveal two booming periods of policy zones: the first is 1990-1993 when the cumulative number of zones jumped from 18 to 130, and the second is 1999-2003 when the number increased from 139 to 196. By 2006, a

foreign investments. Thus, we also include in the regression the cumulative number of national policy zones that had been opened up to a year in a specific province, and its interaction with FDI indicator. The column 2 in Table 3 shows that national policy zones significantly increase the FDI processing exports, but not for the arm's length processing exports.[24] It is worth noting that the role of infrastructure decreases after controlling for the policy zones because there is significant positive correlation between infrastructure and the number of national policy zones.[25]

The third column in Table 3 presents the results with controls for the interaction terms of industry-specific factor intensities and provincial factor endowments. The positive coefficients of those interaction terms indicate the role of regional comparative advantage. Regions with more abundant skilled labor or capital exports more skill intensive or capital intensive products. Provinces with better contract environment exports more contract-intensive products, and the magnitude is also similar to the findings in (Feenstra et al., 2013). The last column includes the province-year pair fixed effect to control for other unobserved province-year varying factors. Thus, the province-year varying variables including infrastructure and national policy zones are dropped due to collinearity. Our main conclusions of ownership policy and trade cost reduction remain to hold. Quantitatively, the encouragement policy increases FDI processing exports by about 24 percent, and the restriction policy reduces FDI processing export by about 43 percent, compared with industries without policy interventions. Those ownership policies do not significant effect on arm's length processing exports. As for infrastructure, one percent of increase in highway and railway density increases 0.22 percent more on FDI processing exports than arm's length processing exports. One additional national policy zone increases 7.9 percent more on FDI processing exports than arm's length processing exports.

total of 221 national policy zones had been established in China.

[24]The setup of national policy zones requires authorization from the central government, which can be arguably considered as an exogenous process beyond the control of provincial governments. Therefore, the endogeneity problem is not a major concern. To avoid the potential contemporaneous correlations between provincial variables with the error term, we use one-year lagged values.

[25]In addition, if infrastructure is not included, we find that policy zones have positive effects on arm's length processing exports as well, but smaller than the effect on FDI processing exports. This is reasonable because police zones are usually associated with better infrastructure and thus promote arm's length processing exports as well.

4.3 Determinants of College Premium

Previous sections have shown the skill intensity difference across FDI and arm's length processing exports and their regional and industrial determinants. In this section we turn to the second stage of our identification strategy, and explore the effect of the regional distribution of two types of processing exports on the skill premium by using the augmented Mincer wage regression in a local labor market setting.

The classic Mincer regression models the log value of real wage as a function of workers' education and years of potential labor market experience. Thus, the dependent variable for analysis, $\ln(wage_{mjt})$, is the log value of real annual wage for individual m in province j and year t. We use college indicator ($coll_{mjt}$) as the basic measure of education, and thus the coefficient of the college indicator reflects the college premium. Because of the local labor market frictions, the college premium may be different due to differential regional exposures to globalization and other factors such as skill biased technology. The augmented Mincer earning regression models the college premium as a function of factors that affect the regional skill demand. Thus, we interact the college indicator with those relevant regional (provincial) variables, including the ratio of processing exports to industrial outputs, denoted as $proexratio_{jt}$, and the FDI processing exports share, denoted $feshr_{jt}$, and obtain the following augmented Mincer regression:[26]

$$ln(wage_{mjt}) = \alpha_0 + [\beta_0 + \beta_1 proexratio_{jt} + \beta_2 feshr_{jt} + \beta_3 X_{jt}] \times coll_{mjt} + \gamma G_{mjt} + \delta_{jt} + \epsilon_{mjt} \quad (15)$$

where X_{jt} are other provincial variables associated with the college premium. G_{mjt} are other personal characteristics including gender, experience, squared experience and the indicator of state owned sector. Province-year pair dummies, i.e., δ_{jt}, are used to capture the province-year differences in the determinants of wage income. Province-year cluster robust standard deviation is adopted to control for the sample dependence. Our theory suggests that regions that have more

[26]An alternative specification is to include the ratios of FDI (or arm's length) processing exports to industrial outputs. However, we prefer the benchmark specification because it reflects both the scale effect and composition effect of the processing exports. Moreover, we can also directly compare the differential impacts on skill premium of processing exports and ordinary exports.

processing exports and higher share of foreign-owned firms have higher skill demand and higher college premium, thus we would expect β_1 and β_2 are positive.

Table 4 presents the summary statistics of household characteristics and related provincial variables. Table 5 column (1) begins with a simple Mincer regression without any interaction terms with college indicator. It shows that on average the college workers earned about 35 percent more than non-college workers, and one additional year of experience is associated with a 4.8 percent increase in real wage. In addition, female earns less than male, and workers in the state sector earn about 20 percent more. These results are consistent with existing literature (Zhang et al., 2005; Ge and Yang, 2014).

Next we include the interaction terms of the college indicator with the ratio of ordinary exports and processing exports to industrial output and the share of FDI processing exports. The column (2) shows that both the size of processing exports and the share of FDI processing exports are significant for the college premium, which are consistent with our theory. However, the ordinary exports have the positive coefficient but the effect is insignificant. Thus, it does not support the Stolper-Samuelson theorem which argues that the relative wage of unskilled workers should increase as the low-skilled abundant country exports more low-skill intensive products.

The regression above does not control for alternative theories of the college premium. Two popular alternatives are skill-biased technology hypothesis (Acemoglu, 1998, 2003) and the capital-skill complementarity hypothesis (Krusell et al., 2000). We use the ratio of R&D expenditure to aggregate output to measure the skilled-biased technology, and capital-to-output ratio to capture capital-skill complementarity.[27]Table 5 column (3) presents the result with those additional controls. Our key variables, the processing exports ratio and the share of FDI processing exports, are still significantly positive. However, both alternative theories are not supported by the data. The R&D expenditure ratio and capital-to-output ratio both have the positive sign but the effects are not significant. Thus, overall our theory is the most possible explanation for the rising college

[27]As a robustness check, we also include the import share of equipment to capture the imported skilled biased technology, following Eaton and Kortum (2001) and Burstein et al. (2011). The results are largely unchanged.

premium in China.[28]

One caveat of these regressions is that our key variable processing exports ratio and the share of FDI processing exports may be endogenous to labor market conditions. For example, processing firms particular foreign affiliates tend to choose regions with abundant high-quality labors. This selection implies a positive bias in the OLS estimates. Inspired by Frankel and Romer (1999), we adopt a two-stage procedure to deal with the endogeneity issue. First, we construct the predicted values of processing exports ratio, and the share of FDI processing exports from the regression of the determinants of the processing exports (regression (14)) as follows:

$$\widehat{proexratio}_{jt} = \sum_{i,o} exp(\widehat{lnR}_{oijt})/ind\_output_{jt}$$
$$\widehat{feshr}_{jt} = \sum_{i,o=F} exp(\widehat{lnR}_{oijt})/\sum_{i,o} exp(\widehat{lnR}_{oijt})$$

where $\widehat{lnR}_{oijt}$ is the predicted log value of processing exports from the regression (14), based on the result in column (4) of Table 3. Then we use these predicted values as the instruments for processing exports ratio and the share of FDI processing exports in the augmented Mincer regression. Those predicted values constitute legitimate instruments because the key determinants of processing exports by types, ownership liberalization policies and infrastructure, are plausibly not correlated with individual households' characteristics. Moreover, although this manual two-stage regression generates consistent estimates of coefficients, but their estimated standard errors are incorrect. Thus, We use non-parametric bootstrap method to correct the standard errors (Angrist and Pischke, 2008).

Table 5 column (4)-(5) report the results using instrument variables.[29] We present the scatter

[28]This result is robust if we adopt a two-step regression, in which we first get a province panel of estimates of college premia by estimating Mincer regression for each province at each year, and then regress the imputed college premium on those provincial variables in Table 5. We prefer the augmented Mincer regression because it allows us to control for personal characteristics and to estimate the two-step regression in one step.

[29]To keep consistent between OLS and IV estimates, for the OLS estimation we exclude observations for which those predicted values of processing export ratio and the share of FDI processing exports are missing. For example, the capital output ratio is missing for Hainan province, and the relative skill labor supply is missing for the year 1992. Including those observations does not change the OLS estimates significantly.

plots of the actual and predicted values of processing export ratio and the share of FDI processing export in Figure F.1 in Appendix F.1, and they show significant correlations between the actual and predicted values of the variables of interest. We also use the F-test for weak instruments, and the F-test statistics in the first stage are all above the Stock-Yogo criteria of 10, rejecting the notion of weak instruments. Moving from OLS to IV slightly decreases the coefficients of processing exports ratio and the share of FDI processing exports. The IV estimates for two key variables are still significant positive, but the coefficients are less precisely estimated under IV than under OLS. As a result, the hypothesis that the IV and OLS estimates are equal cannot be rejected for both the coefficients of the processing exports ratio and the share of FDI processing exports.[30] Based on the IV estimates in the column (5) in Table 5, one percentage point increase in the ratio of processing exports to industrial output and the share of FDI processing exports are associated with about 0.802 and 0.208 percentage point increase in the college premium (log wage differential), respectively. Because China's processing export ratio and the share of FDI processing exports have increased by 5.8 and 26.7 percentage points from 2000 to 2006, each of them contributed 4.7 and 4.6 percentage points, respectively, to the increase in the college wage premium. Overall, they account for 68 percent of the total increase in the college wage premium between 2000 and 2006. Because the 73 percent of growth of total processing export is attributed to FDI during this period, our back-of-envelope calculation implies that overall the FDI processing exports contributed about 60 percent in the increase of the college premium in the manufacturing sector in Urban China.

We achieve the similar results by using the sample of processing export to all China's trade partners. Moreover, for robustness check, we also use years of school as a measure of skills, and explore the impact of the processing exports ratio and the share of FDI processing exports on the return to education. We find that the effect of the size of processing exports and the share of FDI

[30]We perform a Hausman test (Hausman, 1978) of the hypothesis that the processing exports ratio (or the share of FDI processing exports) is uncorrelated with the residual, and thus OLS is unbiased. Under the null, asymptotically the OLS and the IV estimates differ only because of sampling error. As a result, the difference between the two estimates divided by the standard error of the differences is distributed asymptotically as the standard normal. Moreover, under the null the variance of the difference between the IV and OLS estimates is just the difference in their variances. Thus, the t-stat for the Hausman test of $\hat{\beta}_i^{OLS}$ and $\hat{\beta}_i^{IV}$ for $i = 1, 2$ are -0.17 and -0.31 (or -0.21 and -0.29) for regressions (2) and (4)(or (3) and (5)) in Table 5 respectively.

processing exports are still positively significant.

5 Conclusion (tentative and incomplete)

This paper proposes a new mechanism linking offshoring and wage inequality in developing countries and test the model using a natural experiment of ownership liberalization in China. It offers robust evidence that FDI processing exports are more skill intensive than arm's length processing exports. A reduction in trade costs and ownership liberalization shift more skill intensive production to foreign affiliates in the South, which in turn increases the relative demand for high-skilled labor. The augmented Mincer regression shows that FDI processing exports is the main driving force behind the rising college premium between 2000 and 2006. This finding is robust to alternative specifications and theories.

Our finding has important policy implications for developing countries. Conventional wisdom suggests that developing countries should encourage joint ownership between the South and the North in order to create technology spillovers from the North through joint production. Our analysis implies that the multinationals jointly decide on their strategies for offshoring, ownership structure, and skill demand. Thus, if the South imposes foreign ownership restrictions, more skill-intensive products would remain in the North, and only less skill-intensive products are offshored to the South. This policy intervention would lower the demand for high-skilled labor and therefore impedes economic growth in the South.

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Table 1: Test for Stochastic Dominance

P-value	Two-sided test	One-sided test
Year	$G^F(z) = G^D(z)$	$G^F(z) \leq G^D(z)$
1992	0.06	1.00
1993	0.18	1.00
1994	0.26	1.00
1995	0.08	1.00
1996	0.07	1.00
1997	0.02	1.00
1998	0.01	1.00
1999	0.00	1.00
2000	0.00	1.00
2001	0.00	1.00
2002	0.00	1.00
2003	0.00	1.00
2004	0.00	1.00
2005	0.00	1.00
2006	0.00	1.00
2007	0.00	1.00
2008	0.00	1.00

Note: P-value is computed based on the limiting distribution of the Kolmogorov-Smirnov test statistics. $G^O(z)$ is the empirical distribution of processing exports for ownership $O = F or D$.

Table 2: The Kolmogorov-Smirnov Test for Skill Upgrading

	P-value	Two-sided test	One-sided test
	5-years interval	$G^{t+5}(z) = G^t(z)$	$G^{t+5}(z) \leq G^t(z)$
Arm's length processing exports	1992-1997	0.03	1.00
	1997-2002	0.01	1.00
	2002-2007	0.00	1.00
FDI processing exports	1992-1997	0.02	1.00
	1997-2002	0.00	1.00
	2002-2007	0.00	1.00

Note: P-value is computed based on the limiting distribution.

Table 3: Determinants of China's Processing Exports

Independent variables	(1)	(2)	(3)[a]	(4)
Encouragement policy	0.046	0.054	0.077	0.090
	(0.069)	(0.070)	(0.071)	(0.072)
Encouragement policy × FDI	0.278***	0.275***	0.243***	0.243***
	(0.054)	(0.053)	(0.054)	(0.054)
Restriction policy	-0.060	-0.098*	-0.061	-0.067
	(0.057)	(0.058)	(0.056)	(0.055)
Restriction policy × FDI	-0.495***	-0.441***	-0.434***	-0.428***
	(0.061)	(0.058)	(0.060)	(0.060)
Infrastructure	0.459***	0.335***	0.335***	-
	(0.124)	(0.116)	(0.111)	-
Infrastructure × FDI	0.574***	0.237***	0.197**	0.219**
	(0.084)	(0.089)	(0.089)	(0.091)
National policy zones		0.018	0.018	-
		(0.012)	(0.011)	-
National policy zones × FDI		0.084***	0.082***	0.079***
		(0.009)	(0.009)	(0.009)
Contract intensity × Institution			0.136***	0.135***
			(0.012)	(0.012)
Skill intensity × College share			0.826***	0.831***
			(0.100)	(0.100)
Capital intensity × Capital output ratio			0.007**	0.006**
			(0.003)	(0.003)
Industrial and ownership fixed effects	Yes	Yes	Yes	Yes
Provincial and year fixed effects	Yes	Yes	Yes	No
Province-year fixed effects	No	No	No	Yes
N	38,741	38,741	36,006	36,006
R^2	0.505	0.511	0.518	0.529

Note: The dependent variable is log(processing exports value). The sample covers China's processing exports to high-income countries. The panel covers 29 provinces and 112 industries in 1992-2007. Province-year pair cluster robust standard errors are in parentheses. *, **, and *** indicate significance at the 10,5, and 1 percent levels. The column (3) and (4) have less observations because the data of college share is not available in 1992.

[a] Provincial-year varying variables such as college share and capital output ratio are included in the regression, but their coefficients are insignificant and thus not reported in the table.

Table 4: Summary Statistics

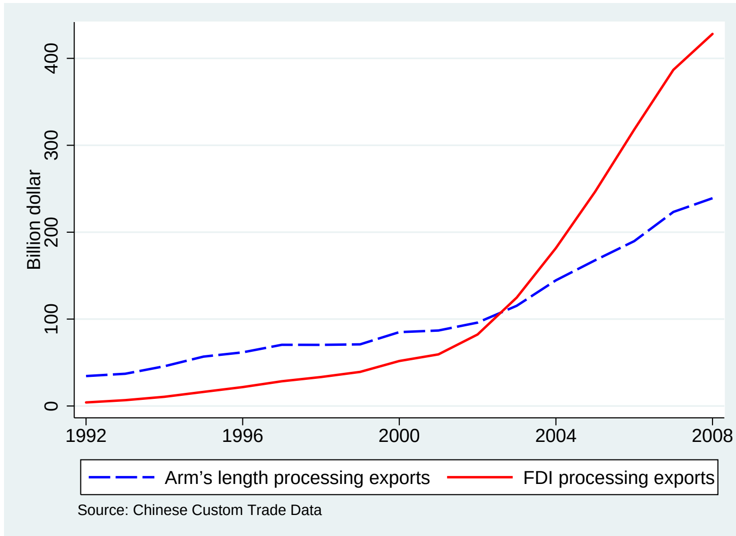
Panel A: Households Characteristics					
Variables	Obs	Mean	Std. Dev.	Min	Max
Lnwage	143010	8.89	0.77	2.09	12.43
College indicator	143010	0.17	0.37	0	1
Schooling years	143010	11.23	2.47	0	18
Age	143010	39.55	8.86	16	60
Experience	143010	21.91	9.23	0	44
Sex	143010	0.45	0.50	0	1
State sector	143010	0.70	0.46	0	1
Panel B: Provincial Characteristics					
Processing exports ratio	388	0.04	0.08	0.00	0.46
Share of FDI processing exports	388	0.19	0.20	0.00	0.82
Ordinary exports ratio	388	0.06	0.05	0.01	0.37
Predicted processing exports ratio	388	0.01	0.02	0.00	0.18
Predicted share of FDI processing exports	388	0.16	0.14	0.00	0.68
K/Y ratio	388	1.43	0.42	0.67	2.78
R&D ratio	388	0.01	0.01	0.00	0.08
Share of population aged above 5 with college degrees	388	0.05	0.04	0.00	0.29
Infrastructure (log)	387	-1.31	0.84	-4.02	0.37
National policy zones	388	5.80	5.05	0	27

Table 5: Determinants of Manufacturing College Premium in Urban China

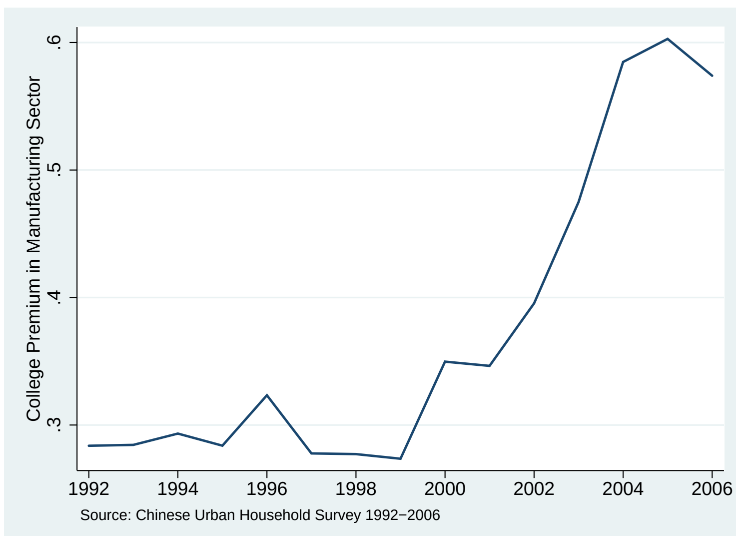
	OLS			IV[a]	
Independent variables	(1)	(2)	(3)	(4)	(5)
College	0.351***	0.251***	0.212***	0.252***	0.218***
	(0.010)	(0.014)	(0.032)	(0.018)	(0.038)
College indicator interaction terms					
College $\times$ Processing exports ratio		0.817***	0.841***	0.784***	0.802***
		(0.205)	(0.207)	(0.281)	(0.280)
College $\times$ Share of FDI processing exports		0.223***	0.229***	0.200***	0.208***
		(0.048)	(0.050)	(0.088)	(0.089)
College $\times$ Ordinary exports ratio		0.166	0.063	0.258	0.171
		(0.200)	(0.244)	(0.264)	(0.318)
College $\times$ R&D ratio			0.478		0.336
			(0.928)		(1.10)
College $\times K/Y$			0.028		0.025
			(0.024)		(0.028)
Individual characteristics					
Experience	0.047***	0.047***	0.047***	0.047***	0.047***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Experience square	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sex	-0.209***	-0.208***	-0.208***	-0.208***	-0.208***
	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)
Stated owned sector	0.192***	0.194***	0.194***	0.194***	0.194***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
First stage F-stat				> 175.15	> 168.12
Constant, Province-year pair dummy	Yes	Yes	Yes	Yes	Yes
N	143,010	143,010	143,010	143,010	143,010
R^2	0.354	0.356	0.356	0.297	0.303

Note: the dependent variable is log annual wage income. Province-year cluster robust standard errors are in parentheses for OLS regression. *, **, and *** indicate significance at the 10,5, and 1 percent levels.

[a] Regressions (4) and (5) are estimated by GMM, where we use the constructed processing exports ratio and the share of FDI processing exports as instruments, based on the sample of China's high-income trade partners (regression (4) in Table 3). The bootstrapped standard errors are in parentheses.



(a) Ownership Structural Change in Processing Exports



(b) College Premium in the Manufacturing Sector

Note: FDI processing exports refers to processing exports by wholly foreign-owned firms, processing exports by joint ventures and domestic firms are called arm's length processing exports.

Figure 1: Processing Exports and College Premium in China

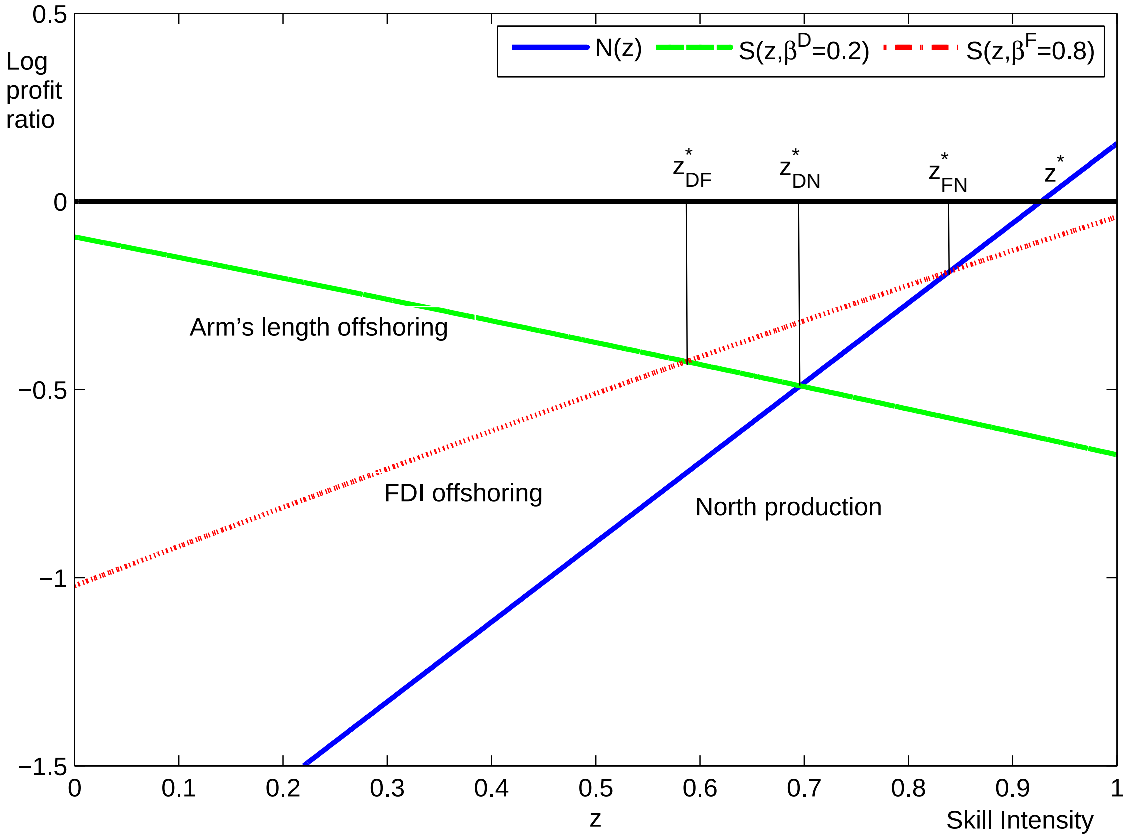


Figure 2: Offshoring, Optimal Ownership and Skill Intensity of Intermediate Goods

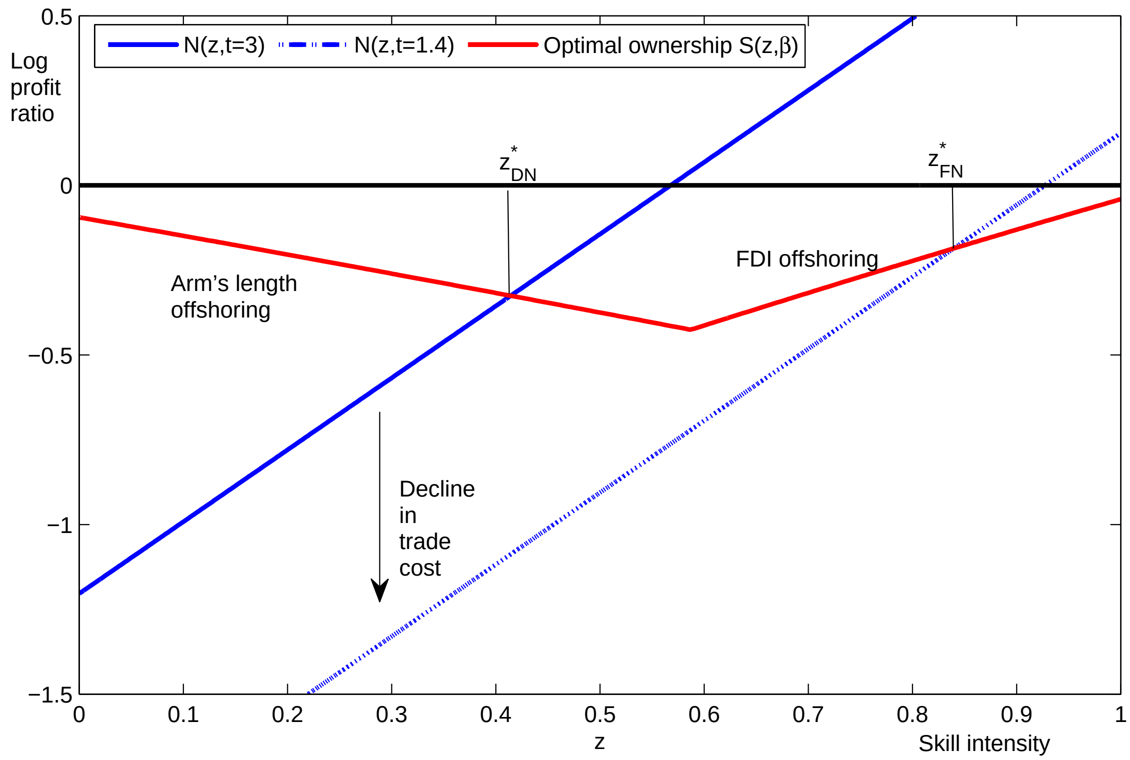


Figure 3: Trade liberalization, Offshoring and Skill Intensity of Intermediate Goods

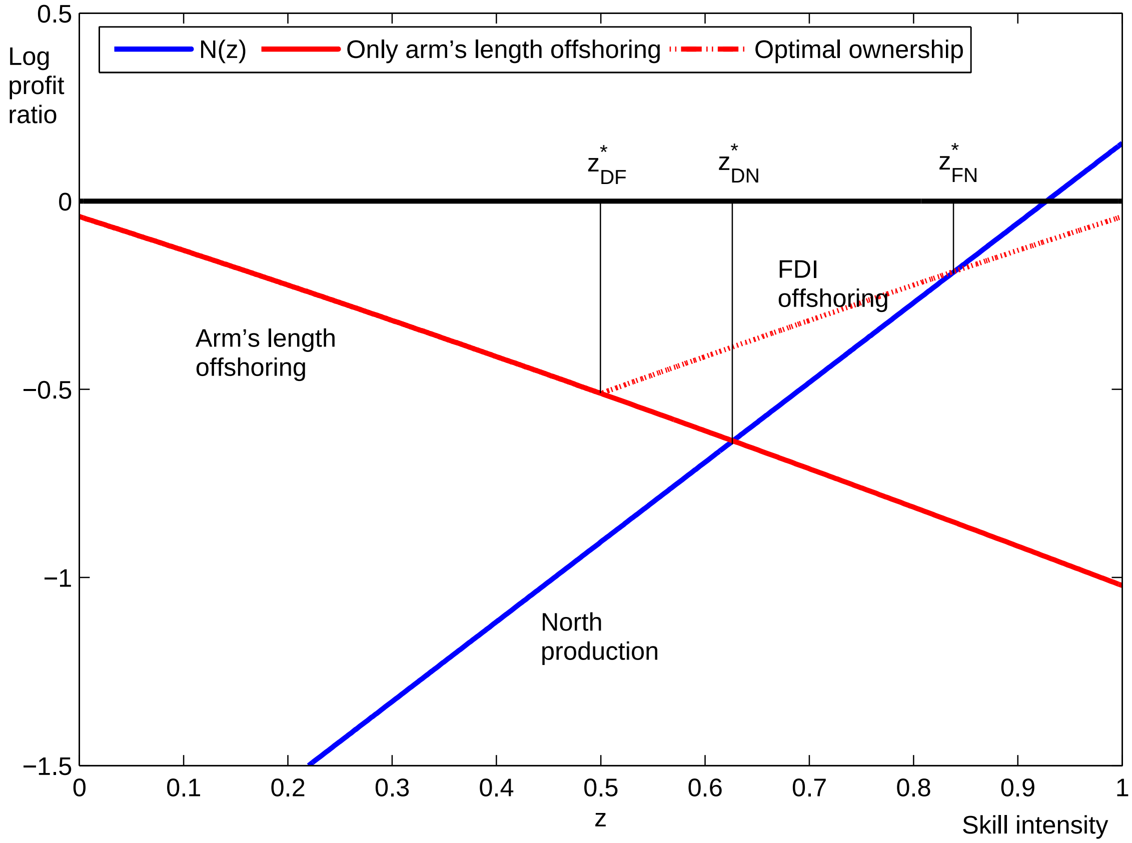
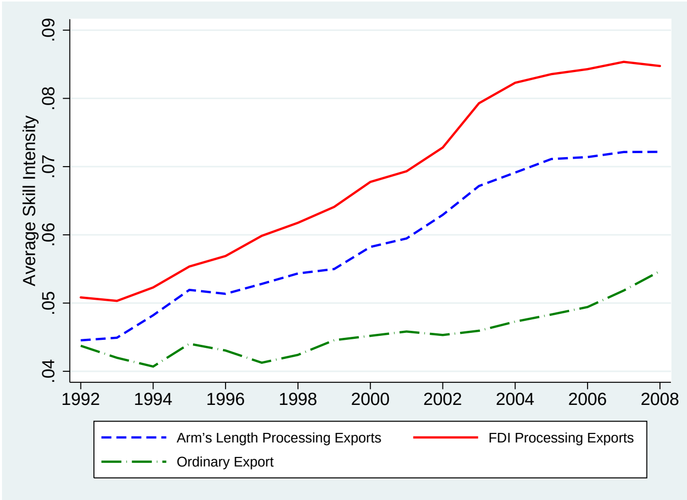


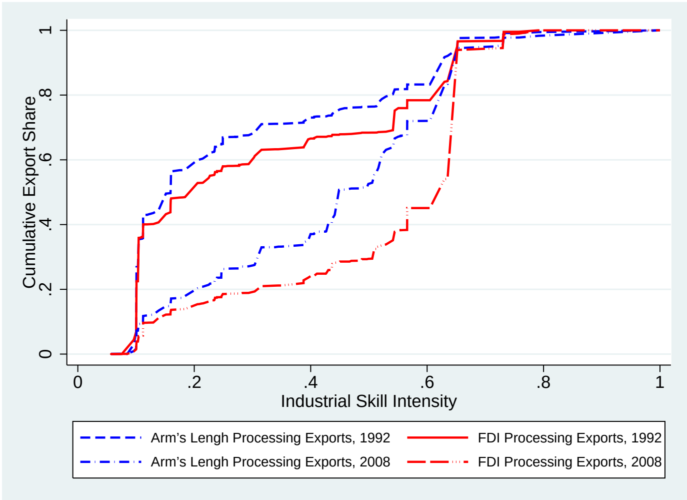
Figure 4: Ownership liberalization, Offshoring and Skill Intensity of Intermediate Goods

Figure 5: Skill Difference of Processing Exports

(a) Average Skill Intensity



(b) The Cumulative Distributions



Note: The average skill intensity is measured as the weighted average of industrial skill intensity, with industrial export shares as the weights, where the skill intensity is measured by the share of college workers within each industry using the 1995 Chinese National Industry Census.

Appendices

A Proof of Lemma 2

Since $S(z, \beta)$ is continuous and differentiable function, we only need to show $\frac{\partial^2 S(z,\beta)}{\partial z \partial \beta} > 0$ for supermodularity, according to Milgrom and Roberts (1990) and Topkis (1998). To show $\frac{\partial^2 S(z,\beta)}{\partial z \partial \beta} > 0$, we only need to show that

$$\frac{1}{\beta(1-\beta)} > \frac{(1-\alpha)(2-\alpha)}{[1-\alpha(1-\beta)+\alpha(1-2\beta)z]^2} \tag{A.1}$$

For $\beta \in [1/2, 1]$, the RHS of inequality (A.1) increases in z. So we only need to show that the inequality holds for $z = 1$, which is

$$[1-\alpha\beta]^2 > \beta(1-\beta)(1-\alpha)(2-\alpha)$$

For $\beta \in [0, 1/2]$, the RHS of this inequality decreases in z. So we only need to show that the inequality holds for $z = 0$, which is

$$[1-\alpha(1-\beta)]^2 > \beta(1-\beta)(1-\alpha)(2-\alpha)$$

It is easy to see that these two inequalities are essential the same if we redefine $\hat{\beta} = 1 - \beta$ for the second one. Thus, we only need to prove the inequality for $\beta \in [1/2, 1]$. This can be shown by proving it in two cases where $\alpha < 2/3$ and $\alpha \geq 2/3$. For $\alpha < 2/3$, it is easy to show that

$$(1-\alpha\beta)^2 \geq (1-\alpha)^2 > (1-\alpha)(2-\alpha)/4 \geq \beta(1-\beta)(1-\alpha)(2-\alpha)$$

For $\alpha \geq 2/3$, we can use convexity property of functions. Clearly $g(\beta) = (1-\alpha\beta)^2$ is a convex function on the compact interval [1/2, 1], so we have

$$\begin{aligned} g(\beta) &\geq g(1) + g'(1)(\beta - 1) = (1-\alpha)^2 + (1-\alpha)(3\alpha-2)(1-\beta) + (2-\alpha)(1-\alpha)(1-\beta) \\ &> 0 + (2-\alpha)(1-\alpha)(1-\beta)\beta \end{aligned}$$

Next step we show $S(z, \beta)$ is concave in z and strictly concave in β.

$$\frac{\partial^2 S(z,\beta)}{\partial z^2} = -\frac{\alpha(1-\alpha)(1-2\beta)^2}{[1-\alpha\beta z-\alpha(1-\beta)(1-z)]^2} \leqslant 0$$

and

$$\frac{\partial^2 S(z,\beta)}{\partial \beta^2} = -\frac{(\beta-z)^2 + z(1-z)}{\beta(1-\beta)} - \frac{\alpha(1-\alpha)(1-2z)^2}{[1-\alpha\beta z-\alpha(1-\beta)(1-z)]^2} < 0$$

Because $S(z, \beta)$ is continuous and strictly concave in a compact set of $\beta \in [0, 1]$, there must be a unique maximizer $\beta^*(z)$ for a given value of z, according to the maximum theory. Moreover, by the Topkis's theorem, the Supermodularity implies $\beta^*(z)$ increases in z. Here we show it by using the implicit function theory. The first order condition for β is $S_\beta(\beta^*(z), z) = 0$ for an inner solution, differentiating the first order condition, with respect to z and using the implicit function theorem, we find that $\frac{\partial \beta^*(z)}{\partial z} = -\frac{S_{\beta z}(\beta^*(z),z)}{S_{\beta\beta}(\beta^*(z),z)} > 0$. For corner solution, we have $\beta^*(0) = 0$ and $\beta^*(1) = 1$, so our statement of $\beta^*(z)$ still holds.

B Proof for lemma 3

Lemma 3 *If the Northern innovators would offshore all intermediate goods to the South, the more skill-intensive intermediate goods are offshored through foreign affiliates ($z > z^*_{DF}$), and the less skill-intensive products are offshored through joint ventures ($z \leq z^*_{DF}$). Moreover, the cutoff z^*_{DF} is independent of trade cost.*

To show Lemma this, we first show the following corollary.

Corollary 1

(a) For $\beta = 1/2$, $\frac{\partial S(z,\beta)}{\partial z} = 0$ and $S(z, 1/2) < 0$.

(b) For $\beta > 1/2$, $\frac{\partial S(z,\beta)}{\partial z} > 0$, $S(z = 0, \beta) < S(z = 0, 1/2) = S(z = 1, 1/2) < S(z = 1, \beta) \leqslant 0$. Since $\beta^F > 1/2$, this implies that the log profit ratio of foreign-owned firms increases in z. Moreover, there exists a unique $z^*_{JF} \in (1/2, 1]$, such that $S(z^*_{JF}, \beta^F) = S(z^*_{JF}, \beta^J)$, $S(z, \beta^F) > S(z, \beta^J)$ if $z > z^*_{JF}$, and $S(z, \beta^F) < S(z, \beta^J)$ if $z < z^*_{JF}$.

(c) For $\beta < 1/2$, $\frac{\partial S(z,\beta)}{\partial z} < 0$, $S(z = 1, \beta < 1/2) < S(z = 1, 1/2) = S(z = 0, 1/2) < S(z = 0, \beta < 1/2) \leqslant 0$. Since $\beta^D < 1/2$, this implies that the log profit ratio of Southern-owned firms decreases in z.

(d) Moreover, there exists a unique cutoff $z^*_{DF} \in (0, 1)$, such that $S(z^*_{DF}, \beta^D) = S(z^*_{DF}, \beta^F)$, and $S(z, \beta^D) > S(z, \beta^F)$ if $z < z^*_{DF}$, and $S(z, \beta^D) < S(z, \beta^F)$ if $z > z^*_{DF}$.

Proof. For (a), evaluating $S(z, \beta)$ and its derivative of z at $\beta = 1/2$ shows that $S(z, 1/2) = \frac{1-\alpha}{\alpha}[\ln(1 - \frac{\alpha}{2}) - \ln(1 - \alpha)] - \ln 2 < 0$ and $\frac{\partial S(z,\beta)}{\partial z}|_{\beta=1/2} = 0$. For (b) and (c), because $S(z, \beta)$ is supermodular, we have $\frac{\partial S(z,\beta)}{\partial z \partial \beta} > 0$, then

$$\frac{\partial S(z, \beta)}{\partial z}|_{\beta>1/2} > \frac{\partial S(z, \beta)}{\partial z}|_{\beta=1/2} = 0 > \frac{\partial S(z, \beta)}{\partial z}|_{\beta<1/2}$$

Thus, $S(z, \beta)$ increases in z for $\beta > 1/2$, and decreases for $\beta < 1/2$. Moreover, since $f(x) = \ln x + \frac{1-\alpha}{\alpha}[\ln(1 - \alpha x) - ln(1 - \alpha)]$ increases in x if $x \in (0, 1)$, then $f(x) \leq 0$ and the equality holds only if $x = 1$. Thus, $S(z = 0, \beta) =$

$\ln(1-\beta)+\frac{1-\alpha}{\alpha}[\ln(1-\alpha(1-\beta))-ln(1-\alpha)]\leq 0$ and $S(z=1,\beta)=\ln\beta+\frac{1-\alpha}{\alpha}[\ln(1-\alpha\beta)-ln(1-\alpha)]\leq 0$. Also we can see $S(z=0,\beta)$ decreases in β and $S(z=1,\beta)$ increases in β. Based on these properties, it is easy to show that corollary (b) and (c) hold. Because $S(z,\beta^F)$ increases in z and $S(z,\beta^D)$ decreases in z, and $S(z=0,\beta^F)<S(z=0,\beta^D)$ and $S(z=1,\beta^F)>S(z=1,\beta^D)$, then there two curves only has one crossing point denoted as $z^*_{DF}\in(0,1)$. Thus, corollary (d) also holds. Moreover, as $S(z,\beta)$ does not depend on the trade cost, thus the cutoff z^*_{DF} also does not change as the trade cost varies.

C Proof of Proposition 1

First we define

$$B(z,\beta,t)\equiv[N(z)-S(z,\beta)]/z=\ln\frac{(1-\beta)\omega_l}{\beta\omega_h}+\frac{1}{z}[\ln\frac{t}{(1-\beta)\omega_l}+\frac{1-\alpha}{\alpha}\ln\frac{1-\alpha}{1-\alpha\beta z-\alpha(1-\beta)(1-z)}]$$

Thus, $N(z)>S(z,\beta)$ is equivalent to $B(z,\beta,t)>0$, and vise versa. Based on Assumption 2, we can show the following corollary.

Corollary 2

(1) *If Assumption 2 holds, for a given value $\beta<\widetilde{\beta}$, we have $\lim_{z\to 0}B(z,\beta,t)<0$, $B(1,\beta,t)>0$, and $B_z(z,\beta,t)>0$. Thus, there exists a unique threshold $z^*(t,\beta)\in(0,1)$ such that $B(\beta,z^*(t,\beta),t)=0$. As a result, the more skill-intensive intermediate goods ($z>z^*(t,\beta)$) are produced in the North. and less skill-intensive intermediate goods ($z<z^*(t,\beta)$) are produced in the South.*

(2) *The cutoff $z^*(t,\beta)$ increases as the trade cost t decreases.*

Proof. $\lim_{z\to 0}B(z,\beta,t)<0$ holds only if the term in the bracket is negative, which is true under the Assumption 2(2). Moreover,

$$B(1,\beta,t)=\ln\frac{t}{\beta\omega_h}+\frac{1-\alpha}{\alpha}\ln\frac{1-\alpha}{1-\alpha\beta}=\ln\frac{t}{\omega_h}+[\frac{1-\alpha}{\alpha}\ln\frac{1-\alpha}{1-\alpha\beta}-\ln\beta]>0$$

due to the facts that $t>\omega_h$ and the term in the bracket decreases in β and has a minimum at zero. To show $B_z(\beta,z,t)>0$, we only need to show

$$r(z,\beta)=\frac{1-\alpha}{\alpha}[\ln(1-\alpha)-\ln(1-\alpha\beta z-\alpha(1-\beta)(1-z))]+\ln(t/(1-\beta)\omega_l)+\frac{z(1-2\beta)(1-\alpha)}{1-\alpha\beta z-\alpha(1-\beta)(1-z)}<0$$

It is easy to show that $r(z,\beta)$ is non-increasing in z, so $r(z,\beta)\leq r(0,\beta)=\ln(\frac{t}{(1-\beta)\omega_l}(\frac{1-\alpha}{1-\alpha(1-\beta)})^{\frac{1-\alpha}{\alpha}})$. Since $r(0,\beta)$ is strictly increasing in β if $\beta>0$, then $r(0,\beta)<r(0,\widetilde{\beta})=0$ for $\beta<\widetilde{\beta}$. The last strict inequality holds due to Assumption 2(2). Thus $B(z,\beta,t)$ is an increasing and continuous function of z, and $B(1,\beta,t) > 0$, $\lim_{z\to 0} B(\beta,z,t) < 0$. Clearly there must be a unique cutoff $z^*(t,\beta) \in (0,1)$ such that $B(z^*(t,\beta),\beta,t) = 0$. Total differentiate with respective to β, z and t at $z^*(t,\beta)$, we get $B_\beta d\beta + B_z dz + B_t dt = 0$ Since $B_t > 0$ and $B_z > 0$, $d\beta = 0$, we have $\frac{dz^*(t,\beta)}{dt} = -\frac{B_t}{B_z} > 0$. Since $\beta^D < \beta^F$, there exists at most two different cutoffs $z^*_{ON}(t) \in (0,1)$, for $O = F, D$. The above lemma implies that the most skill-intensive intermediate goods are produced in the North, i.e. for any $z > \max\{z^*_{DN}(t), z^*_{FN}(t)\}$, and $\pi(z) = \pi^N(z)$. Moreover, it is easy to show that the order of $z^*_{FN}(t), z^*_{DN}(t)$ must be one of the four cases: (1) $z^*_{FN}(t) > z^*_{DN}(t)$; (2) $z^*_{FN}(t) = z^*_{DN}(t)$; (3) $z^*_{DN}(t) > z^*_{FN}(t)$. In the first case, three production modes coexist; in the second and third case, the North foreign ownership ($O = F$) will not be optimal for any product z. Moreover, the first case also implies $z^*_{FN}(t) > z^*_{DF}$. Because if $z^*_{FN}(t) \leq z^*_{DF}$, then $z^*_{DN}(t) \geq z^*_{FN}(t)$ which is contradictory to the inequality in the first case. Thus, in the case of three production modes coexist, the most skill-intensive intermediate goods $z > z^*_{FN}(t)$ remain in the North, and the less skill-intensive goods are offshored to the South. Based on Lemma 3, among these products offshored to the South, the more skill-intensive are through FDI offshoring ($z^*_{FN}(t) > z > z^*_{DF}$), the less skill-intensive are through arm's length offshoring ($z \leq z^*_{DF}$). Thus, there exists a unique set $(z^*_{FN}(t), z^*_{DF})$, which indicates the boundary of four production modes. Moreover, as the trade cost t decreases, $z^*_{FN}(t)$ increases.

D Proof for Proposition 2

The optimal revenue can be derived from firm's optimization problem when the Northern innovator chooses to offshore her production.

$$R(z,\beta^O) = \lambda(\frac{1}{t})^{\alpha/(1-\alpha)}[\alpha(\beta^O/q^S)^z((1-\beta^O)/w^S)^{(1-z)}]^{\alpha/(1-\alpha)} \tag{D.1}$$

If two types of offshoring coexist, we must have $z^*_{DF} < z^*_{FN}(t)$. Thus, the revenue share of foreign firms in process export is given by

$$\Upsilon^F(t) = \frac{\int_{z^*_{JF}}^{z^*_{FN}(t)} R(z,\beta^F)dF(z)}{\int_0^{z^*_{DF}} R(z,\beta^D)dF(z) + \int_{z^*_{DF}}^{z^*_{FN}(t)} R(z,\beta^F)dF(z)} = \frac{\int_{z^*_{JF}}^{z^*_{FN}(t)} \tilde{R}(z,\beta^F)dF(z)}{\int_0^{z^*_{DF}} \tilde{R}(z,\beta^D)dF(z) + \int_{z^*_{DF}}^{z^*_{FN}(t)} \tilde{R}(z,\beta^F)dF(z)}$$

where $F(z)$ is the distribution of intermediate goods z, and $\widetilde{R}(z,\beta) = R(z,\beta)/(\frac{1}{t})^{\alpha/(1-\alpha)}$. Now the trade cost t affects the revenue share of foreign firms only through the extensive margin, i.e. cutoff $z^*_{FN}(t)$. It is easy to show that the share of foreign firms increases as $z^*_{FN}(t)$, and we know $z^*_{FN}(t)$ increases as the trade cost t decreases. Thus a reduction in the trade cost increases the FDI offshoring.

E Proof of Proposition 4

(1). The proof is straightforward for the case where only arm's length offshoring is possible. Below we provide the proof when two types of offshoring coexist:

$$\frac{\partial D(q,w,\overline{z})}{\partial \overline{z}} = \frac{\sum\limits_{O=D,F} \int_{\Omega_O} l(\overline{z},\beta^F) l(z,\beta^O)[h(\overline{z},\beta^F)/l(\overline{z},\beta^F) - h(z,\beta^O)/l(z,\beta^O)]dz}{[\sum\limits_{O=D,F} \int_{\Omega_O} l(z,\beta^O)dz]^2} > 0$$

due to the fact that $h(\overline{z},\beta^F)/l(\overline{z},\beta^F) \geq h(\overline{z},\beta^O)/l(\overline{z},\beta^O) > h(z,\beta^O)/l(z,\beta^O)$ for $z < \overline{z}$, and for $O = D, F$. This increasing skill demand due to the extensive margin growth is similar to the mechanism of Feenstra and Hanson (1996a), but note that the ownership structure amplifies the impact of the extensive margin of export on the skill demand. Because the term in bracket of numerator can be decomposed into two parts: $[h(\overline{z},\beta^F)/l(\overline{z},\beta^F) - h(z,\beta^O)/l(z,\beta^O)] = [\frac{h(\overline{z},\beta^F)}{l(\overline{z},\beta^F)} - \frac{h(\overline{z},\beta^O)}{l(\overline{z},\beta^O)}] + [\frac{h(\overline{z},\beta^O)}{l(\overline{z},\beta^O)} - \frac{h(z,\beta^O)}{l(z,\beta^O)}]$. Both terms in brackets are non-negative, and the first term indicates the amplification effect of ownership structure, while the second term captures the pure effect of extensive margin growth on skill demand. (2). Define $\Omega_1 = [0, z^*_{DF}], \Omega_2 = [z^*_{DF}, z^*_{DN}]$, and $\Omega_3 = [z^*_{DN}, z^*_{FN}]$, then

the aggregate skill demands before and after ownership liberalization are given as follows:

$$D_0 = \frac{\int_{\Omega_{1,2}} h(z,\beta^D)dz}{\int_{\Omega_{1,2}} l(z,\beta^D)dz}$$

$$D_1 = \frac{\int_{\Omega_1} h(z,\beta^D)dz + \int_{\Omega_{2,3}} h(z,\beta^F)dz}{\int_{\Omega_1} l(z,\beta^D)dz + \int_{\Omega_{2,3}} l(z,\beta^F)dz}$$

We can show

$$\begin{aligned}
D_1 - D_0 \sim & \left(\int_{\Omega_1} h(z,\beta^D)dz + \int_{\Omega_{2,3}} h(z,\beta^F)dz\right) \int_{\Omega_{1,2}} l(z,\beta^D)dz \\
& - \int_{\Omega_{1,2}} h(z,\beta^D)dz \left(\int_{\Omega_1} l(z,\beta^D)dz + \int_{\Omega_{2,3}} l(z,\beta^F)dz\right) \\
& = \left[\int_{\Omega_1} l(z,\beta^D)dz \left(\int_{\Omega_2} h(z,\beta^F) - h(z,\beta^D)dz\right) - \int_{\Omega_1} h(z,\beta^D)dz \left(\int_{\Omega_2} l(z,\beta^F) - l(z,\beta^D)dz\right)\right] \\
& + \left[\int_{\Omega_3} h(z,\beta^F)dz \int_{\Omega_{1,2}} l(z,\beta^D)dz - \int_{\Omega_{1,2}} h(z,\beta^D)dz \int_{\Omega_3} l(z,\beta^F)dz\right] \\
& + \left[\int_{\Omega_2} h(z,\beta^F)dz \int_{\Omega_2} l(z,\beta^D)dz - \int_{\Omega_2} h(z,\beta^D)dz \int_{\Omega_2} l(z,\beta^F)dz\right].
\end{aligned}$$

Next we show each term in three brackets are all non-negative. The first one is

$$
\begin{aligned}
&\int_{\Omega_1} l(y,\beta^D)dy\left(\int_{\Omega_2} h(z,\beta^F)-h(z,\beta^D)dz\right)-\int_{\Omega_1} h(y,\beta^D)dy\left(\int_{\Omega_2} l(z,\beta^F)-l(z,\beta^D)dz\right)\\
&=\int_{y\in\Omega_1}\int_{z\in\Omega_2} l(y,\beta^D)\left[h(z,\beta^F)-h(z,\beta^D)\right]-h(y,\beta^D)\left[l(z,\beta^F)-l(z,\beta^D)\right]dzdy\\
&=\int_{y\in\Omega_1}\int_{z\in\Omega_2} h(z,\beta^D)l(y,\beta^D)\left[h(z,\beta^F)/h(z,\beta^D)-1\right]-h(y,\beta^D)\left[l(z,\beta^F)-l(z,\beta^D)\right]dzdy\\
&>\int_{y\in\Omega_1}\int_{z\in\Omega_2} h(z,\beta^D)l(y,\beta^D)\left[l(z,\beta^F)/l(z,\beta^D)-1\right]-h(y,\beta^D)\left[l(z,\beta^F)-l(z,\beta^D)\right]dzdy\\
&=\int_{y\in\Omega_1}\int_{z\in\Omega_2} \frac{h(z,\beta^D)}{l(z,\beta^D)}l(y,\beta^D)\left[l(z,\beta^F)-l(z,\beta^D)\right]-h(y,\beta^D)\left[l(z,\beta^F)-l(z,\beta^D)\right]dzdy\\
&\geqslant\int_{y\in\Omega_1}\int_{z\in\Omega_2} \frac{h(y,\beta^D)}{l(y,\beta^D)}l(y,\beta^D)\left[l(z,\beta^F)-l(z,\beta^D)\right]-h(y,\beta^D)\left[l(z,\beta^F)-l(z,\beta^D)\right]dzdy\\
&=0
\end{aligned}
$$

The first inequality is because $h(z,\beta^F)/l(z,\beta^F)>h(z,\beta^D)/l(z,\beta^D)$, and the second is because $h(z,\beta^D)/l(z,\beta^D)\geqslant h(y,\beta^D)/l(y,\beta^D)$, for $z\geqslant y$. Also the second bracket is

$$
\begin{aligned}
&\int_{\Omega_3} h(z,\beta^F)dz\int_{\Omega_{1,2}} l(y,\beta^D)dy-\int_{\Omega_{1,2}} h(y,\beta^D)dz\int_{\Omega_3} l(z,\beta^F)dy\\
&=\int_{\Omega_3}\int_{\Omega_{1,2}} h(z,\beta^F)l(y,\beta^D)-h(y,\beta^D)l(z,\beta^F)dydz\\
&=\int_{\Omega_3}\int_{\Omega_{1,2}}\left[\frac{h(z,\beta^F)}{l(z,\beta^F)}-\frac{h(y,\beta^D)}{l(y,\beta^D)}\right]l(z,\beta^F)l(y,\beta^D)dydz>0
\end{aligned}
$$

Next we show that the third bracket is non-negative if $\alpha\leq 1/2$.It is sufficient to show $h(z,\beta^F)\geqslant h(z,\beta^D)$, and $l(z,\beta^D)\geqslant l(z,\beta^F)$ for $z\in[0,1]$.

$$
\frac{h(z,\beta^F)}{h(z,\beta^D)}=\frac{\alpha\beta^F zR(z,\beta^F)/q}{\alpha\beta^D zR(z,\beta^D)/q}=\frac{\beta^F[(\frac{\beta^F}{1-\beta^F})^z]^{\alpha/(1-\alpha)}(1-\beta^F)^{\alpha/(1-\alpha)}}{\beta^D[(\frac{\beta^D}{1-\beta^D})^z]^{\alpha/(1-\alpha)}(1-\beta^D)^{\alpha/(1-\alpha)}}
$$

Using the fact that $\beta^F+\beta^D=1$, and $\beta^F>1/2$, we can show $\frac{h(z,\beta^F)}{h(z,\beta^D)}=(\frac{\beta^F}{1-\beta^F})^{(1-2\alpha+2\alpha z)/(1-\alpha)}\geq 1$ for $z\in[0,1]$ if $\alpha\leq 1/2$. Similarly we can show that this condition is sufficient for $l(z,\beta^D)\geqslant l(z,\beta^F)$, i.e.,

$$
\begin{aligned}
\frac{l(z,\beta^F)}{l(z,\beta^D)}&=\frac{\alpha(1-\beta^F)(1-z)R(z,\beta^F)/w}{\alpha(1-\beta^D)(1-z)R(z,\beta^D)/w}\\
&=\frac{(1-\beta^F)[(\beta^F)^z(1-\beta^F)^{(1-z)}]^{\alpha/(1-\alpha)}}{(1-\beta^D)[(\beta^D)^z(1-\beta^D)^{(1-z)}]^{\alpha/(1-\alpha)}}\\
&=(\frac{1-\beta^F}{\beta^F})^{(1-2\alpha z)/(1-\alpha)}\leq 1 \text{ for } z\in[0,1].
\end{aligned}
$$

Thus, we have $D_1 > D_0$, i.e., ownership liberalization increases the aggregate relative demand for skilled workers. Note the second bracket implies that $\int_{\Omega_3} h(z, \beta^F)dz / \int_{\Omega_3} l(z, \beta^F)dz > \int_{\Omega_{1,2}} h(z, \beta^D)dz / \int_{\Omega_{1,2}} l(z, \beta^D)dz$, indicating that the the aggregate relative skill demand due to newly offshored goods $z \in \Omega_3$ is higher than previous offshored goods. Moreover, the term in third bracket also implies that $\int_{\Omega_2} h(z, \beta^F)dz / \int_{\Omega_2} l(z, \beta^F)dz \geq \int_{\Omega_2} h(z, \beta^D)dz / \int_{\Omega_2} l(z, \beta^D)dz$, therefore the relative skill demand also increases due to the ownership reconstruction for the goods $z \in \Omega_2$.

F Empirical Appendix

F.1 Augmented Mincer Wage Regression

The following graphs plot the actual processing exports ratio and the share of FDI processing exports against their predicted values, and clearly show significant correlations between the actual and predicted values.

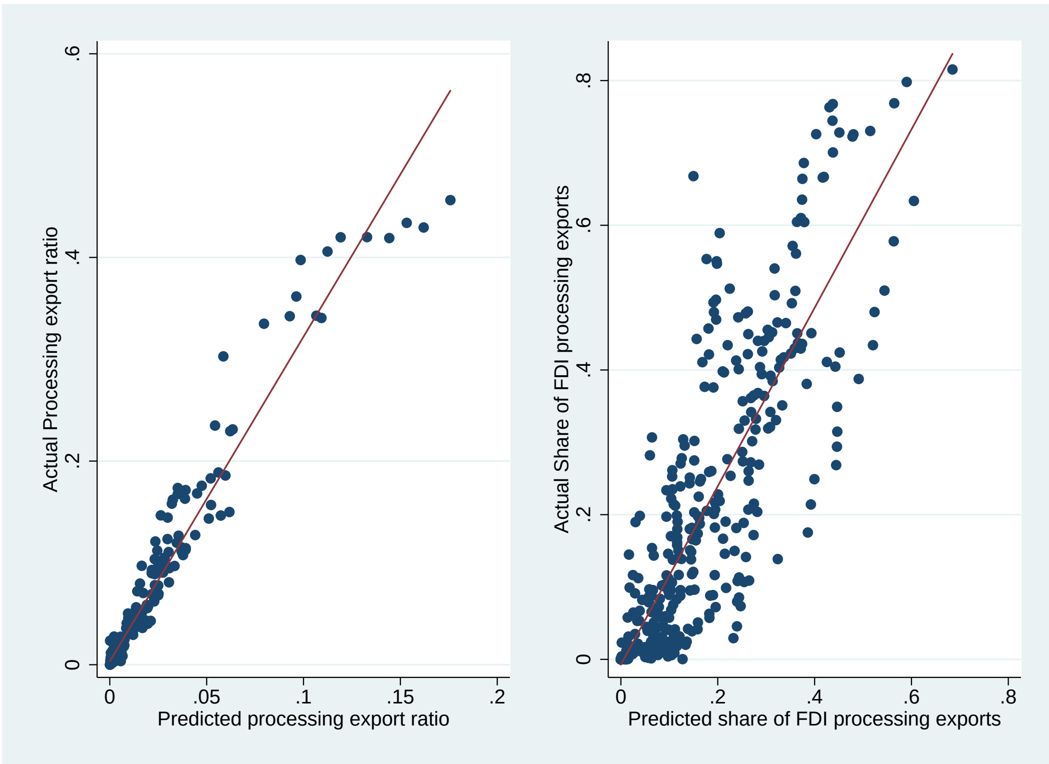


Figure F.1: Scatter Plot for First Stage Regression

F.2 Concordance

The Chinese National Industry Census 1995 (CNIC1995) is based on Chinese Standard Industrial Classification 1994 (CSIC1994 at 3 digits level), which has similar structure as ISIC REV.3. So we do the industry concordance for manufacturing as follows. First, the National Bureau of Statistics provides the concordance between CSIC1994 and CSIC2002 at 4 digits, and also the concordance between CSIC2002 and ISIC REV.3 at 4 digits level. Thus, we first get the concordance between CSIC1994 (172 groups at 3 digits level) and ISIC REV.3 (125 groups at 4 digits level) through CSIC2002. The concordance between CSIC1994 and ISIC REV.3 requires reclassification and some many-to-many matches occur. For these industries in ISIC REV.3 have multiple matches in CSIC1994, we compute the weighted skill intensity, with the employment share as the weights. Secondly, World Integrated Trade Solution (WITS) provides a concordance between ISIC REV.3 (4 digits) and Harmonized system (6 digits for various versions). Since the China trade data record at least at HS 6 digits level, then we can convert HS 6 digits to ISIC REV.3 (4 digits) as well. Consequently we can match CNIC1995 and trade data based on ISIC REV.3. Once we restrain ourselves to manufacturing, we cover 113 out of 127 groups of ISIC REV.3.

F.3 Provincial variables

Table F.1: Variable discription

Variable	Definition	Source
Collshr	The Share of population aged above 5 with college degrees	Annual Population Survey, published in China Population Statistics Yearbook, 1993-2009.
R&D ratio	R&D expenditure/nominal GDP	China Statistical Yearbook on Science and Technology, 1993-2009.
K/Y	Capital stock/real GDP, in 1978 price	Capital stock is provided by Qian et al. (2007). Real GDP is computed from China Compendium of Statistics 1949-2008.
Infrastructure	Log(the # of km of highways and railways per square km)	China Compendium of Statistics 1949-2008
National policy zones	The number of national policy zones	China Development Zone Review Announcement Catalogue, NDRC, 2007.