Offshoring and Firm Overlap

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Abstract

We set up a model of offshoring with heterogeneous producers, in which firms differ in the mass of tasks they perform and the share of tasks they can offshore to a low-cost host country. The model captures the empirical regularity that larger, more productive firms are more likely to make use of the offshoring opportunity and that only a fraction of firms of a specific type engages in offshoring. This gives rise of an overlap of firms, which is type-specific and, in the aggregate, non-monotonic in the costs of offshoring. In an empirical exercise, we use firm-level data from Germany to structurally estimate key parameters of the model. These parameters are then used for counterfactual analyses, in which we quantify at the role of overlap for welfare and study the consequences of a reduction in offshoring costs for the extent of overlap and welfare.

JEL-Classification: C30, F12, F14
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1 Introduction

Easier access to offshoring opportunities in low-income countries provoked a heated debate on globalization and its impact on job security. Advocates highlight the potential benefits due to soaring exports, whereas detractors are usually more concerned about potential job losses through offshoring of more routine tasks. Our paper contributes to this debate by studying the role of size and management for the decision to offshore. On average, the probability of offshoring increases with firm size. Only few small firms offshore but most large firms with higher dependency on foreign markets report to import intermediate goods. Our paper adds to the literature by providing a channel through which the decision to offshore depends on the knowledge a firm has about its offshoring potential.

Whether jobs performed by certain workers can be outsourced or not must be discovered by the firm’s management through an in-dept analysis of the production chain and the tasks involved. This feature of the model is highly realistic. Using plant-level data for Germany, we are able to show that the decision to offshore is not as sharp as recent studies in international trade would suggest. Figure 1 shows the fraction of firms in different size-bins. We construct those bins using the percentiles of firm-revenue.

![Figure 1: Share of offshoring firms within different revenue categories](image-url)
Only 5 percent of firms with revenue up to the 10th percentile report to import intermediate goods. The fraction increases with size (and revenue). The shares of offshoring and non-offshoring firms approximately coincide between the 60th and 70th percentile. Around the 80th and 90th percentile, we find that almost all firms offshore. However, the picture is less clear-cut in the middle of the revenue distribution, where the share of offshoring and non-offshoring firms is almost identical.

We develop a general equilibrium model that rationalizes why firms may refrain from using potential cost-saving opportunities. We argue that the management of a firm has to sink fixed offshoring costs in order to uncover and communicate offshoring potentials. We aim at bringing the model to the data in order to elaborate a counter factual analysis. Firstly, we study the role of fixed costs in our model and how they interact with transportation costs. Secondly, we explore the role of wages in the foreign-country and its effects on job-security in the home-country.

The paper is structured as follows: Section 2 develops the general equilibrium framework. Section 3 describes how we structurally estimate the key parameters of the model. Section 4 discusses the outcomes of our counter factual experiments [FUTURE]. Section 5 concludes.

2 A model of offshoring and firm overlap

2.1 Basic assumptions and intermediate results

We consider a world with two economies. Consumers in both countries have CES preferences over a continuum of differentiated and freely tradable goods \( q(\omega) \). The representative consumer’s utility is given by

\[
U = \left[ \int_{\omega \in \Omega} q(\omega)^{\frac{\sigma}{\sigma - 1}} d\omega \right]^{\frac{\sigma - 1}{\sigma}}, \quad (1)
\]

where \( \sigma > 1 \) is the elasticity of substitution between different varieties \( \omega \) and \( \Omega \) is the set of available consumer goods. Maximizing \( U \) subject to the representative consumer’s budget constraint \( I = \int_{\omega \in \Omega} p(\omega) q(\omega) \) gives isoelastic demand for variety \( \omega \):

\[
q(\omega) = \frac{I}{P} \left[ \frac{p(\omega)}{P} \right]^{-\sigma}, \quad (2)
\]
where \( I \) is aggregate income, \( p(\omega) \) is the price of good \( \omega \) and

\[
P = \left[ \int_{\omega \in \Omega} p(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}
\]

is a CES price index.

The two economies differ in their level of development and are populated by \( L \) and \( L^* \) units of labor, respectively, where an asterisk refers to the economy with the lower level of development. This economy is the host country of offshoring, whereas the more advanced economy is the source country of offshoring. We adopt the modeling strategy of Egger et al. (2013) and assume that the host country lacks the technology to operate its own firms. This implies that all (industrial) producers are headquartered in the source country and it makes the host country a big labor reservoir that is inactive in the absence of offshoring. Firms perform different tasks, which are combined in a Cobb-Douglas production technology to produce output \( q \):\(^1\)

\[
q = \frac{z}{1-z} \exp \frac{1}{z} \int_0^z \ln x(i) di,
\]

where \( x(i) \) denotes the output for task \( i \) and \( z \) is the length of the task interval, i.e. the mass of the tasks, performed by the firm. The technology in Eq. (4) captures in a simple way the gains from labor division, as performing more tasks increases a firm’s productivity. Assuming that task output equals labor input, the firm’s total variable production costs are given by

\[
C^v = \int_0^z \zeta(i)x(i) di,
\]

where \( \zeta(i) \) is the effective labor cost, which equals the domestic wage \( w \) if a task is performed at home and the foreign wage \( w^* \) multiplied by an iceberg trade cost parameter \( \tau > 1 \) if the task is performed abroad. Cost minimization establishes the well-known result that expenditures are the same for all tasks, i.e. \( \zeta(i)x(i) = \zeta x \) for all \( i \). Furthermore, the marginal production cost of a firm that performs all tasks at home (superscript \( d \)) and a firm that offshores a share \( s \) of tasks to the host country (superscript \( o \)) are given by

\[
c^d = (1-z)w, \quad c^o = (1-z)w\kappa^s
\]

where \( \kappa \equiv \tau w^*/w \) denotes the effective wage differential. As we explain later, offshoring has fixed costs, and hence \( \kappa < 1 \) must hold in order to make it attractive for firms to shift task production.

\(^1\)To save on notation, we use the same variable for production and consumption and suppress firm indices, where this is possible without generating confusion.
abroad. Accordingly, we can associate the inverse of $\kappa^s$ with the marginal cost saving effect of offshoring (cf. Egger et al., 2013).

To enter the source country, firms must make an initial investment of $f_e$ units of labor. This investment gives them a single draw from a task lottery and is immediately sunk. The outcome of the lottery is a technology tuple $(z, s)$ with $z$ and $s$ being the length of the task interval and the share of tasks that are offshorable, respectively. The length of the task interval $z$ is Pareto distributed over the unit interval with a probability density function $f_z(z) = k(1 - z)^{k-1}$. The distribution of $s$ is more sophisticated and depends on a firm’s $z$-level. We assume that a firm’s probability to have at least some offshorable tasks is a positive function of the length of its task interval, and in the interest of tractability we set this probability equal to $z$. If a firm has some offshorable tasks, the share of offshorable tasks $s$ is uniformly distributed over the interval $[0, 1]$.

The interdependence of the two random variables $z$ and $s$ allows us to capture two stylized facts: (i) firms which perform more tasks are more likely to offshore the production of some of these tasks; (ii) for a given length of the task interval only a subset of firms engages in offshoring. After the lottery, firms are informed about their $z$-level, but they cannot observe which and how many tasks are offshorable. However, firms form expectations on $s$, i.e. on the potential of their technology for and the gains from offshoring. Depending on their $z$-level, they can then invest $f$ units of labor into a fixed offshoring service input that provides information on the share $s$ of offshorable tasks and the type of tasks that can be moved offshore.

We consider a static model and assume that firms are active, irrespective of their $z$-draw. By maximizing profits, firms set prices as a constant markup $\sigma/(\sigma - 1)$ over their marginal costs, $c$: $p = c\sigma/(\sigma - 1)$, where $c = c^d$ if the firm produces purely domestically and $c = c^o$ if the firm moves a share $s$ of its tasks abroad. Revenues are given by $r = IP^{\sigma-1}p^{1-\sigma}$, and in view of constant markup pricing, we can therefore determine the following two revenue ratios:

$$\frac{r^i(z_1)}{r^i(z_2)} = \left(\frac{1 - z_1}{1 - z_2}\right)^{1-\sigma}, \quad \frac{r^o(z)}{r^d(z)} = \kappa^s(1-\sigma).$$

(6)

The first expression gives the revenues ratio of two firms with the same offshoring status $i \in (d, o)$ and differing $z$-length, with higher revenues realized by the firm which makes use of more tasks in the production of its goods. The second expression gives the revenue ratio of two firms with the same $z$-length and differing offshoring status, with higher revenues realized by the offshoring firm due to the cost-saving involved in shifting production abroad. According to Eq. (6), the
position of any firm in the revenue distribution is fully characterized by its $z$ and $s$ draws.

As outlined above, firms must invest $f$ units of labor to learn about their offshoring status, and this is attractive if the expected profit with offshoring $\pi^o(z, s) = (1 - z)r^d(z)/\sigma + zE[r^o(z)/\sigma] - f$ for a given task interval $z$ exceeds the profit without offshoring $\pi^d(z) = r^d(z)/\sigma$. Hence, firms make the investment if $z\{E[r^o(z)] - r^d(z)]\geq \sigma f$ or, in view of Eq. (6), if $z(1 - z)^{1-\sigma}r^d(1)\{E[\kappa^{(1-\sigma)}] - 1\} \geq \sigma f$. It is immediate that the attractiveness of offshoring investment increases with $z$, and this allows to determine a unique $\hat{z}$ that renders firms indifferent between investing and not investing into the offshoring service. Accounting for $E[\kappa^{(1-\sigma)}] = \int_0^1 \kappa^{(1-\sigma)}ds$, the indifferent firm is characterized by the following condition

$$\sigma f = \hat{z}(1 - \hat{z})^{1-\sigma}r^d(1) \left[ \frac{\kappa^{1-\sigma} - 1}{(1 - \sigma) \ln \kappa - 1} \right].$$

(7)

### 2.2 The general equilibrium

To solve for the general equilibrium, we choose source country labor as numéraire and set the respective wage rate equal to one: $w = 1$. Since marginal costs contain all relevant information of a firm’s success in the task lottery, we can rank firms according to their $c$-level, with the advantage that we do not have to further distinguish between the offshoring and domestic mode of production. Put differently, we can omit indices $d$ and $o$ in the subsequent discussion. The marginal cost of the least productive firm – which has task length 0 and is therefore a purely domestic producer – is given by $c = 1$. The marginal cost of all producers with $z < \hat{z}$ is given by $c = 1 - z$ and hence there is no difference if we rank purely domestic producers according to $z$ or $c$. Things are different however for offshoring firms, which operate a task length of $z \geq \hat{z}$. For these firms marginal costs are either given by $c = 1 - z$ if none of their tasks is offshorable or by $c = (1 - z)\kappa^s$ if some tasks are offshorable. In the latter case, marginal costs are the product of two random variables, and hence the ranking of $c$ cannot be directly inferred from the ranking of $z$. The picture becomes even more complicated, when taking into account that the probability of offshoring for a firm with $z \geq \hat{z}$ depends on the mass of tasks, $z$, operated by the firm. In the appendix, we show how we can link the distributions of $z$ and $s$ to compute the distribution of $c$. The result of this computations are summarized in the following lemma.
Lemma 1 The probability density function (pdf) of marginal production costs $c$ is given by

$$f_c(c) = \begin{cases} 
kc^k - \frac{1}{\ln \kappa} \left\{ c^{k-1} \left[ \left( \frac{1}{\kappa} \right)^k - 1 \right] - \frac{k^k}{k+1} \left[ \left( \frac{1}{\kappa} \right)^{k+1} - 1 \right] \right\} & \text{if } c \leq \hat{c} \\
kc^k - \frac{1}{\ln \kappa} \left\{ c^{k-1} \left[ (\hat{c})^k - 1 \right] - \frac{k^k}{k+1} \left[ (\hat{c})^{k+1} - 1 \right] \right\} & \text{if } c \in (\kappa \hat{c}, \hat{c}], \\
k_c^{k-1} & \text{if } c > \hat{c} 
\end{cases}$$

with $\hat{c} \equiv 1 - \hat{z}$.

Figure 2 displays $f_c(c)$. As we can see from this figure, the pdf in Lemma 1 has support on the unit interval and features a discontinuity at $\hat{c}$. This is because at this cutoff cost level a subset of firms starts offshoring, experiences a cost saving effect, and hence ends up with $c < \hat{c}$. Put differently, offshoring shifts firms towards lower marginal costs, and this explains the discontinuity in Figure 2. The kink of the pdf function at $\kappa \hat{c}$ is also a result of offshoring firms being shifted towards lower marginal costs and the fact that offshoring firms are confined by condition $z \geq \hat{z}$. Non-offshoring firms are not shifted in the $c$-distribution and this constrains $f_c(c)$ for all $c \in (\kappa \hat{c}, \hat{c}]$.

Figure 2: The probability density function $f_c(c)$
With the distribution of marginal costs at hand, we can compute economy-wide revenues. As formally shown in the appendix, this gives

\[
R = M \int_0^1 r(c)f(c)dc = Mr(1) \left[ \frac{k}{k - \sigma + 1} + \hat{c}^{k-\sigma+1} \left( \frac{k}{k - \sigma + 1} - \hat{c} \frac{k}{k - \sigma + 2} \right) \left( \frac{\kappa^{1-\sigma} - 1}{(1-\sigma)\ln \kappa} - 1 \right) \right], \tag{9}
\]

where \( k > \sigma - 1 \) has been assumed to ensure a finite positive value of \( R \). Since free entry implies that firms make zero profits on average, constant markup pricing establishes \( R = M\sigma (f_e + \hat{c}^k f) \). Accounting for Eqs. (7), we can solve for \( r(1) \) as a function of \( \hat{c} \) and \( \kappa \). Substitution into Eq. (9) gives offshoring indifference condition (OC)

\[
\Gamma_1(\hat{c}, \kappa) = \hat{c}^{\sigma-1} \frac{k}{1 - \hat{c}} \left( \frac{\sigma - 1}{k - \sigma + 1} - \hat{c} \frac{\sigma - 2}{k - \sigma + 2} \right) \left( \frac{\kappa^{1-\sigma} - 1}{(1-\sigma)\ln \kappa} - 1 \right) = 0.
\]

As formally shown in the appendix, \( \Gamma_1(\cdot) = 0 \) establishes a negative link between \( \hat{c} \) and \( \kappa \). The larger is \( \kappa \), the smaller is the cost saving effect of offshoring and the more productive the marginal firm that is indifferent between investing and not investing \( f \) must be. As outlined above a higher productivity is associated with a longer task interval and thus a lower marginal production cost \( c \) in the absence of offshoring. Intuitively, if the cost saving effect of offshoring vanishes due to \( \kappa = 1 \), all firms prefer domestic production and hence \( \hat{c} = 0 \). In contrast, if the cost saving effect of offshoring goes to infinity due to \( \kappa = 0 \), \( \hat{c} \) reaches a maximum at \( \hat{c}_1 < 1 \), where \( \hat{c}_1 \) is implicitly determined by

\[
\frac{\hat{c}_1^k}{1 - \hat{c}_1} \left( \frac{\sigma - 1}{k - \sigma + 1} - \hat{c}_1 \frac{\sigma - 2}{k - \sigma + 2} \right) = \frac{f_e}{f}. \tag{10}
\]

To obtain a second link between \( \hat{c} \) and \( \kappa \) we can use the adding up condition for foreign wages. Starting from the observation that a firm’s total expenditures for variable labor input, \( C^v \), are proportional to the firm’s revenues \( r \), with the factor of proportion being given by \( (\sigma - 1)/\sigma \), we can write \( C^v(c) = [(\sigma - 1)/\sigma]r(c) \). Due to the Cobb-Douglas technology in Eq. (4), an offshoring firm’s expenditure for foreign labor input is given by \( sC^v(c) \), with \( s \) denoting the share of offshored tasks. Since foreign workers can only be employed in the production of

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2One may have expected that \( \hat{c} \) converges to one if \( \kappa \) falls to expected profit gain from offshoring must go to infinity in this case. However, there is a counteracting effect, because \( r(1) \) falls to zero if \( \kappa = 0 \) (see below), and with the expected profit gain from offshoring being proportional to \( r(1) \) this counteracting effect leads to \( \hat{c}_1 < 1 \).
offshored tasks, we can write total labor income in the host country of offshoring as
\[ w^*L^* = M\mathbb{E}(s)\frac{\sigma - 1}{\sigma} \int_0^{\hat{c}} r(c) \hat{f}_c(c) dc = M\mathbb{E}(s)\frac{\sigma - 1}{\sigma} r(1) \int_0^{\hat{c}} c^{1-\sigma} \hat{f}_c(c) dc, \]

where \( \mathbb{E}(s) = 1/2 \) is the expected value of \( s \) if at least some of a firm’s tasks are offshorable and \( \hat{f}_c(c) = f_c(c) - kc^k \) is the density of offshoring producers. Solving the integral and replacing \( r(1) \) from above gives
\[ R = w^*L^* \frac{2\sigma}{\sigma - 1} \left\{ 1 + \frac{(1 - \sigma) \ln \kappa}{\kappa^{1-\sigma} - 1} \frac{k - \sigma + 2}{\hat{c}_k^{k-\sigma+1} [1 + (1 - \hat{c})(k - \sigma + 1)] - 1} \right\}. \]

Noting further that \( R = L + w^*L^* \) and replacing \( w^* \) bei \( \kappa/\tau \) allows us to write labor market constraint (LC):
\[ \Gamma_2(\kappa, \hat{c}) \equiv \kappa \left\{ \frac{\sigma + 1}{\sigma - 1} - \frac{2\sigma \ln \kappa}{\kappa^{1-\sigma} - 1} \frac{k - \sigma + 2}{\hat{c}_k^{k-\sigma+1} [1 + (1 - \hat{c})(k - \sigma + 1)] - 1} \right\} - \frac{\tau L}{L^*} = 0. \]

As formally shown in the appendix, \( \Gamma_2(\cdot) = 0 \) establishes a positive link between \( \kappa \) and \( \hat{c} \). The larger is \( \hat{c} \), the more firms are engaged in offshoring and the larger is \( \kappa \) ceteris paribus the demand for foreign workers. However, a larger demand for foreign workers drives up foreign wages and thereby raises \( \kappa \). If \( \hat{c} \) falls to zero, there is no offshoring, and in this case the host country becomes inactive and \( w^* \) as well as \( \kappa \) fall to zero. In contrast, \( \kappa \) reaches its maximum at a high level of \( \hat{c} \). Two cases can be distinguished, depending on the ranking of \( \mu \equiv L^* [\sigma + 1 + 2\sigma(k - \sigma + 1)] - \tau L(\sigma - 1) >, =, < 0. \) If \( \mu < 0, \kappa \) approaches \( \kappa_2 < 1 \) when \( \hat{c} \) goes to one, with \( \kappa_2 \) being implicitly given by
\[ \kappa_2 \left\{ \frac{\sigma + 1}{\sigma - 1} + \frac{2\sigma}{\kappa_2^{1-\sigma} - 1} \frac{(1 - \sigma) \ln \kappa_2}{\hat{c}_k^{k-\sigma+1} [1 + (1 - \hat{c})(k - \sigma + 1)] - 1} \right\} = \frac{\tau L}{L^*}. \]

If \( \mu > 0, \kappa_0 \) approaches one when \( \hat{c} \) goes to \( \hat{c}_2 < 1 \), with \( \hat{c}_2 \) being implicitly given by
\[ \left\{ \frac{\sigma + 1}{\sigma - 1} + \frac{2\sigma}{\hat{c}_2^{k-\sigma+1} [1 + (1 - \hat{c}_1)(k - \sigma + 1)] - 1} \right\} = \frac{\tau L}{L^*}. \]

Irrespective of the specific parameter constellation, \( \Gamma_1(\cdot) = 0 \) and \( \Gamma_2(\cdot) = 0 \) give a system of two equations which jointly determine a unique interior equilibrium with \( \hat{c}, \kappa \in (0,1) \). This equilibrium is depicted by the intersection point of \( OC \) and \( LC \) in Figure 3. As illustrated,
an increase in variable offshoring costs $\tau$ rotates the $LC$-locus counter-clockwise, leading to an increase in $\kappa$ and a decline in $\hat{c}$. In contrast, an increase in fixed offshoring cost $f$ rotates the $OC$-locus clockwise, and this lowers both $\hat{c}$ and $\kappa$.

![Figure 3: Equilibrium values of \( \hat{c} \) and \( \kappa \)](image)

### 2.3 Welfare and offshoring overlap

Setting $\hat{z} = 1 - \hat{c}$ in Eq. (7) and combining the resulting expression with $\Gamma_1(\cdot) = 0$, we can solve for the revenues of the least productive firm:

$$r(1) = \sigma f \left[ \frac{f_e}{f} - \frac{\hat{c}^k}{1 - \hat{c}} \left( \frac{\sigma - 1}{k - \sigma + 2} - \hat{c} \frac{\sigma - 2}{k - \sigma + 2} \right) \right] \frac{k - \sigma + 1}{k},$$

implying that $r(1)$ decreases in $\hat{c}$ and reaches a minimum value of zero at $\hat{c}_1$. Source country welfare, $W$, is given by per-capita income, which, in view of $w = 1$, equals $P^{-1}$. To determine the price index, we can start from the observation that $r(1) = IP^{\sigma-1}[(\sigma-1)/\sigma]^{\sigma-1}$. Accounting for $I = L + w^*L^*$ and Eq. (15), we can compute

$$P^{-1} = \left\{ \frac{L + w^*L^*}{\sigma f} \left[ \frac{f_e}{f} - \frac{\hat{c}^k}{1 - \hat{c}} \left( \frac{\sigma - 1}{k - \sigma + 2} - \hat{c} \frac{\sigma - 2}{k - \sigma + 2} \right) \right]^{-1} \left( \frac{1}{k} \right)^{\frac{\sigma-1}{\sigma}} \frac{\sigma - 1}{\sigma} \right\},$$

for $I = L + w^*L^*$ and Eq. (15), we can compute

$$P^{-1} = \left\{ \frac{L + w^*L^*}{\sigma f} \left[ \frac{f_e}{f} - \frac{\hat{c}^k}{1 - \hat{c}} \left( \frac{\sigma - 1}{k - \sigma + 2} - \hat{c} \frac{\sigma - 2}{k - \sigma + 2} \right) \right]^{-1} \left( \frac{1}{k} \right)^{\frac{\sigma-1}{\sigma}} \frac{\sigma - 1}{\sigma} \right\}.$$
In the appendix, we show that \( W = P^{-1} \), declines in both \( \tau \) and \( f \), implying that offshoring provides a welfare stimulus in our setting. The intuition for this result is similar to other settings that feature monopolistic competition between heterogeneous firms. The factor allocation in the one sector economy is efficient, and hence offshoring simply expands the production possibilities with gains for the source country (cf. Dhingra and Morrow, 2013).\(^3\)

To obtain a measure for the overlap of offshoring firms, we compute for \( c \leq \hat{c} \)

\[
O(c) = 1 - \left| 2 \frac{f_c(c) - kc}{f_c(c)} - 1 \right| = 1 - \left| 1 - 2 \frac{kc}{f_c(c)} \right|. \tag{17}
\]

Thereby, the overlap reaches a maximum value of one if 50 percent of firms with a certain cost level engage in offshoring. Substitution of \( f_c(c) \) from Lemma 1, we can compute

\[
O(c) = \begin{cases} 
1 - \frac{c^{-1}[(1/κ)^k - 1] - k/κ}{c^{-1}[(1/κ)^k - 1] - k/κ + 1} & \text{if } c \leq \kappa \hat{c} \\
1 - \frac{c^{-1}[(\hat{c}/c)^k - 1] - k/κ}{c^{-1}[(\hat{c}/c)^k - 1] - k/κ + 1} & \text{if } c \in (\kappa \hat{c}, \hat{c}]
\end{cases} \tag{18}
\]

As formally shown in the appendix, \( O(c) \) is hump-shaped, reaching a unique maximum of one at some \( c \in (0, \hat{c}) \). An economy-wide measure of the overlap can then be computed according to \( O = F_c(\hat{c})^{-1} \int_{0}^{\hat{c}} O(c) f_c(c) dc \). Considering Eq. (17) and \( f_c(c) \) from Lemma 1, we can compute

\[
O = \begin{cases} 
1 - \frac{1}{f_c(c) \int_{0}^{\hat{c}}} \left\{ \frac{c^{k-1} \left[ (\frac{1}{κ})^k - 1 \right] - \frac{k}{κ + 1} \left[ (\frac{1}{κ})^{k+1} - 1 \right] \} - kc \right\} dc & \text{if } c \leq \kappa \hat{c} \\
1 - \frac{1}{f_c(c) \int_{\kappa \hat{c}}} \left\{ \frac{\hat{c}^{k-1} \left[ (\hat{c}/κ)^k - 1 \right] - \frac{k}{κ + 1} \left[ (\hat{c}/κ)^{k+1} - 1 \right] \} - kc \right\} dc & \text{if } c \in (\kappa \hat{c}, \hat{c}]
\end{cases}. \tag{19}
\]

The impact of falling offshoring costs \( \tau \) and \( f \) on the overlap measure \( O \) is non-monotonic. If the respective costs are high, only few firms with high \( z \) make the investment \( f \) and the overlap is small. A decline in offshoring costs allows additional firms to make the \( f \)-investment and since for these newly offshoring firms the overlap is higher than for the incumbent ones, the economy-wide measure of overlap \( O \) increases. Things are different is offshoring costs are already low and hence a significant fraction of firms, including some with low \( z \), make the \( f \)-investment.

A further decline in offshoring costs now adds new offshoring firms for whom the overlap is relatively small and this lowers \( O \). Of course, there are additional effects at the intensive margin

\(^3\)For completeness, we can also determine the mass of firms. Substituting \( R = L + w^*L^* \) in Eq. (9) and accounting for (15), we can solve for \( M = (L + w^*L^*)/|\sigma f_e + \hat{c} f| \).
as newly offshoring firms are spread over a whole interval of \( c \). However, these additional effects do not alter the general picture of a non-monotonic relationship between offshoring costs and offshoring overlap.

3 Empirical application

We estimate the model based on three different data sources: firm information from the IAB establishment panel, worker-level data from the administrative employment records, and occupational task-content from the BIBB-BAuA 2006 data. Firm and worker data can be combined into a matched employer-employee data set, the so-called LIAB. Detailed information about the workers’ occupations allows us to construct different task-measures at the firm-level. We begin the empirical section with a description of the data and the main variables of interest, while the last subsection lays out the estimation strategy and results.

3.1 Data sources and preparation

Two variables are particularly relevant for our estimation: the share of offshoring firms in the sample and an empirical measure of the length of the firm task-interval \( z \). The former piece of information was collected in only three survey years of the IAB establishment panel (1999, 2001 and 2003), when employers were asked whether and where they purchased inputs from external sources in the previous business year. For this reason, besides restricting the sample to manufacturing firms, we also concentrate only on those three waves. Similarly to Moser et al. (2014), we define offshoring as the purchase of intermediates or other inputs from abroad in the previous business year. As for the length of the task interval, we construct it using the BIBB BIBB-BAuA 2006 "Survey of the Working Population on Qualification and Working Conditions in Germany" (see Rohrbach-Schmidt, 2009). In this survey, individuals are asked about the frequency with which they perform given tasks.\(^4\) For each of the 29 questions regarding the task-content of their job, respondents answer whether they perform that task “often”, “sometimes” or “never”. Since the unit of analysis in the BIBB data is the individual and not the occupation, it may well be the case that individuals in the same occupation provide slightly different answers about the content of their job. Thus, we have to apply some criterion according to which tasks

\(^{4}\)Several studies have already used the BIBB survey to measure the task-content of occupations, see for example Spitz-Oener (2006) and Becker et al. (2013).
can be straightforwardly assigned to occupations. Specifically, we link an occupation to a given task if at least 60 percent of the interviewees in that occupation declare to perform that task “often” or “sometimes”. In this way we are able to construct a dataset where the observational unit is an occupation, and for each one we can establish how many of the 29 tasks belong to it. We match the above dataset with the LIAB (IAB linked employer-employee) data, using the occupational classification as the key matching variable. This allows us to compute the number of unique tasks performed in every firm by simply counting the tasks attached to each occupation. For consistency with our theoretical model, we need a measure of the length of the task interval ranging between 0 and 1. We obtain that by simply dividing the number of tasks in each firm by the total number of tasks (i.e. 29). We will use this measure and its moments for our estimation. Our final sample is made up of 8330 firms, 8173 of which report valid information on their offshoring status. Table 1 summarizes the main characteristics the offshoring and task variables we have just described. The figures reported in the tables are weighted using inverse probability weights, so as to be representative of the whole population of German firms.

Table 1: Summary statistics on firm offshoring status and number of tasks

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshoring</td>
<td>0.31</td>
<td>0.00</td>
<td>0.46</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Nr. of tasks</td>
<td>12.00</td>
<td>12.00</td>
<td>4.45</td>
<td>1</td>
<td>26</td>
</tr>
<tr>
<td>Nr. of tasks/total nr. tasks</td>
<td>0.41</td>
<td>0.41</td>
<td>0.15</td>
<td>0.035</td>
<td>0.90</td>
</tr>
</tbody>
</table>


Table 2 relates the firm offshoring status to the number of tasks. The categories are constructed using the deciles of the distribution of both variables. For example, the first category in Table 2 denotes firms where up to 9 tasks are performed, because this is the first decile of the distribution of the number of tasks. The stylized facts presented in Table 2 indicate that (i) firms which perform more tasks are more likely to offshore the production of some of these tasks; and (ii) for a given length of the task interval only a subset of firms engages in offshoring, while this share is increasing in firm size, in accordance with our theoretical model.
Table 2: Number of tasks and offshoring status

<table>
<thead>
<tr>
<th>Nr. tasks</th>
<th>Offshoring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td>1-9</td>
<td>82.91</td>
</tr>
<tr>
<td>10-12</td>
<td>76.65</td>
</tr>
<tr>
<td>13-14</td>
<td>68.00</td>
</tr>
<tr>
<td>15-16</td>
<td>56.86</td>
</tr>
<tr>
<td>17</td>
<td>52.36</td>
</tr>
<tr>
<td>18</td>
<td>30.77</td>
</tr>
<tr>
<td>19-22</td>
<td>45.44</td>
</tr>
<tr>
<td>23</td>
<td>24.92</td>
</tr>
<tr>
<td>24</td>
<td>16.69</td>
</tr>
<tr>
<td>&gt; 24</td>
<td>11.58</td>
</tr>
<tr>
<td>Total</td>
<td>69.29</td>
</tr>
</tbody>
</table>

IAB establishment panel, manufacturing firms only. Descriptive statistics computed using inverse probability weights. Sample size: 8173 firms.

3.2 Estimation strategy

In our structural estimation, we use in particular information on domestic producers, because it is only these firms for which we can directly observe the number of tasks performed in the production process. Two key parameters of our model are $k$ and $\hat{c}$, and we can estimate these parameters by combining the following two equations of our model. The first one is the probability density function of $c$ for domestic producers

$$f_c^d(c) = \begin{cases} 
kc^k & \text{if } c \leq \hat{c} \\
kc^{k-1} & \text{if } c > \hat{c} 
\end{cases}$$

(20)

Whereas marginal production costs $c$ are not directly observable in the data, we can make use of the link $c = 1 - z$ from the model, and use observe values for the length of the task interval in order to infer the required information on $f_c^d(c)$. The second equation is the adding up condition
for the share of offshoring firms, $\chi$.

$$
\chi = 1 - \int_0^{\hat{c}} f_c(c) dc = 1 - \int_0^{\hat{c}} k c^{-1} dc - \int_{\hat{c}}^1 k c^{k-1} dc = \hat{c} \left[ 1 - \frac{k}{k + 1} \right]. \quad (21)
$$

Based on the data for $1 - z$ and $\chi$, we construct three model moments, i.e. the first and the second moments of the distribution of a firm’s length of the task interval and the share of offshoring firms $\chi$.\(^5\) In order to estimate $\hat{c}$ and $k$, we apply a minimum distance estimation procedure, which searches for a parameter constellation that minimizes the distance between the data and the model moments. The vector of distances $g(\hat{c}, k)$ between model and data moments is made up of the following three elements:

$$
g_1 = \chi(k, \hat{c}) - \chi_o = \hat{c} \left[ 1 - \frac{k}{k + 1} \right] - \chi_o, \quad (22)
$$

$$
g_2 = \tilde{c}(k, \hat{c}) - \tilde{c}_o = \frac{k}{k + 2} \hat{c}^{k+2} + \frac{k}{k + 1} - \frac{k}{k + 1} \hat{c}^{k+1} - \tilde{c}_o, \quad (23)
$$

$$
g_3 = v(k, \hat{c}) - v_o = \frac{k}{k + 3} \hat{c}^{k+3} + \frac{k}{k + 2} - \frac{k}{k + 2} \hat{c}^{k+2} - [\tilde{c}(k, \hat{c})]^2 - v_o \quad (24)
$$

Where $\chi_o$ and $\tilde{c}_o$ and $v_o$ are the targeted data moments observed in the data.\(^6\) The estimates of our structural parameters $\hat{c}$ and $k$ are as follows:

$$
\hat{c}, k = \arg\min g(\hat{c}, k)'Wg(\hat{c}, k), \quad (25)
$$

$$
s.t.
$$
$$
0 \leq \hat{c} \leq 1, \quad k > 1,
$$

where $W$ is a $3 \times 3$ weighting matrix. We adopt a diagonally weighted minimum distance approach, which requires that $W$ is diagonal and its diagonal elements are given by the variances of the data moments.

To estimate the elasticity of substitution, $\sigma$, we can apply Eq. (6) for domestic producers and compute

$$
\ln r^d(1 - z) = \ln r^d(1) + (1 - \sigma) \ln(1 - z). \quad (26)
$$

\(^5\) All data moments are computed using inverse probability weights.

\(^6\) The model moments $\tilde{c}$ and $v$ are computed as $\tilde{c} = \int_0^\hat{c} k(1 - z)(1 - z)^k + \int_\hat{c}^1 k(1 - z)(1 - z)^{k-1}$ and $v = E(x^2) - (E(x))^2 = \int_0^\hat{c} k(1 - z)^2(1 - z)^k + \int_\hat{c}^1 k(1 - z)^2(1 - z)^{k-1} - \hat{c}^2.$
To recover $\sigma$ and $r_1$ we make use of four moment conditions. The first two are the familiar necessary moment conditions for the identification of the parameters in (26) in an OLS context. Namely, in order for equation (26) to be estimated by OLS the error term has to be uncorrelated with the covariates and its expected value must be equal to zero:

$$\zeta_1 = E \left[ \ln r^d - \ln r^d_1 - (1 - \sigma) \ln (1 - z) \right] = 0,$$

$$\zeta_2 = E \left[ \ln r^d - \ln r^d_1 - (1 - \sigma) \ln (1 - z) \right] \ln (1 - z) = 0$$

Moreover, we exploit the time variation in our variables of interest, i.e. the length of the firm and firm revenue. Hence, we impose that the same moment conditions for identification hold for the data in first differences. This enables us to exploit the following additional two equations:

$$\zeta_3 = E \left[ \Delta \ln r^d - (1 - \sigma) \Delta \ln (1 - z) \right] = 0,$$

$$\zeta_4 = E \left[ \Delta \ln r^d - (1 - \sigma) \Delta \ln (1 - z) \right] \Delta \ln (1 - z) = 0$$

Where $\Delta$ denotes the first difference of the data. Our estimates for $\sigma$ and $r_1$ thus solve:

$$\sigma, r_1 = \arg \min \zeta(\sigma, r_1)'A\zeta(\sigma, r_1),$$

$$s.t. \quad 1 \leq \sigma \leq k + 1, \quad r_1 > 0,$$

where $A$ is a $4 \times 4$ diagonal weighting matrix constructed as explained above.

In a next step, we aim to compute $\kappa$. For this purpose, we first compute total revenues of domestic firms. This gives

$$R^d = M \int_0^1 r(c) f_c^d(c) dc = M \int_{\hat{c}}^1 r(c) k c^k dc + M \int_{\hat{c}}^1 r(c) k \hat{c}^{k-1} dc$$

$$= Mr^d(1) \frac{k}{k - \sigma + 2} \hat{c}^{k+2-\sigma} + Mr^d(1) \frac{k}{k - \sigma + 1} \left[ 1 + \hat{c}^{k+1-\sigma} \right]$$

$$= Mr^d(1) \left[ \frac{k}{k - \sigma + 2} \hat{c}^{k+2-\sigma} + \frac{k}{k - \sigma + 1} \left( 1 - \hat{c}^{k+1-\sigma} \right) \right].$$
Combining Eqs. (9) and (32), we can then compute

\[
\frac{R^d}{R} = \frac{1 - \hat{c}^{k+1-\sigma} (1 - \hat{c}^{k-\sigma+1})}{1 + \hat{c}^{k-\sigma+1} (1 - \hat{c}^{k-\sigma+1}) (\frac{\kappa^1-\sigma-1}{(1-\sigma)\ln\kappa} - 1)},
\]

(33)

We can use this equation to recover a value for \(\kappa\) using our estimates of \(\sigma, k, \hat{c}\). Furthermore, Eq. (32) allows us to compute \(r^d(1)\).

Finally, we apply Eq. (7) to compute \(f\) using the parameter estimates at hand. Thereby, we make use of \(\hat{c} = 1 - \hat{z}\). Furthermore, \(f_e\) can be computed from Eq. (15). Finally, we can compute \(\tau L/L^*\) by applying \(\Gamma_2(\kappa, \hat{c}) = 0\).

### 3.3 Estimation results

Table 3 gives an overview over all parameters estimated according the procedure outlined above. The upper panel reports the moments obtained for \(\hat{c}\) and \(k\). The results can be evaluated by the difference between model and target moments reported in the third line. The middle panel reports \(\sigma\) estimated based on the OLS moments. Taking all parameters together we are able to recover \(\kappa\) and the fixed costs as reported in the lower panel of Table 3.

Solving problem (25) yields a local minimum at \(k = 1.541, \hat{c} = 0.628\). The solution appears to be regular as measured by the gradient vector of the solver but the distance between the estimated model moments and the targeted moments is greater zero. The model precisely replicates the share of offshoring firms but it slightly deviates for the first moment of the distribution of \(1 - z\). The weighting matrix gives highest weight to the observable share of offshoring firms and lowest weight to the variance of \(1 - z\), which explains why the distance is largest for the second moments.
Table 3: Results of the benchmark parameters

<table>
<thead>
<tr>
<th>Estimated parameters: $\hat{c}$, $k$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Targeted moments: Share of non-offshoring firms, mean and variance of $c = (1 - z)$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$\hat{c}$</th>
<th>$k$</th>
<th>$\chi$</th>
<th>$\hat{c}$</th>
<th>var($c$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimates</td>
<td>0.628</td>
<td>1.541</td>
<td>0.303</td>
<td>0.504</td>
<td>0.138</td>
</tr>
<tr>
<td>Targets</td>
<td></td>
<td></td>
<td>0.307</td>
<td>0.555</td>
<td>0.016</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td></td>
<td>−0.004</td>
<td>−0.051</td>
<td>0.122</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimated parameters: $\sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Targeted moments: OLS moment conditions (27) and (28)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\sigma$</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.828</td>
</tr>
</tbody>
</table>

| Recovered parameters: $\kappa$, $f$, and $f_E$ |

<table>
<thead>
<tr>
<th>Parameters</th>
<th>$\kappa$</th>
<th>$f$</th>
<th>$f_E$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.098</td>
<td>3.744e$^{+05}$</td>
<td>1.0544e$^{+06}$</td>
</tr>
</tbody>
</table>

Notes: The first and second line in the first panel report the moments obtained from the model (computed using the minimum distance estimates) and the targets obtained from the data. $\chi$ denotes the share of offshoring firms, $\hat{c}$ denotes the first moment of the distribution of $1 - z$, and var($c$) denotes the second moment of the distribution of $1 - z$. The numbers in the third line report the difference between the moments obtained from the model and the moments obtained from the data. The second panel reports the estimate for $\sigma$. Based on the parameters reported in the first and second panel we compute $\kappa$, fixed costs $f$ and $f_E$. Results are reported in the third panel.

An estimate for $\sigma$ of 1.828 is at the lower bound of estimates from other studies. Therefore, we have run several robustness checks, using different methods to estimate $\sigma$, including OLS, random-, and fixed-effects regressions. The respective results are listed in Table 4 in the Appendix. Our preferred methods of moments approach used as benchmark has the advantage that we are able to take both the level and the changes into consideration when estimating $\sigma$, which significantly lowers the problem of an omitted variable bias relative to OLS. Moreover, we are able to impose the constraint that $\sigma - 1 < k$. The $\sigma$ reported as benchmark lies between the OLS and fixed-effects regression outcomes reported in the Appendix. Aside from the method of moments approach, the restriction dictated by the model is fulfilled in the fixed-effects regression.
only. Whereas the coefficient obtained from the fixed-effects regression is insignificant, a test reveals that $\sigma$ itself is significantly different from zero.

In a final step, we use the parameters and the estimates for $r^d(1)$ in order to recover the remaining parameters according to equations (33), (7), and (15). With $\kappa = 0.098$, the cost saving from offshoring is significant in our model. Fixed costs of offshoring $f = 555.659$ are higher than the fixed costs of market entry $f_e = 425.375$.

4 Conclusion
5 Appendix

5.1 Proof of Lemma 1

Let us define $b(z) = 1 - z$. Then, the probability of $b \leq \tilde{b}$, $P_b(b \leq \tilde{b})$ equals the probability of $z \geq 1 - \tilde{b}$, $P_z(z \geq 1 - \tilde{b})$. Accounting for

$$P_z(z \geq 1 - \tilde{b}) = 1 - P_z(z \leq 1 - \tilde{b}) = 1 - \int_0^{1 - \tilde{b}} f_z(z)dz,$$

we can compute $P_b(b \leq \tilde{b}) = 1 - \hat{b}^k$. The cumulative distribution function of $b$ is therefore given by $F_b(b) = \hat{b}^k$. Since $c = b$ if $z \leq \hat{c}$ and thus $c \geq \hat{c}$, the third segment of the productivity density function of $c$ is given by $f_c(c) = kc^{k-1}$.

To determine the probability density function of $c$ for interval $c \leq \hat{c}$, we can first note that the probability for $1 - \hat{b} \leq z \leq 1 - \tilde{b}$ is given by $P_z(1 - \hat{b} \leq 1 - \tilde{b}) = k \int_{1-\tilde{b}}^{1-\hat{b}} (1 - z)^{k-1}dz$ and disentangling non-offshoring firms (superscript $d$) from offshoring firms (superscript $o$), we can write

$$P_z(1 - \hat{b} \leq z \leq 1 - \tilde{b}) = k \int_{1-\tilde{b}}^{1-\hat{b}} (1 - z)^{k-1}dz + k \int_{1-\tilde{b}}^{1-\hat{b}} z(1 - z)^{k-1}dz.$$  \hspace{1cm} (35)

Solving the integrals establishes

$$P^d_z(1 - \tilde{b} \leq z \leq 1 - \hat{b}) = -\frac{k}{k+1} \left[ \hat{b}^{k+1} - \hat{b}^{k+1} \right]$$ \hspace{1cm} (36)

$$P^o_z(1 - \hat{b} \leq z \leq 1 - \tilde{b}) = -\frac{1}{1+k} \left[ \hat{b}^k (1+k(1-\tilde{b})) - \hat{b}^k (1+k(1-\tilde{b})) \right]$$ \hspace{1cm} (37)

Summing up and adding $P_z(z \leq 1 - \tilde{b}) = 1 - \hat{b}^k$, we can compute the probability of $z \leq (1 - \tilde{b})$:

$$P_z(z \leq 1 - \tilde{b}) = 1 - \frac{k}{k+1} \hat{b}^{k+1} - \frac{1}{k+1} \hat{b}^k \left[ 1+k(1-\tilde{b}) \right] = \frac{1}{k+1} \left( 1 - \hat{b}^k \right).$$ \hspace{1cm} (38)

In view of $P_b(b \leq \tilde{b}) = 1 - P_z(z \leq 1 - \tilde{b})$, we can express the cumulative distribution function of $b$ as $F_b(b) = F^d_b(b) + F^o_b(b)$, with $F^d_b(b) = [k/(k+1)]\hat{b}^{k+1}$ and $F^o_b = \hat{b}^k - [k/(k+1)]\hat{b}^{k+1}$ in the relevant interval. This establishes the probability density function $f_b(b) = f^d_b(b) + f^o_b(b)$, with $f^d_b(b) \equiv k\hat{b}^k$ and $f^o_b(b) \equiv k\hat{b}^{k-1}(1-\tilde{b})$, respectively. For purely domestic producers, we have
\(c = b\), and can thus write \(f_c^b(c) = k e^b\). For offshoring firms, things are different, because \(\kappa < 1\) establishes \(c = b n^s < b\). Let us define \(a \equiv \kappa^s\). We can compute \(s = \ln a / \ln \kappa\), and hence can write \(P_a(a \leq \bar{a}) = P_s(s \geq s(\bar{a})) = 1 - P_s(s \leq s(\bar{a}))\). Accounting for \(P_a(a \leq \bar{a}) = 1 - \int_0^{s(\bar{a})} ds\) allows us to compute \(P_a(a \leq \bar{a}) = 1 - \ln \bar{a} / \ln \kappa\). The probability density function of \(a\) is then given by \(f_a(a) = -1/(a \ln \kappa)\).

![Figure 4: Iso-c lines in \((b,a)\)-space](image)

We now have all necessary ingredients and can compute the probability density function of \(c\) for those firms drawing \(s\) from the unit interval according to

\[
f_c^a(c) = \int_{b \in B} f_b^2(b) f_a \left( \frac{c}{b} \right) \left| \frac{1}{b} \right| db = -\frac{1}{c \ln \kappa} \int_{b \in B} k b^{k-1} (1 - b) db, \quad (39)
\]

where \(B\) is the set of feasible \(b\)’s. To determine the explicit bounds of the integral, we can look at Figure 4. There, we see that \(b\) varies over the interval \([c, c/\kappa]\) if \(c < \kappa \hat{b}\), whereas \(b\) varies over the interval \([c, \hat{b}]\) if \(c \geq \kappa \hat{b}\). Let us first consider parameter domain \(c < \kappa \hat{b}\). In this case, we have

\[
f_c^{a1}(c) = -\frac{k}{c \ln \kappa} \int_c^{c/\kappa} \left( b^{k-1} - b^k \right) db
\]

20
\[ -\frac{1}{\ln \kappa} \left\{ c^{k-1} \left[ \left( \frac{1}{\kappa} \right)^k - 1 \right] - \frac{k\hat{c}^k}{k+1} \left[ \left( \frac{1}{\kappa} \right)^{k+1} - 1 \right] \right\}. \] (40)

In contrast, if \( c \geq \kappa \hat{b} \), we obtain

\[ f_{c_2}^d(c) = -\frac{k}{c \ln \kappa} \int_{c}^{\hat{b}} \left( b^{k-1} - \hat{c}^k \right) db \]
\[ = -\frac{1}{\ln \kappa} \left\{ c^{k-1} \left[ \left( \frac{\hat{b}}{c} \right)^k - 1 \right] - \frac{k\hat{c}^k}{k+1} \left[ \left( \frac{\hat{b}}{c} \right)^{k+1} - 1 \right] \right\}. \] (41)

Replacing \( \hat{b} \) by \( \hat{c} \), and summing up \( f_{c_2}^d(c) \) and \( f_{c_1}(c) \) for the two parameter domains gives the first and the second segment of the probability density function in Lemma 1. This completes the proof. \( QED \)

5.2 Derivation of Eq. (9)

Accounting for \( r(c)/r(1) = c^{1-\sigma} \), aggregate revenues can be written as

\[ R = Mr \int_0^1 r(c)f(c)dc = Mr \int_0^1 c^{1-\sigma} f(c)dc. \]

We have to compute the integrals separately for the three segments of \( f(c) \).

For the first segment, we can compute

\[ R_1 = Mr(1) \int_{0}^{\kappa \hat{c}} c^{1-\sigma} f(c)dc \]
\[ = Mr(1) \int_{0}^{\kappa \hat{c}} c^{1-\sigma} \left\{ k^c - \frac{1}{\ln \kappa} \left\{ c^{k-1} \left[ \left( \frac{1}{\kappa} \right)^k - 1 \right] - \frac{k\hat{c}^k}{k+1} \left[ \left( \frac{1}{\kappa} \right)^{k+1} - 1 \right] \right\} \right\} dc. \] (42)

Solving for the integral, gives

\[ R_1 = Mr(1) \left\{ \frac{k}{k - \sigma + 2} (\kappa \hat{c})^{k-\sigma+2} \left[ \frac{\kappa^{-k-1}}{\ln \kappa} \frac{1}{k - \sigma + 1} (\kappa \hat{c})^{k-\sigma+1} \right] \right. \]
\[ \left. + \frac{\kappa^{-(k+1)}}{\ln \kappa} \frac{1}{k + 1} \frac{1}{k - \sigma + 2} (\kappa \hat{c})^{k-\sigma+2} \right\}. \] (43)

Thereby, \( k > \sigma - 1 \) has been assumed to obtain a finite value of \( R(1) \). For the second segment, we can write

\[ R_2 = Mr(1) \int_{\kappa \hat{c}}^{1} c^{1-\sigma} f(c)dc \]
\[= M r(1) \int_{\hat{c}}^{\hat{c}} c^{1-\sigma} \left\{ k e^k - \frac{1}{\ln \kappa} \left\{ e^{k-1} \left[ \left( \frac{\hat{c}}{c} \right)^k - 1 \right] - \frac{k e^k}{k+1} \left[ \left( \frac{\hat{c}}{c} \right)^{k+1} - 1 \right] \right\} \right\} dc. \] (44)

Solving for the integral establishes

\[R_2 = M r(1) \left\{ \left( 1 - \kappa^{k-\sigma+2} \right) \frac{k^{k-\sigma+2}}{k-\sigma+2} - \frac{1 - \kappa^{1-\sigma} \hat{c}^{k-\sigma+1}}{\ln[\kappa]} \frac{\hat{c}^{k-\sigma+1}}{\sigma - 1} + \frac{1 - \kappa^{k-\sigma+1} \hat{c}^{k-\sigma+1}}{\ln[\kappa]} \frac{\hat{c}^{k-\sigma+1}}{k - \sigma + 1} \right. \]
\[\left. + \frac{\kappa^{1-\sigma} - 1}{\ln[\kappa]} \frac{k^{k-\sigma+2}}{(\sigma - 1)(k+1)} - \frac{1 - \kappa^{k-\sigma+2} \hat{c}^{k-\sigma+2}}{\ln[\kappa]} \frac{k^{k-\sigma+2}}{(k+1)(k - \sigma + 2)} \right\}. \] (45)

Finally, for the first segment, we obtain

\[R_1 = M r(1) \int_{\hat{c}}^{1} c^{1-\sigma} f(c) dc = M r(1) \int_{\hat{c}}^{1} c^{1-\sigma} k c^{k-1} dc \]
\[= M r(1) \left\{ k \frac{k}{k - \sigma + 1} - \frac{k}{k - \sigma + 1} \right\}. \] (46)

Total revenues in Eq. (9) can then be computed by adding up \(R_1\), \(R_2\) and \(R_3\). This completes the proof. \textit{QED}

### 5.3 Properties of the offshoring indifference condition

Let us define

\[\alpha(\kappa) = \frac{\kappa^{1-\sigma} - 1}{(1 - \sigma) \ln \kappa} - 1, \] (47)

with \(\alpha(0) = \lim_{\kappa \to 0} \kappa^{1-\sigma} - 1 = \infty\), \(\alpha(1) = \lim_{\kappa \to 1} \kappa^{1-\sigma} - 1 = 0\), and

\[\alpha'(\kappa) = \frac{\hat{\alpha}(\kappa)}{(1 - \sigma)[\ln \kappa]^2 \kappa^{\sigma}}, \quad \hat{\alpha}(\kappa) \equiv (1 - \sigma) \ln \kappa + \kappa^{\sigma-1} - 1. \] (48)

Accounting for \(\lim_{\kappa \to 0} \hat{\alpha}(\kappa) = \infty\), \(\hat{\alpha}(1) = 0\), and \(\hat{\alpha}'(\kappa) = [(1 - \sigma)/\kappa](\kappa^{\sigma-1} - 1) < 0\), it follows that \(\hat{\alpha}(\kappa) > 0\) holds for all possible \(\kappa < 1\). Considering \(\sigma > 1\), we get \(\alpha'(\kappa) < 0\). This allows us to compute

\[\frac{\partial \Gamma_1(\cdot)}{\partial \kappa} = \left\{ \frac{\hat{b} k}{1 - \hat{b}} \left[ \frac{\sigma - 1}{k - \sigma + 1} - \frac{\sigma - 2}{k - \sigma + 2} \right] - \frac{f e}{f} \right\} \alpha'(\kappa). \] (49)
and since the bracket expression must be negative if \( \Gamma(\cdot) = 0 \), we can safely conclude that 
\[
\partial \Gamma_1(\cdot) / \partial \kappa > 0.
\]

Differentiation \( \Gamma_1(\cdot) \) with respect to \( \hat{b} \) yields

\[
\frac{\partial \Gamma_1(\cdot)}{\partial \hat{c}} = \frac{(\sigma - 1)c^{\sigma - 2}(1 - \hat{c}) + \hat{c}^{\sigma - 1} k}{(1 - \hat{c})^2} - \frac{\hat{c}k}{k - \sigma + 1} + \frac{\hat{c}^{k-1}}{1 - \hat{c}} \left[ \frac{\sigma - 1}{k - \sigma + 1} - \hat{c} \frac{\sigma - 2}{k - \sigma + 2} \right] \alpha(\kappa)
\]

In view of \( \hat{c} \leq 1 \), the first two expressions on the right-hand side of this derivative must be positive. Furthermore, it follows from \( k^2 > (\sigma - 2)(k - \sigma + 1) \) that \( k(\sigma - 1)/(k - \sigma + 1) > (k + 1)(\sigma - 2)/(k - \sigma + 2) \) and this is sufficient for the third term to be positive. This implies 
\[
\partial \Gamma_1(\cdot) / \partial \hat{b} > 0.\]

Putting together, we have shown

\[
\frac{d\hat{c}}{d\kappa|_{\Gamma_1(\cdot) = 0}} = -\frac{\partial \Gamma_1 / \partial \kappa}{\partial \Gamma_1 / \partial \hat{c}} < 0. \tag{50}
\]

As noted in the main text, \( \Gamma_1(\cdot) = 0 \) gives \( \hat{c} \) as an implicit function of \( \kappa \). If \( \kappa \) goes to one, \( \alpha(\kappa) \) becomes zero, and hence \( \hat{c} \) must fall to zero in order to restore \( \Gamma_1(\cdot) = 0 \). In contrast, if \( \kappa \) falls to zero, \( \alpha \) goes to infinity, and hence \( \hat{c} \) must increase to \( \hat{c}_1 \) in order to restore \( \Gamma_1(\cdot) = 0 \). This completes the formal discussion on the properties of \( OC \). \textit{QED}

### 5.4 Properties of the labor market constraint

To see whether LC establishes a positive or negative link between \( \kappa \) and \( \hat{c} \), we can first look at the properties of \( \beta(\kappa) \equiv (1 - \sigma) \ln k/(k^{1-\sigma} - 1) \). Differentiating \( \beta(\kappa) \) gives

\[
\beta'(\kappa) = -\frac{(\sigma - 1)\dot{\beta}(\kappa)}{\kappa(\kappa^{\sigma - 1} - 1)^2}; \quad \ddot{\beta}(\kappa) \equiv \kappa^{1-\sigma}[1 - (1 - \sigma) \ln k] - 1. \tag{51}
\]

Noting that \( \lim_{\kappa \to 0} \dot{\beta}(\kappa) = -\infty, \ddot{\beta}(1) = 0 \), and \( \beta'(\kappa) = -(\sigma - 1)^2 \kappa^{-\sigma} \ln k > 0 \), it is immediate that \( \beta'(\kappa) > 0 \) holds for all possible \( \kappa \). Thereby, \( \beta(\kappa) \) increases from a minimum value 0 if \( \kappa = 0 \) to a maximum value of one at \( \kappa = 1 \). The positive sign of \( \beta'(\kappa) > 0 \) establishes \( \partial \Gamma_2(\cdot) / \partial \kappa > 0 \).

In a second step, we can look at the properties of \( \gamma(\hat{c}) = \hat{c}^{k-\sigma} + 1/[1 + (1 - \hat{c})(k - \sigma + 1)] \). Differentiating \( \gamma(\hat{c}) \) gives \( \gamma'(\hat{c}) = (k - \sigma + 2)(k - \sigma + 1)\hat{c}^{k-\sigma}(1 - \hat{c}) > 0 \). Hence, \( \gamma(\hat{c}) \) increases from a minimum value of zero at \( \hat{c} = 0 \) to a maximum value of 1 at \( \hat{c} = 1 \). The positive sign of
\( \gamma'(\hat{c}) \) establishes \( \partial \Gamma_2(\cdot)/\partial \hat{c} < 0 \). Applying the implicit function theorem to \( \Gamma_2(\cdot) = 0 \) therefore establishes a positive link between \( \kappa \) and \( \hat{c} \):

\[
\frac{d\kappa}{d\hat{c}} \bigg|_{\Gamma_2(\cdot) = 0} = -\frac{\partial \Gamma_2/\partial \hat{c}}{\partial \Gamma_2/\partial \kappa} > 0.
\]  

(52)

\( \Gamma_2(\cdot) = 0 \) determines \( \kappa \) as implicit function of \( \hat{c} \). If \( \hat{c} = 0 \), \( \gamma(\hat{c}) \) falls to zero, and hence \( \kappa \) must fall to zero as well in order to establish \( \beta = 0 \) and to restore \( \Gamma_2(\cdot) = 0 \). Furthermore, if \( \mu < 0 \) (with \( \mu \) defined in the main text), \( \kappa \) is smaller than one for any \( \hat{c} \in [0,1] \). If \( \hat{c} \) goes to one, \( \gamma \) also reaches a value of 1, and in this case \( \kappa \) must increase to \( \kappa_2 \) in order to restore \( \Gamma_2(\cdot) = 0 \).

Things are different if \( \mu < 0 \). In this case, \( \kappa \) reaches a maximum value of one if \( \hat{c} = \hat{c}_2 \). This completes the formal discussion on the properties of \( LC \). QED

5.5 The impact of \( \tau \) and \( f \) on \( W \)

For a given global income, \( L + w^*L^* \), \( W = P^{-1} \) increases in \( \hat{c} \), and hence it declines in \( \tau \) and \( f \).

Furthermore, from \( \Gamma_2(\cdot) = 0 \), we can infer

\[
w^*L^* = L \left\{ \frac{\sigma + 1}{\sigma - 1} + \frac{2\sigma}{\sigma - 1} \beta(\kappa) \left[ \frac{k - \sigma + 2}{\gamma(\hat{c})} - 1 \right] \right\}^{-1}.
\]  

(53)

Accounting for \( \beta'(\kappa) > 0 \) and \( \gamma'(\hat{b}) > 0 \) from above and considering \( d\kappa/d\tau > 0 \), \( d\hat{c}/d\tau < 0 \) from Figure 3, we can safely conclude that \( d(w^*L^*)/d\tau < 0 \). Furthermore, considering \( w^*L^* = \kappa L^*/\tau \) and accounting for \( d\kappa/df < 0 \) from Figure 3, it follows that \( d(w^*L^*)/df < 0 \). Putting together, we can safely conclude that \( W = P^{-1} \) decreases in \( f \) and \( \tau \). This completes the proof. QED

5.6 Proof of a hump-shaped pattern of \( O(c) \)

We can define

\[
a(c) \equiv \begin{cases} 
\left\{ \frac{k}{\kappa} \right\}^k - \frac{k}{k+1} \left[ \left( \frac{k}{\kappa} \right)^{k+1} - 1 \right] & \text{if } c \leq \kappa \hat{c} \\
\left\{ \frac{k}{\hat{c}} \right\}^k - \frac{k}{k+1} \left[ \left( \frac{k}{\hat{c}} \right)^{k+1} - 1 \right] & \text{if } c \in (\kappa \hat{c}, \hat{c}] 
\end{cases}
\]  

(54)

with \( a'(c) < 0 \). Since in view of Eqs. (17) and (18), we can write

\[
1 - 2\frac{kc^k}{f_c(c)} = \frac{a(c) + k \ln \kappa}{a(c) - k \ln \kappa}.
\]  

(55)
it follows that $1 - 2k\frac{c^k}{f_c(c)}$ decreases in $c$ from a maximum level of one at $c = 0$ to a minimum level of $-1$ at $c = \hat{c}$. This proves the hump-shaped pattern of $O(c)$. QED

References


Revenue distribution

The probability density function (pdf) of marginal production costs $c$ is given by

$$f_c(c) = \begin{cases} \frac{k}{\ln \kappa} \left( c^{k-1} \left( \frac{1}{c} \right)^k - 1 \right) - \frac{k}{k+1} \left( \frac{1}{c} \right)^{k+1} - 1 \right) & \text{if } c \leq \kappa \hat{c} \\ \frac{k}{\ln \kappa} \left( c^{k-1} \left( \frac{1}{c} \right)^k - 1 \right) - \frac{k}{k+1} \left( \frac{1}{c} \right)^{k+1} - 1 \right) & \text{if } c \in (\kappa \hat{c}, \hat{c}] \\ \frac{k}{\ln \kappa} c^{k-1} & \text{if } c > \hat{c} \end{cases}$$

(56)

with $\hat{c} \equiv 1 - \hat{\xi}$.

Using $r(c)/r(1) = c^{1-\sigma}$ we have $r(c) = r(1)c^{1-\sigma}$ and $c(r) = [r(c)/r(1)]^{1/(1-\sigma)}$.

$$P_r(r \leq \hat{r}) = P_r(c \geq \hat{c}(r)) = 1 - P_r(c(r) \leq \hat{c}(r))$$

(57)

Suppose $\hat{c}(r) > \hat{c}(r)$. Then the cdf is given by

$$P^1_r = 1 - \int_{\hat{c}(r)}^{\hat{c}(r)} k c^{k-1} \, dc = 1 - \left[ c \right]_{\hat{c}(r)}^{\hat{c}(r)} = 1 - \left[ \frac{r(\hat{c})}{r(1)} \right]^{\frac{1}{1-\sigma}} + \left[ \frac{r(\hat{c})}{r(1)} \right]^{\frac{1}{1-\sigma}}$$

(58)

and thus, the pdf of revenues in the region $r(c) < r(\hat{c})$ are given by

$$f^1_r(r) = \frac{1}{\sigma - 1} \left[ \frac{r(c)}{r(1)} \right]^{\frac{k}{\sigma - 1}} - \frac{1}{r(1)} \quad \text{if } r(c) < r(\hat{c})$$

(59)

Now suppose $\kappa \hat{c} < \hat{c} < \hat{c}$. The cdf is therefore given by

$$P^2_r = 1 - \int_{\kappa \hat{c}(r)}^{\hat{c}(r)} k c^{k-1} \, dc = 1 - \left[ c \right]_{\kappa \hat{c}(r)}^{\hat{c}(r)} = 1 - \left[ \frac{r(\hat{c})}{r(1)} \right]^{\frac{k}{k+1}} - \left[ \frac{r(\hat{c})}{r(1)} \right]^{\frac{k}{k+1}}$$

(60)

$$= 1 - \left[ \frac{k}{k+1} \left[ \frac{r(\hat{c})}{r(1)} \right]^{\frac{k}{k+1}} \right] - \int_{\kappa \hat{c}(r)}^{\hat{c}(r)} k c^{k-1} \, dc$$

(61)

$$= 1 - \frac{k}{k+1} \left[ \frac{r(\hat{c})}{r(1)} \right]^{\frac{k}{k+1}} + \frac{1}{k+1} \ln \kappa \left[ \frac{r(\hat{c})}{r(1)} \right]^{\frac{k}{k+1}} + \ln \kappa \left[ \frac{r(\hat{c})}{r(1)} \right]^{\frac{k}{k+1}} + \frac{k}{k+1} \ln \kappa \ln \left[ \frac{r(\hat{c})}{r(1)} \right]^{\frac{k}{k+1}}$$

(62)
Thus, the pdf of revenues in the region \( r(\hat{c}) < r(c) < r(\kappa \hat{c}) \) are given by \( dP^0_r/d\bar{r} \)

\[
f^2_r(r) = \frac{k}{\sigma - 1} \left[ \frac{r(c)}{r(1)} \right]^{\frac{k+1}{\sigma}} \frac{1}{r(1)} + \frac{1}{\ln \kappa} \frac{1}{1 - \sigma} \left[ \frac{r(\hat{c})}{r(1)} \right]^{\frac{1}{\sigma}} \frac{1}{r(c)} + \frac{1}{\ln \kappa} \frac{1}{\sigma - 1} \left[ \frac{r(c)}{r(1)} \right]^{\frac{k+1}{\sigma - 1}} \frac{1}{r(1)} \]

\[
- \frac{k}{k + 1} \frac{1}{\ln \kappa} \left[ \frac{r(\hat{c})}{r(1)} \right]^{\frac{k+1}{\sigma}} \frac{1}{1 - \sigma} \left[ \frac{1}{r(c)} \right]^{\frac{1}{\sigma}} - \frac{k}{k + 1} \frac{1}{\ln \kappa} \right] + \]

\[
= \left[ \frac{r(c)}{r(1)} \right]^{\frac{k+1}{\sigma}} \frac{1}{r(1)} \sigma - 1 \left\{ k + \frac{1}{\ln \kappa} \left[ \frac{r(\hat{c})}{r(1)} \right]^{\frac{1}{\sigma}} - \frac{k}{k + 1} \frac{1}{\ln \kappa} \right\}
\]

Finally, suppose \( \hat{c} < \kappa \hat{c} \). Then we get

\[
P^3_r = 1 - \int_0^{\hat{c}(r)} k c^k - \frac{1}{\ln \kappa} \left\{ c^{k+1} \left[ \left( \frac{1}{\kappa} \right)^k - 1 \right] - k c^k \left[ \left( \frac{1}{\kappa} \right)^{k+1} - 1 \right] \right\} dc - \int_{r(\kappa \hat{c})}^{\hat{c}(r)} ... dc - \int_{1}^{\hat{c}(r)} k c^{k-1} dc
\]

\[
= 1 - \left[ \frac{k}{k + 1} c^{k+1} - \frac{\kappa^{-k} - 1}{\ln \kappa} \frac{1}{k} c^k + \frac{k}{k + 1} \frac{\kappa^{-(k+1)} - 1}{\ln \kappa} \frac{1}{k + 1} c^{k+1} \right]_0 - ...
\]

\[
= 1 - \frac{k}{k + 1} \left[ \frac{r(c)}{r(1)} \right]^{\frac{k+1}{\sigma}} + \frac{\kappa^{-k} - 1}{\ln \kappa} \frac{1}{k} \left[ \frac{r(\hat{c})}{r(1)} \right]^{\frac{1}{\sigma}} - \frac{k}{k + 1} \frac{\kappa^{-(k+1)} - 1}{\ln \kappa} \frac{1}{k + 1} \left[ \frac{r(c)}{r(1)} \right]^{\frac{k+1}{\sigma}} - ...
\]

Thus, the pdf of revenues in the region \( r(c) > r(\kappa \hat{c}) \) are given by

\[
f^3_r(r) = \frac{k}{\sigma - 1} \left[ \frac{r(c)}{r(1)} \right]^{\frac{k+1}{\sigma}} \frac{1}{r(1)} - \frac{\kappa^{-k} - 1}{\ln \kappa} \frac{1}{\sigma - 1} \left[ \frac{r(c)}{r(1)} \right]^{\frac{k+1}{\sigma - 1}} \frac{1}{r(1)}
\]

\[
+ \frac{k}{\sigma - 1} \frac{1}{k + 1} \frac{\kappa^{-(k+1)} - 1}{\ln \kappa} \frac{1}{r(1)} \left[ \frac{r(c)}{r(1)} \right]^{\frac{k+1}{\sigma}} - \frac{1}{\sigma - 1} \frac{1}{r(1)} \left[ \frac{r(c)}{r(1)} \right]^{\frac{k+1}{\sigma}} \frac{k}{k + 1} \frac{\kappa^{-(k+1)} - 1}{\ln \kappa}
\]

\[
= \frac{1}{\sigma - 1} \frac{1}{r(1)} \left[ \frac{r(c)}{r(1)} \right]^{\frac{k+1}{\sigma}} \left\{ k - \frac{\kappa^{-k} - 1}{\ln \kappa} \left[ \frac{r(c)}{r(1)} \right]^{\frac{1}{\sigma}} + \frac{k}{k + 1} \frac{\kappa^{-(k+1)} - 1}{\ln \kappa} \right\}
\]
Combining we get the revenue distribution

\[
f_r(r) = \begin{cases} 
\frac{1}{\sigma - 1} \frac{1}{r(1)} \left[ \frac{r(c)}{r(1)} \right]^{k + \sigma - 1} \left\{ k - \frac{\kappa - 1}{\ln \kappa} \frac{r(c)}{r(1)} \right\}^{\frac{1}{\sigma - 1}} + \frac{k}{k + 1} \frac{\kappa^{-(k+1)} - 1}{\ln \kappa} & \text{if } r(c) \geq r(\kappa \hat{c}) \\
\frac{r(c)}{r(1)} \left( \frac{k}{1 - \sigma} \right) \left\{ 1 - \frac{k}{k + 1} \left[ \frac{r(c)}{r(1)} \right]^{\frac{1}{1 - \sigma}} \right\} + \frac{1}{\ln \kappa} \frac{1}{1 - \sigma} \frac{1}{r(c)} \left[ \frac{r(c)}{r(1)} \right]^{\frac{k}{1 - \sigma}} \left\{ k + \frac{1}{\ln \kappa} \frac{r(c)}{r(1)} \right\}^{\frac{1}{\sigma - 1}} - \frac{k}{k + 1} \frac{1}{\ln \kappa} & \text{if } r(c) \in (r(\hat{c}), r(\kappa \hat{c}]) \\
\left( \frac{k}{\sigma - 1} \right) \left[ \frac{r(c)}{r(1)} \right]^{\frac{k + \sigma - 1}{1 - \sigma}} \frac{1}{r(1)} & \text{if } r(c) < r(\hat{c}) 
\end{cases}
\]

with \( \frac{r(\hat{c})}{r(1)} = \hat{c}^{1 - \sigma} = (1 - \hat{z})^{1 - \sigma} \).
### Tables

**Table 4: Alternative estimation of σ**

<table>
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<th>Estimated Model:</th>
<th>OLS</th>
<th>FE</th>
<th>RE</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \ln r^d(1-z) = \ln r^d(1) + (1-\sigma) \ln(1-z) )</td>
<td>( \ln c = \ln(1-z) )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimator</td>
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<td>( -0.319 )</td>
<td>( -2.687^{***} )</td>
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<td>(0.077)</td>
<td>(0.340)</td>
<td>(0.096)</td>
</tr>
<tr>
<td>( \sigma )</td>
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<td>1.318***</td>
<td>3.687***</td>
</tr>
<tr>
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<td>420114</td>
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<tr>
<td>R-squared</td>
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<td>0.965</td>
<td></td>
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</table>

Notes: Robust standard errors in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%. The sample is restricted to non-offshoring firms and we apply probability weights to the regression. The elasticity of substitution is computed as \( \sigma = -(b-1) \), where \( b \) is the coefficient reported in the upper panel of the table. \( r^d(1) \) is equal to the estimated constant of the regression in levels \( r^d(1) = \exp C \), where \( C \) is the estimated constant.
.2 Figures

Figure 5: Share of offshoring firms within different revenue categories

Texiles

Share of firms

Firm revenue (categories)

Non−offshoring Offshoring

Figure 5: Share of offshoring firms within different revenue categories
Figure 6: Share of offshoring firms within different revenue categories

Figure 7: Share of offshoring firms within different revenue categories
Figure 8: Share of offshoring firms within different revenue categories