The Impact of Foreign Production Activities:
Firm-Level Evidence from Taiwan’s Multinationals

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Abstract
A prominent phenomenon characterizing the increasing level of globalization is that many firms move some or all of their production activities abroad for different reasons. One of the main concerns is that the domestic industries will be hollowed out, and only the most skilled labor will survive. On the other hand, some people argue that firms’ foreign production activities may be a complement to domestic production and even raise the domestic employment level. Must foreign production activities result in job-exportation? Using firm-level data from Taiwan, this paper finds that the outcome depends on the location of the firms’ foreign affiliates and the proportion of the foreign output. More specifically, increasing the proportion of foreign output has a negative impact on domestic manufacturing labor, while engaging in foreign activities in developing countries has a positive impact on R&D labor in the home country. These findings suggest that there exists a geographical fragmentation of R&D and production activities.

Keywords: Multinational; Outward FDI; Job-exportation

J.E.L. Classification numbers: F14; F16; F23

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1 Introduction

A prominent phenomenon characterizing the increasing level of globalization is that many firms move some or even all of their production activities abroad for different reasons. One of the main concerns is whether the domestic industries will be hollowed out when the production activities are moved abroad. Many people in more developed countries are worrying about losing their jobs because the cheaper foreign labor will prompt firms to relocate more production activities outside their home countries.

For instance, in Germany, workers fear that cheaper labor in the new eastern EU member countries will attract companies to invest there and shut down domestic plants. In the United States, giant companies such as General Electric, IBM, and United Technologies have recently taken many of their operations overseas. It seems that those multinationals are exporting jobs rather than goods (BusinessWeek, 2006; 2008). Besides the anecdotal evidence, earlier empirical studies have found that the outward foreign direct investment (FDI) can have negative impacts on domestic output and employment.\(^1\)

However, more recent studies also find that the effect of outward FDI can be quite mixed. For example, if the foreign affiliate uses more inputs (the inputs could be services or intermediate goods, etc.) produced by the parent firm, there could be a positive impact on some specific type of domestic employment. At the same time, the impact can vary across different labor categories, industries, and countries.\(^2\)

Recent research on the foreign activities of U.S. multinationals has explicitly taken into account the role of trade in intermediate inputs between a firm and its foreign affiliate (Feenstra and Hanson, 2001; Hanson, Mataloni, and Slaughter, 2001; 2005). These studies find that trade in intermediate inputs is also one of the important factors that determines the factor demands and prices.

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\(^1\) See Singh (1977), Frank and Freeman (1978), and Glickman and Woodward (1989).

Besides the evidence from a large economy, like the U.S., what happens in a small economy elsewhere? Hsieh and Woo (2005) find that outsourcing from Hong Kong to China has positive and negative impact on the demand of skilled and non-skilled labor in Hong Kong, respectively. In contrast, this paper takes Taiwan as an example and studies the impact of the multinationals’ foreign production activities on domestic employment.

The case of Taiwan is of interest for the following reasons. First, Taiwan is an active participant in foreign production activities. As shown in Table 1-1, when considering the Asian newly industrialized or developing economies, Taiwan has been among the top-ranking countries in terms of both the outward FDI flow and stock since the 1990s, which is comparable to Singapore and just behind Hong Kong (UNCTAD, 2007). Second, although there have been many studies investigating relevant issues in Taiwan, perhaps due to the lack of data until recent years, very few of them consider the role of trade in intermediate inputs between a firm and its foreign affiliate.

When studying the impact of outward FDI, one often compares some characteristics or performances of firms with outward FDI to those without it. This paper, on the other hand, will just focus on multinationals (those firms who have already undertaken outward FDI) and answer the following question: will the multinationals’ foreign production activities inevitably result in job-exportation?

This paper finds that the outcome depends on the location of the firms’ foreign affiliates and the proportion of the foreign output. More specifically, while increasing the proportion of foreign output has a negative impact on the domestic manufacturing labor, the impact on those employees who engage in R&D activities is not (statistically) significant. On the other hand, while engaging in foreign production activities in developing countries has a positive impact on those employees in the domestic R&D sector, the impact on domestic manufacturing labor is not significant.

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3 In fact, part of the outward FDI by Hong Kong is either Taiwanese investment or Chinese capital from China, or round-tripping. See Hsiao and Hsiao (2004) and UNCTAD (2001).
4 The only exception is Sung (2007), who uses Taiwan’s data for 2001 to study firms’ foreign production activities on domestic manufacturing and R&D employees.
The empirical evidence suggests that, first, in recent years, the geographical fragmentation of R&D and production activities is a prevailing phenomenon for those Taiwanese multinationals with affiliates in developing countries. Those multinationals often hire more skilled labor domestically to provide some services like R&D as input for the foreign affiliates. Second, the insignificant coefficient for trade in intermediates could suggest that in Taiwan, the positive impact on the domestic skilled labor might come from providing intangible input like R&D related services rather than from producing tangible intermediates for the foreign affiliates. The paper is organized as follows: Section 2 discusses the implications of the theory of multinational firms; Section 3 reviews the relevant research on Taiwan; Section 4, 5 and 6 present the data, model and the results, respectively; and Section 7 concludes the paper.
### Table 1-1 Outward FDI Flow and Stock in Asia

Unit: Millions of the U.S. dollars

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Sources: Annex Table B.1 and B.2 in UNCTAD (2007).
2 Implications of the Theory of Multinational Firms

Multinationals are often broken down into two categories: the horizontal multinationals which produce similar goods or services in different countries, and the vertical multinationals which geographically fragment the production stages. Firms choose to be horizontal multinationals to expand their businesses when the benefit of doing so (avoiding the trade cost) outweighs the corresponding cost (establishing and running the foreign affiliates). Alternatively, the vertical multinationals try to internationally utilize the cheaper factors used intensively for some stages of production, provided that the cost of doing so (for example, trade cost, administrative expenses, etc.) does not dominate.\(^5\)

It is quite plausible that for both types of multinationals, the foreign affiliates use the headquarters services as input provided by the parent firm, which means that horizontal multinationals could also fragment their production processes. Markusen et al. (1996) and Markusen (1997) present the knowledge capital model, which combines both the horizontal and vertical motives for firms’ FDI activities.\(^6\) It predicts that horizontal firms will be the dominant type of multinationals if the countries are similar in size and relative endowments and the transport costs are high. In contrast, vertical multinationals headquartered in the home country will prevail if the home country is small and skilled-labor-abundant and the trade cost is not too high.

Many Taiwanese firms have had their products produced abroad for the past decade, especially in other developing countries like China. According to the knowledge capital model, one would predict that these multinationals would become the vertical firms that keep the skilled-labor-intensive jobs (like R&D) in Taiwan while gradually shifting the relatively labor-intensive production processes

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\(^5\) Earlier theoretical frameworks for the vertical and horizontal multinationals can be found in Helpman (1984) and Markusen (1984), respectively.

\(^6\) The three major assumptions for the model are: first, the location of knowledge-based assets may be fragmented from production, and the cost of supplying the services of the assets to the foreign affiliates is low. Second, knowledge-based assets are skilled labor intensive relative to final production. Third, knowledge-based services can be utilized simultaneously by multiple production facilities, i.e., they have a (partial) joint input characteristic. See Markusen et al. (1996), Markusen (1997), and Carr (2001).
(like assembly) to China since the trade costs between Taiwan and China are not overly high since 1990. Furthermore, many Taiwanese firms sell the products produced by their affiliates in China not just back to Taiwan, but also to the third countries. Thus, while skilled labor could benefit from the expansion of the multinationals’ businesses, the non-skilled labor would be substituted for by the cheaper foreign labor.

The rising proportions of Taiwanese multinational’s foreign outputs are confirmed in Table 2-1. For example, in 1999, the share of the export produced domestically for electronic parts and components is 90.86%, while that for computer communication and video and radio electronic products is 76.41%. However, in 2007, these shares drop to merely 56.33% and 16.41%, respectively.

Theoretically, the rising proportion of foreign output could be accomplished without sacrificing the level of domestic output. If this is the case, the domestic manufacturing employment might not suffer. On the other hand, if firms do keep their R&D activities within the home country while increasing the proportion of the foreign output, those employees in R&D sectors would not be hurt.

This means that for the case in Taiwan, if the vertical multinationals become more and more prevalent, according to the prediction of the knowledge capital model, empirically, the rising proportion of foreign output would have a negative impact on domestic manufacturing employees. However, it should not be the case for employment in the domestic R&D sector.

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7 Taiwanese government opened up the import from China in 1988, and opened up the export and FDI to China in 1990. Although before 2002, the trade and FDI between Taiwan and China are still indirect (For example, officially, the destination of the export cannot be China), which are often through Hong-Kong, the trade costs between Taiwan and China are not prohibitively high at all since the sum of the distance from Taiwan to Hong-Kong and from Hong-Kong to China is still relatively short compared to other trade partners, and there are no abnormally high duties involved in these activities. Note that even after the direct trade and FDI are allowed since 2002 (i.e., officially, the source of import and destination of export could be China), nevertheless, most trade between Taiwan and China is yet through Hong-Kong since Taiwan and China are still negotiating the shipping navigation issues. See the details in MOEA (2005; 2008).
Table 2-1 Share of the Export Produced Domestically

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<td>95.57%</td>
<td>95.51%</td>
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<td>92.07%</td>
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<td>72.00%</td>
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<tr>
<td>S05</td>
<td>78.81%</td>
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<td>63.56%</td>
<td>59.41%</td>
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<td>98.20%</td>
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Definition:

S01: Food, Beverage, and Tobacco Manufacturing
S02: Textile Mills, Apparel Clothing Accessories & Other Textile Product Manufacturing
S03: Leather Fur & Applied Product Manufacturing
S04: Wood & Bamboo Products Manufacturing
S05: Furniture & Fixtures Manufacturing
S06: Chemical Material and Chemical Product Manufacturing
S07: Rubber Products and Plastic Products Manufacturing
S08: Non-Metallic Mineral Products Manufacturing
S09: Basic Metal Industries and Fabricated Metal Products Manufacturing
S10: Machinery & Equipment Manufacturing & Repairing
S11: Computer Communication & Video & Radio Electronic Products
S12: Electronic Parts & Components
S13: Electrical Machinery Supplies & Equipment Manufacturing & Repairing
S14: Transport Equipment Manufacturing and Repairing
S15: Precision Optical Medical Equipment Watches & Clocks Manufacturing
S16: Other Industrial Products Manufacturing

Source: Taiwan Economic Statistical Databank System developed by Taiwan Economic Data Center (TEDC).
3 Relevant Research and Industry-level Information of Taiwan

Earlier research on issues regarding the activities of Taiwanese multinationals often classified the outward FDI into expansionary and defensive categories.\(^8\) The former and the latter could result in horizontal and vertical firms, respectively. Using Taiwan’s data from 1986 to 1994, Chen and Ku (2000) find that either types of outward FDI (expansionary and defensive) are neutral to domestic employment. They argue that the trend of manufacturing employment decline during that period seems to be driven by the structural change toward the capital-intensive industries.

To determine the types of outward FDI, the aforementioned research compares the wage rate in the host country and that in the home country (or some other benchmark level). If the former is higher than the latter, the outward FDI is regarded as expansionary, or it is classified as defensive if the wage rate in the host country is lower than that in the home country.\(^9\) However, recently, many Taiwanese firms investing in China, where the wage rate is much lower than that in Taiwan, are not just seeking cheaper labor, but are also accessing the market there or meeting the customers’ needs, etc. (MOEA, 2002; 2003; 2004). Thus, it would be dubious for these investments to be classified as defensive simply because the wage rate in the host country is lower.

Another issue is that the firms’ motivations to invest in low-wage countries are often mixed.\(^10\) Classifying each firm’s outward FDI to be one of the two mutually exclusive parts might oversimplify the whole story. For example, Hanson, Mataloni, and Slaughter (2001) find the fact that U.S. multinationals were shifting activities towards low-income countries is consistent with vertical FDI where factor-cost differences matter, and also with horizontal FDI since many of these host countries were characterized by growing markets.

Recently, the survey on Taiwanese multinationals’ foreign activities conducted by the Ministry of

\(^8\) For example, see Chen and Chen (1995).
\(^9\) In Taiwan, the practice is appropriate before the early nineties because most outward FDIs to low-wage countries then were to seek cheap labor (Chun, 1996).
\(^10\) Chen and Ku (2000) argue that when investing in low-wage countries, the cost-saving motivation often dominates, which is just the case mentioned in the previous footnote.
Economic Affairs (MOEA) of Taiwan asks firms about their motives behind investing abroad. This allows the researchers to consider the coexistence of expansionary and defensive motives. Based on this database for 2001, Hsu and Liu (2002) find that the defensive and expansionary motives do have negative and positive impacts on a firm’s domestic production scale, respectively, while Sung (2007) finds that when firms move the production activities to China, there will be a negative impact on employees in the manufacturing sectors.

MOEA’s survey provides the firm-level evidence for researchers. However, until now, the relevant studies based on MOEA’s database are all but cross-sectional. In contrast, to get more extensive information, this paper uses the panel data analysis. Although the MOEA’s database covers 2000 to 2006, in this paper, only three years (from 2001 to 2003) will be selected due to the data availability issues on some variables.

To study the impact of firms’ foreign production activities on domestic employment, this paper first analyzes the industry-level data from the Taiwan Economic Data Center (TEDC) before investigating the firm-level data from MOEA. The manufacturing sector from 1999 to 2007 is classified into 24 industries. The available data include the number of skilled labor, non-skilled labor, output, and the foreign production ratio for each industry.

Table 3-1 (Table 3-2) demonstrates both the fixed effect and random effect regressions of non-skilled (skilled) labor on foreign production ratio and other independent variables. The preliminary results show that increasing the foreign production ratio has negative (positive) impact on domestic non-skilled (skilled) labor, which suggest that the non-skilled (skilled) labor intensive jobs are more likely to be carried out abroad (domestically).

11 The database from TEDC is named the Taiwan Economic Statistical Databank System, which is also known as the AREMOS Economic Statistical Databanks.
12 The skilled labor includes supervisor, professional, and technician, while the non-skilled labor is just the complement of skilled labor. The raw data for calculating the foreign production ratios (or domestic production ratios shown in Table 2-1) are based on commodities rather than industries. Since the author has to combine some industries when mapping the commodities into the industries, there are only 16 rather than 24 industries in Table 2-1. Finally, when mapping the 16 industries back to the 24 industries, there are no data available for: 1) Pulp Paper and Paper Products Manufacturing; and 2) Printing and Related Support Activities. In these two cases, the foreign production ratio in terms of the average industrial level will be used.
### Table 3-1 The Impact on Manufacturing Employees (Industry-level Linear Regression)

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</tr>
<tr>
<td>R² (within)</td>
<td>0.5126</td>
<td>0.5126</td>
<td></td>
</tr>
<tr>
<td>R² (between)</td>
<td>0.6916</td>
<td>0.4844</td>
<td></td>
</tr>
<tr>
<td>R² (overall)</td>
<td>0.6875</td>
<td>0.4645</td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-2221.1768</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LR test for $\beta=0$ (p-value)</td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

***(*): Significant at 1% (5%; 10%) level. The output is in terms of 2001 price.

13 These industries include: 1) Metal; 2) Machinery; and 3) Transportation equipment.
14 These industries include: 1) Computer; 2) Electronic parts and components; and 3) Electrical machinery.
15 These industries include: 1) Food; 2) Tobacco; 3) Textile; 4) Apparel; 5) Wood and bamboo product; 6) Furniture and fixture; and 7) Non-metallic mineral products manufacturing.

### Table 3-2 The Impact on R&D Employees (Industry-level Linear Regression)

<table>
<thead>
<tr>
<th>Dependent variable: Number of skilled labor</th>
<th>Random effect (GLS)</th>
<th>Random effect (MLE)</th>
<th>Fixed effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>22.01 ***</td>
<td>22.71 ***</td>
<td>21.76 ***</td>
</tr>
<tr>
<td>Industry dummy-Met</td>
<td>25033.14 **</td>
<td>24723.38 **</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(12251.92)</td>
<td>(11737.19)</td>
<td></td>
</tr>
<tr>
<td>Industry dummy-Inf</td>
<td>58677.60 ***</td>
<td>58102.46 ***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(13665.02)</td>
<td>(13181.63)</td>
<td></td>
</tr>
<tr>
<td>Industry dummy-Liv</td>
<td>1432.25</td>
<td>1428.68</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(10197.38)</td>
<td>(9745.50)</td>
<td></td>
</tr>
<tr>
<td>Foreign production ratio</td>
<td>14430.22 ***</td>
<td>13604.39 ***</td>
<td>14716.47 ***</td>
</tr>
<tr>
<td></td>
<td>(2437.95)</td>
<td>(4638.82)</td>
<td>(2429.41)</td>
</tr>
<tr>
<td>R² (within)</td>
<td>0.7280</td>
<td>0.7280</td>
<td></td>
</tr>
<tr>
<td>R² (between)</td>
<td>0.7034</td>
<td>0.7116</td>
<td></td>
</tr>
<tr>
<td>R² (overall)</td>
<td>0.7039</td>
<td>0.6597</td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-2167.0904</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LR test for $\beta=0$ (p-value)</td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


4 Data

This paper uses the data from the survey on Taiwanese multinationals in the manufacturing industry conducted by MOEA. In the survey, each firm was asked to provide the information including: 1) the employment status (shortage, balance, or surplus) of domestic manufacturing and R&D sectors; 2) the relationship between parent firm and foreign affiliate; 3) total sales; 4) total assets; 5) domestic and foreign investments; 6) domestic and foreign R&D expenditures; 7) the location of its main foreign affiliate; 8) the proportion of foreign output; 9) the motivation to engage in foreign production; and 10) the global employees (sum of domestic and foreign employees), etc.

There are, however, some deficiencies in MOEA’s survey. For instance, although there is information about each firm’s global employees, it cannot be broken down into: 1) domestic and foreign employees; and 2) skilled and non-skilled labor. Thus, this paper has to use the shortages in domestic manufacturing and R&D employees as dependent variables. Nevertheless, these two variables are only available from 2001 to 2003. On the other hand, the exact proportion of foreign output for each firm is only available from 2003 to 2006, and the information about whether there is trade in intermediates between the parent firm and its foreign affiliate is not available from 2003 onward. Finally, each firm’s total assets are not available for 2003.

As a result, this paper only uses the data from 2001 to 2003. To approximate each firm’s proportion of foreign output for 2001 and 2002, this paper uses the industry-level data from TEDC’s database (See Table 2-1).16 Finally, this paper assumes that the status of intra-firm trade for each multinational in 2003 is the same as that in 2002, and each firm’s total assets for 2003 is estimated by

---

16 For example, to inference each firm’s proportion of foreign output in 2002 (denoted by fpr_2), this paper uses the following formula: \( fpr_2 = \frac{FPR[2]}{FPR[3]} \times fpr_3 \). Here, \( fpr_3 \), which is available from MOEA’s survey, is the firm’s proportion of foreign output in 2003. \( FPR[2] \) (\( FPR[3] \)) is the industrial level share of the export produced abroad in 2002 (2003), which comes from the database of Taiwan Economic Journal and is just the complement information shown in Table 2-1. In some rare cases, if the survey classifies the firm into a different industry in 2002 compared to that of 2003, then \( FPR[2] \) will be used as a proxy to \( fpr_2 \).
summing its net assets (after depreciation) of 2002 and its investment of 2003.\footnote{17}

Other data issues are, first, in the survey, firms that do respond to the questionnaire in a particular year but fail to do that later might still survive. This means that treating them as exiting the market at some time is inappropriate. Second, even for those firms who do respond to the survey annually, some of them might not provide the complete information, and it causes the issue of missing values.

To simplify things, this paper will just extract a balanced panel without missing values in the dependent and independent variables from the MOEA’s survey. From 2001 to 2003, there will be 633 (583) multinationals with manufacturing (R&D) employees each year. The above treatment, however, means that this paper cannot account for the sample selection bias, if any. The output from these multinationals in the sample constitutes about a quarter of the total industrial output every year, as shown in Table 4-1.

### Table 4-1 Share of the Sum of the Sample Output

<table>
<thead>
<tr>
<th>Year</th>
<th>Total sales (NT$ 1 billion)</th>
<th>[C] = [A]/[B]</th>
<th>Number of firms [D]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample [A]</td>
<td>Manufacturing total [B]</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>2417.09 (2309.07)</td>
<td>9903.36</td>
<td>24.41% (23.32%)</td>
</tr>
<tr>
<td>2002</td>
<td>2209.60 (2124.83)</td>
<td>9726.34</td>
<td>22.72% (21.85%)</td>
</tr>
<tr>
<td>2003</td>
<td>2734.68 (2626.91)</td>
<td>9585.81</td>
<td>28.53% (27.40%)</td>
</tr>
</tbody>
</table>

Figures with (without) parenthesis are from sample for firms with manufacturing (R&D) sector (Except [B]).

\footnote{17 Each year, only the depreciation rate of the whole manufacturing industry (4.55% in 2002) is available. The calculation is based on: 1) the macroeconomic database (depreciation), and 2) the National Wealth Statistic (capital stock) from the Directorate General of Budget Accounting and Statistics of Taiwan.}
5 Model

Since the employment status is classified into shortage, balance, or surplus, there are two different ways of analyzing the dependent variable \( y_{it} \). Let the unobserved latent variable \( y_{it}' \) be firm i’s shortage in manufacturing (or R&D) employees in year t. When \( y_{it}' > 0 \), it has an incentive to hire more employee. Otherwise, it might want to lay off some employees (or at least not to hire more employees). Thus, one can apply the binary choice model with the following correspondence:

\[
\begin{align*}
    y_{it} &= 1 \text{ (shortage) if and only if } y_{it}' = \alpha_i + x_{it}'\beta + u_{it} > 0 \\
    y_{it} &= 0 \text{ (balance or surplus) if and only if } y_{it}' = \alpha_i + x_{it}'\beta + u_{it} \leq 0
\end{align*}
\]

The drawback of (1) is that it cannot distinguish the employment status “surplus” from “balance”. As a result, one can set up the following three-alternative ordered model:

\[
\begin{align*}
    y_{it} &= 1 \text{ if and only if } \gamma_0 < y_{it}' = \alpha_i + x_{it}'\beta + u_{it} \leq \gamma_1 \\
    y_{it} &= 0 \text{ if and only if } \gamma_{-1} < y_{it}' = \alpha_i + x_{it}'\beta + u_{it} \leq \gamma_0 \\
    y_{it} &= -1 \text{ if and only if } \gamma_{-2} < y_{it}' = \alpha_i + x_{it}'\beta + u_{it} \leq \gamma_{-1}
\end{align*}
\]

In (2), \( \gamma_{-2} = -\infty \) and \( \gamma_1 = \infty \). Also, note that \( \gamma_{-1} < \gamma_0 \), which means that there is a range for \( y_{it}' \) which corresponds to the status “balance”. However, this characteristic could be the drawback of applying the ordered model in this case.\(^{18}\) Since the binary choice model and the three-alternative ordered model have their own advantage and limitation, in this paper, both of them will be adopted.

In both models, \( x_{it} \) is the \( K \times 1 \) vector of independent variables, while \( \alpha_i \) represents the unobserved individual specific effect. Based on section II, the independent variables should include

---

\(^{18}\) This is because usually, the balance (equilibrium) status of employment level for a firm corresponds to a single number.
at least the proportion of foreign output and the location of the foreign affiliate. (In order to utilize the cheaper foreign labor, the multinationals might want to assemble their products in developing countries.) Luckily, they are both part of the available information. Other independent variables include: 1) total sales; 2) sum of domestic and foreign employees; 3) total assets; 4) domestic and foreign investments; 5) domestic and foreign R&D expenses; 6) dummy variables for industries; 7) motivation to be a multinational; and 8) whether the foreign affiliate uses the intermediates provided by the parent firm (and vice versa).

For a discrete choice model with panel data, pooled estimation fails to account for the individual specific effect. In a nonlinear model, this can lead to inconsistent estimates of $\beta$. To solve this issue, the fixed effect and random effect models are proposed. However, not every fixed effect model can have a consistent estimator due to the incidental parameters problem (Neyman and Scott, 1948). For instance, there is no consistent estimator for a fixed effect probit model (Hsiao, 1986; Wooldridge, 2002).

Similarly, most fixed effect logit models are inconsistent. One exception is within the class of binary choice logit models. Anderson (1973) and Chamberlain (1980) suggest the conditional likelihood approach and apply it on the binary choice logit model. They demonstrate that the corresponding estimator is consistent. However, since this approach excludes those observations with $y_{it} = 1$ or $y_{it} = 0$ all the time, it is less efficient.

Alternatively, in a random effect model, $a_i$ is treated as a random disturbance term under the specified distribution. Since the logit model inherits more restriction from the multivariate logistic distribution, the probit model is more popular when considering the random effect model (Maddala, 1987). The random effect probit model assumes $a_i \sim \text{IN}(0, \sigma_a^2)$, $u_{it} \sim \text{IN}(0, \sigma_u^2)$, and both of them are mutually independent as well as independent of $x_{it}$. By conditioning on the individual specific

---

19 See p.787 in Cameron and Trivedi (2005).
20 Since discarding those observations could result in greater standard errors and thus insignificant estimates especially when the sample size is not that large (Allison, 2008).
21 See Heckman and Willis (1976).
random disturbance term $\alpha$, the joint density function can be decomposed, which simplifies the joint probability and makes the log-likelihood function only involve a single integration over $\alpha$. Thus, the corresponding estimator becomes computationally feasible.22

In short, since: 1) for the binary choice model, when applying the fixed effect setting in MOEA’s data, the conditional likelihood approach will discard about two-thirds of the observations, which is a great loss of efficiency; 2) for the three-alternative ordered model, the random effect probit model is the most appropriate setting as explained above; and 3) for both models, this paper has included the dummy variables for different industries to control for (part of) the firm specific effect. These dummies are basically time-invariant.23 Thus, this paper will adopt the random effect probit estimation to estimate both models (1) and (2).

22 See Butler and Moffitt (1982).
23 Almost for every firm, its foreign affiliate belongs to the same industry all the time.
6 Empirical Results

To find whether the multinationals’ foreign production activities result in job-exportation, this section uses the MOEA’s survey from 2001 to 2003 to investigate the impacts on domestic manufacturing and R&D employees, respectively. The definitions of the variables are shown in Table 6-1. Table 6-2 demonstrates the summary statistics and shows that: 1) the proportion of foreign output is increasing; 2) most Taiwanese multinationals engage in foreign production activities in developing countries; 3) multinationals tend to report more shortages in R&D employment; 4) multinationals in the sample are large firms in terms of the number of global employees.24

Let us consider the impact on domestic manufacturing employees first. This paper considers the 633 multinationals which have domestic manufacturing sectors from 2001 to 2003. Thus, there will be 1899 observations in the balanced panel. In Table 6-3, M-1 through M-4 are results from the random effect probit estimations with binary choice models, while M-5 through M-8 apply the random effect probit estimations with three-alternative ordered models.

The main findings are as follows. First, the coefficient of the variable f_liv is not significant, which implies that the multinationals in “light industries” are less likely to report shortages in manufacturing employees than those in “heavy industries” or high-tech sectors.25 This might implicitly suggest that the situation of job-exportation is more likely to happen to multinationals in light industries.

Second, the coefficient of the variable f_fpr is negative and significant (regardless of using the binary choice models M-1 through M-4 or the three-alternative ordered models M-5 through M-8), which suggests that increasing the proportion of foreign output, as expected, has negative impact on domestic manufacturing employees. This confirms the common worry about job-exportation in the

---

24 Following MOEA’s definition, large enterprises are those with 200 or more employees.
25 In this paper, light industries include the following industries: 1) Food; 2) Tobacco; 3) Textile; 4) Apparel; 5) Wood and bamboo product; 6) Furniture and fixture; and 7) Non-metallic mineral products manufacturing. Heavy industries include: 1) Metal; 2) Machinery; and 3) Transportation equipment industries. High-tech sectors include: 1) Computer; 2) Electronic parts and components; and 3) Electrical machinery industries.
manufacturing sectors.

Third, the coefficient of the variable m_cos is negative and significant, which verifies that the multinationals’ cost-saving motives to produce abroad have negative impact on domestic manufacturing employees.

Fourth, when the multinationals increase the domestic investment, it could have a positive impact on domestic manufacturing employees, as suggested by the positive and significant coefficient of the variable i_dom in models M-1 through M-4. (In models M-5 through M-8, this coefficient is positive but not significant.)

Fifth, to control for the size of the multinational, this paper uses either total sales (models M-1; M-2; M-5; M-6) or total assets (models M-3; M-4; M-7; M-8). The corresponding coefficients are all negative. However, the coefficients for f_cap (total assets) are significant only in M-3 and M-4. This might suggest weak evidence that in Taiwan, larger multinationals are less likely to hire new manufacturing employees.

Finally, the coefficients for the variables v_tpi and v_fpi are both insignificant, which suggests that whether there is trade in intermediates does not significantly affect the domestic employment in manufacturing sectors.

Let us turn to the impact on R&D employees. There are 1749 observations coming from the 3-year (2001-2003) balanced panel for the 583 multinationals which have domestic R&D sectors. The results are shown in Table 6-4.\(^{26}\) The main findings are as follows. First, those multinationals in heavy industries or high-tech sectors are more likely to report shortages in R&D employees, as suggested by the positive and significant coefficients for f_met and f_inf, respectively. This is similar to the case for manufacturing employees.

Second, in Taiwan, smaller multinationals might be more active in R&D activities, as suggested by the negative and significant coefficients for f_sal in models R-1 and R-2 and f_cap in models R-3 and

---

\(^{26}\) Similarly, R-1 through R-4 are results from the random effect probit estimations with binary choice models, while R-5 through R-8 apply the random effect probit estimations with three-alternative ordered models.
R-4. (In models R-5 through R-8, the coefficients are negative but not significant.)

Third, engaging in foreign production activities in developing countries has positive impact on domestic R&D employment, as suggested by the positive and significant coefficient for the variable f_ing in models R-1 through R-4 (In models R-5 through R-8, the coefficients are positive but their p-values are between 0.15 and 0.20). This could suggest some evidence that multinationals tend to fragment the production activities such that the more skilled labor intensive activities, like R&D, are kept in Taiwan, while other production activities are gradually moved abroad.

Fourth, a somewhat striking result would be the positive and significant coefficient for the variable r_for in models R-1 and R-2 (In models R-3 through R-8 the corresponding coefficients are positive but not significant), which suggests weak evidence that higher foreign R&D expenditures correspond to higher domestic R&D employment. A possible scenario could be that for those multinationals engaging in more R&D activities abroad, the R&D services provided by the parent firm in Taiwan still play important roles.

Fifth, a higher level of domestic investment would be beneficial to domestic R&D employment, as suggested by the positive and significant coefficient for i_dom in models R-1 through R-4. (In models R-5 through R-8 the corresponding coefficients are positive but not significant.)

Sixth, the coefficients for i_fdi are all negative. Although they are not significant in models R-1 through R-4, they are significant in models R-5 through R-8. This might suggest that for those firms which engage in higher level of outward FDI, they are less likely to have shortages in R&D employees.27

Finally, as in the previous case, whether there is trade in intermediates does not significantly affect the domestic employment in R&D sectors. This could suggest that in Taiwan, the positive impact on the domestic skilled labor might come from providing intangible input like R&D related services

---

27 In this paper, a firm’s outward FDI has been limited to that with a destination which is the same as where its main foreign affiliate is. This suggests that the positive impact on R&D employees when firms engage in foreign production activities could be offset when firms decide to engage in more outward FDI. Note that in models R-5 through R-8, the coefficients of i_fdi are very close to (although still smaller than) those of f_ing in terms of absolute values.
rather than from producing tangible intermediates for the foreign affiliates. In fact, in both types of regression (impact on manufacturing and R&D employment), excluding $v_{tpi}$ and $v_{fpi}$ as independent variables yields an even better fit to the model.\(^{28}\)

The empirical evidence above shows a sign of geographical fragmentation in multinationals’ production and R&D activities. That is, increasing the proportion of foreign output has negative impact on domestic manufacturing employees, while engaging foreign production activities in developing countries could have positive impact on domestic R&D employees. These findings conform to the implication from the knowledge capital model, which predicts that for a small and skilled-labor abundant country (in a relative sense) like Taiwan, the vertical multinationals headquartering at home and producing abroad would be the prevalent type of organization provided that the trade cost is not too high.

\(^{28}\) Compared the model M-1(M-3; M-5; M-7) with M-2(M-4; M-6; M-8), and the model R-1(R-3; R-5; R-7) with R-2(R-4; R-6; R-8), the latter has better fit in terms of Akaike’s information criterion and Schwartz criterion, as shown in Table 6-3 and 6-4, respectively.
Table 6-1 Definition of the Variables

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>d_man</td>
<td>= 1 if the firm has a shortage in domestic manufacturing employees; = 0 otherwise.</td>
<td>= 1 if the firm has a shortage in domestic manufacturing employees; = 0 if the firm’s domestic manufacturing employment status is balance; = 1 if the firm has a shortage in domestic manufacturing employees.</td>
</tr>
<tr>
<td>d_rea</td>
<td>= 1 if the firm has a shortage in domestic R&amp;D employees; = 0 otherwise.</td>
<td>= 1 if the firm has a shortage in domestic R&amp;D employees; = 0 if the firm’s domestic R&amp;D employment status is balance; = 1 if the firm has a shortage in domestic R&amp;D employees.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>f_sal</td>
<td>Total sales</td>
</tr>
<tr>
<td>f_tas</td>
<td>Total assets</td>
</tr>
<tr>
<td>f_met</td>
<td>= 1 if the firm belongs to Metal, Machinery, or Transportation Equipment industry = 0 otherwise</td>
</tr>
<tr>
<td>f_inf</td>
<td>= 1 if the firm belongs to Computer, Electronic Parts and Components, and Electrical Machinery industry = 0 otherwise</td>
</tr>
<tr>
<td>f_liv</td>
<td>= 1 if the firm belongs to Food, Tobacco, Textile, Apparel, wood and bamboo product, Furniture and Fixture, Non-Metallic Mineral Products Manufacturing industry = 0 otherwise</td>
</tr>
<tr>
<td>f_ing</td>
<td>= 1 if the foreign affiliate locates at a developing country (China, Indonesia, Malaysia, Philippine, Thailand, Vietnam, and Other South Asia countries) = 0 otherwise</td>
</tr>
<tr>
<td>f_fpr</td>
<td>Proportion of foreign output (Foreign output / Total output)</td>
</tr>
<tr>
<td>m_exp</td>
<td>= 1 if the firm has the market expansion motivation to engage in foreign production = 0 otherwise</td>
</tr>
<tr>
<td>m_cos</td>
<td>= 1 if the firm has the cost-saving motivation to engage in foreign production = 0 otherwise</td>
</tr>
<tr>
<td>i_fdi</td>
<td>Amount of foreign investment</td>
</tr>
<tr>
<td>i_dom</td>
<td>Amount of domestic investment</td>
</tr>
<tr>
<td>r_for</td>
<td>R&amp;D expenditures by the foreign affiliate</td>
</tr>
<tr>
<td>r_dom</td>
<td>R&amp;D expenditures in the home country</td>
</tr>
<tr>
<td>v_tpi</td>
<td>= 1 if the foreign affiliate uses intermediates produced by parent firm in Taiwan = 0 otherwise</td>
</tr>
<tr>
<td>v_fpi</td>
<td>= 1 if the parent firm uses intermediates produced by foreign affiliate = 0 otherwise</td>
</tr>
<tr>
<td>γ&lt;sub&gt;−1&lt;/sub&gt;</td>
<td>Lower bound of the interval for γ&lt;sub&gt;IT&lt;/sub&gt; which corresponds to the “balance” status</td>
</tr>
<tr>
<td>γ&lt;sub&gt;0&lt;/sub&gt;</td>
<td>Upper bound of the interval for γ&lt;sub&gt;IT&lt;/sub&gt; which corresponds to the “balance” status</td>
</tr>
</tbody>
</table>
Table 6-2 Summary Statistics

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Observations per year</strong></td>
<td>583</td>
<td>633</td>
<td></td>
</tr>
<tr>
<td><strong>d_man</strong></td>
<td>(s = 1; b or s = 0)(^{29})</td>
<td>0.1011 (0.3017)</td>
<td>0.0821 (0.2748)</td>
</tr>
<tr>
<td></td>
<td>(s = 1; b = 0; s = -1)</td>
<td>-0.0095 (0.4604)</td>
<td>-0.0063 (0.4133)</td>
</tr>
<tr>
<td><strong>f_tas</strong></td>
<td>(billion NT$)</td>
<td>5.8680 (29.6363)</td>
<td>4.9881 (19.5879)</td>
</tr>
<tr>
<td><strong>f_sal</strong></td>
<td>(billion NT$)</td>
<td>3.8185 (26.2139)</td>
<td>3.4907 (14.4536)</td>
</tr>
<tr>
<td><strong>f_met</strong></td>
<td>(yes = 1; no = 0)</td>
<td>0.2812 (0.4499)</td>
<td>0.2812 (0.4499)</td>
</tr>
<tr>
<td><strong>f_inf</strong></td>
<td>(yes = 1; no = 0)</td>
<td>0.3491 (0.4771)</td>
<td>0.3491 (0.4771)</td>
</tr>
<tr>
<td><strong>f_liv</strong></td>
<td>(yes = 1; no = 0)</td>
<td>0.1769 (0.3819)</td>
<td>0.1769 (0.3819)</td>
</tr>
<tr>
<td><strong>f_ing</strong></td>
<td>(yes = 1; no = 0)</td>
<td>0.7646 (0.4246)</td>
<td>0.7930 (0.4054)</td>
</tr>
<tr>
<td><strong>f_fpr</strong></td>
<td>(proportion)</td>
<td>0.3085 (0.3579)</td>
<td>0.3131 (0.3585)</td>
</tr>
<tr>
<td><strong>m_exp</strong></td>
<td>(yes = 1; no = 0)</td>
<td>0.6919 (0.4621)</td>
<td>0.6667 (0.4718)</td>
</tr>
<tr>
<td><strong>m_cos</strong></td>
<td>(yes = 1; no = 0)</td>
<td>0.6177 (0.4863)</td>
<td>0.6082 (0.4885)</td>
</tr>
<tr>
<td><strong>i_fdi</strong></td>
<td>(billion NT$)</td>
<td>0.1672 (1.1118)</td>
<td>0.1733 (1.0930)</td>
</tr>
<tr>
<td><strong>i_dom</strong></td>
<td>(billion NT$)</td>
<td>0.9806 (6.8858)</td>
<td>0.7285 (3.9498)</td>
</tr>
<tr>
<td><strong>r_for</strong></td>
<td>(billion NT$)</td>
<td>0.0055 (0.0320)</td>
<td>0.0067 (0.0382)</td>
</tr>
<tr>
<td><strong>r_dom</strong></td>
<td>(billion NT$)</td>
<td>0.0639 (0.4298)</td>
<td>0.0684 (0.4237)</td>
</tr>
<tr>
<td><strong>v_tpi</strong></td>
<td>(yes = 1; no = 0)</td>
<td>0.0695 (0.2545)</td>
<td>0.1359 (0.3429)</td>
</tr>
<tr>
<td><strong>v_fpi</strong></td>
<td>(yes = 1; no = 0)</td>
<td>0.1011 (0.3017)</td>
<td>0.0521 (0.2225)</td>
</tr>
<tr>
<td><strong>Global employees (1000 people)</strong></td>
<td>1.2613 (9.7912)</td>
<td>0.5980 (1.3173)</td>
<td>0.8610 (2.1388)</td>
</tr>
</tbody>
</table>

Statistics for firms with domestic manufacturing sectors. (Observations per year = 633)

Figures without (with) the parenthesis are the means (standard errors).

Statistics for firms with domestic R&D sectors. (Observations per year = 583)

Statistics for firms with both the domestic manufacturing and R&D sectors. (Observations per year = 522)

---

29 \( s \) = shortage; \( b \) = balance; \( s \) = surplus.
## Table 6-3 The Impact on Manufacturing Employees

### Dependent variable: d_man; Number of firms = 633; Period = 3; Observations = 1899

### Random Effect Probit Estimations with Binary Choice Models (M-1 to M-4)

<table>
<thead>
<tr>
<th>Model:</th>
<th>M-1</th>
<th>M-2</th>
<th>M-3</th>
<th>M-4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef. (Std Err.)</td>
<td>Coef. (Std Err.)</td>
<td>Coef. (Std Err.)</td>
<td>Coef. (Std Err.)</td>
</tr>
<tr>
<td>f_sal</td>
<td>-0.0102 (0.0098)</td>
<td>-0.0102 (0.0098)</td>
<td>-0.0192 * (0.0116)</td>
<td>-0.0193 * (0.0117)</td>
</tr>
<tr>
<td>f_tas</td>
<td>0.5615 *** (0.2004)</td>
<td>0.5616 *** (0.1999)</td>
<td>0.5561 *** (0.1998)</td>
<td>0.5567 *** (0.1992)</td>
</tr>
<tr>
<td>f_met</td>
<td>0.3802 * (0.1994)</td>
<td>0.3798 * (0.1989)</td>
<td>0.3783 * (0.1989)</td>
<td>0.3782 * (0.1984)</td>
</tr>
<tr>
<td>f_inf</td>
<td>0.2409 (0.2284)</td>
<td>0.2412 (0.2284)</td>
<td>0.2547 (0.2282)</td>
<td>0.2552 (0.2281)</td>
</tr>
<tr>
<td>f_liv</td>
<td>0.0953 (0.1581)</td>
<td>0.0942 (0.1573)</td>
<td>0.0962 (0.1579)</td>
<td>0.0956 (0.1570)</td>
</tr>
<tr>
<td>f_fpr</td>
<td>-0.4121 ** (0.1852)</td>
<td>-0.4117 ** (0.1851)</td>
<td>-0.4175 ** (0.1846)</td>
<td>-0.4171 ** (0.1845)</td>
</tr>
<tr>
<td>m_exp</td>
<td>-0.1095 (0.1194)</td>
<td>-0.1115 (0.1188)</td>
<td>-0.1061 (0.1191)</td>
<td>-0.1082 (0.1185)</td>
</tr>
<tr>
<td>m_cos</td>
<td>-0.2634 ** (0.1092)</td>
<td>-0.2635 ** (0.1086)</td>
<td>-0.2675 ** (0.1092)</td>
<td>-0.2672 ** (0.1086)</td>
</tr>
<tr>
<td>i_fdi</td>
<td>-0.0905 (0.1152)</td>
<td>-0.0899 (0.1151)</td>
<td>-0.0250 (0.1265)</td>
<td>-0.0244 (0.1265)</td>
</tr>
<tr>
<td>i_dom</td>
<td>0.0373 * (0.0198)</td>
<td>0.0372 * (0.0198)</td>
<td>0.0544 ** (0.0243)</td>
<td>0.0543 ** (0.0243)</td>
</tr>
<tr>
<td>r_for</td>
<td>2.1620 (2.4531)</td>
<td>2.1634 (2.4551)</td>
<td>1.4985 (1.8740)</td>
<td>1.4987 (1.8744)</td>
</tr>
<tr>
<td>r_dom</td>
<td>-0.5333 (0.4977)</td>
<td>-0.5359 (0.4981)</td>
<td>-0.2927 (0.5031)</td>
<td>-0.2933 (0.5037)</td>
</tr>
<tr>
<td>v_tpi</td>
<td>-0.0254 (0.1698)</td>
<td>-0.0209 (0.1695)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>v_fpi</td>
<td>0.0249 (0.2533)</td>
<td>0.0303 (0.2534)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>= -620.56</td>
<td>= -620.57</td>
<td>= -619.15</td>
<td>= -619.17</td>
</tr>
<tr>
<td>AIC</td>
<td>= 1269.12</td>
<td>1265.14</td>
<td>1266.30</td>
<td>1262.34</td>
</tr>
<tr>
<td>SC</td>
<td>= 1346.81</td>
<td>1331.73</td>
<td>1343.99</td>
<td>1328.93</td>
</tr>
<tr>
<td>LR test for $H_0: \beta = 0$</td>
<td>p-value = 0.0106</td>
<td>0.0041</td>
<td>0.0043</td>
<td>0.0015</td>
</tr>
</tbody>
</table>

***(**,*): Significant at 1% (5%; 10%) level.
Table 6-3 The Impact on Manufacturing Employees (Continued)

Dependent variable: d_man; Number of firms = 633; Period = 3; Observations = 1899
Random Effect Probit Estimations with 3-Alternative Ordered Models (M-5 to M-8)

<table>
<thead>
<tr>
<th>Model:</th>
<th>M-5</th>
<th>M-6</th>
<th>M-7</th>
<th>M-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Std Err.)</td>
<td>(Std Err.)</td>
<td>(Std Err.)</td>
<td>(Std Err.)</td>
<td>(Std Err.)</td>
</tr>
<tr>
<td>f_sal</td>
<td>-0.0041</td>
<td>-0.0041</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0032)</td>
<td>(0.0032)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f_tas</td>
<td>0.1031</td>
<td>0.1129</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.1272)</td>
<td>(0.1264)</td>
<td>0.0998</td>
<td>(0.1264)</td>
</tr>
<tr>
<td>f_met</td>
<td>0.0275</td>
<td>0.0345</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.1238)</td>
<td>(0.1234)</td>
<td>0.0277</td>
<td>(0.1233)</td>
</tr>
<tr>
<td>f_inf</td>
<td>-0.0881</td>
<td>-0.0876</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.1428)</td>
<td>(0.1425)</td>
<td>-0.0856</td>
<td>(0.1424)</td>
</tr>
<tr>
<td>f_lobby</td>
<td>-0.0348</td>
<td>-0.0272</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.1065)</td>
<td>(0.1059)</td>
<td>-0.0400</td>
<td>(0.1057)</td>
</tr>
<tr>
<td>f_fpr</td>
<td>-0.2820</td>
<td>-0.2799</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.1185)</td>
<td>(0.1183)</td>
<td>-0.2861</td>
<td>(0.1182)</td>
</tr>
<tr>
<td>m_exp</td>
<td>-0.0399</td>
<td>-0.0428</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0827)</td>
<td>(0.0822)</td>
<td>-0.0401</td>
<td>(0.0822)</td>
</tr>
<tr>
<td>m_cos</td>
<td>-0.2550</td>
<td>-0.2488</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0739)</td>
<td>(0.0734)</td>
<td>-0.2551</td>
<td>(0.0734)</td>
</tr>
<tr>
<td>i_fdi</td>
<td>0.0115</td>
<td>0.0115</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0596)</td>
<td>(0.0596)</td>
<td>0.0128</td>
<td>(0.0617)</td>
</tr>
<tr>
<td>i_dom</td>
<td>0.0120</td>
<td>0.0120</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.120)</td>
<td>(0.120)</td>
<td>0.0121</td>
<td>(0.121)</td>
</tr>
<tr>
<td>r_for</td>
<td>0.8683</td>
<td>0.8512</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.9622)</td>
<td>(0.9619)</td>
<td>0.8769</td>
<td>(0.9755)</td>
</tr>
<tr>
<td>r_dom</td>
<td>-0.0347</td>
<td>-0.0332</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.1387)</td>
<td>(0.1387)</td>
<td>-0.0183</td>
<td>(0.1444)</td>
</tr>
<tr>
<td>v_tpi</td>
<td>0.0580</td>
<td>0.0610</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.1143)</td>
<td>(0.1144)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>v_fpi</td>
<td>0.1234</td>
<td>0.1304</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.1751)</td>
<td>(0.1750)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>γ_1</td>
<td>-1.9175</td>
<td>-1.9184</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.1585)</td>
<td>(0.1583)</td>
<td>-1.9248</td>
<td>(0.1582)</td>
</tr>
<tr>
<td>γ_0</td>
<td>1.2704</td>
<td>1.2665</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.1532)</td>
<td>(0.1529)</td>
<td>1.2632</td>
<td>(0.1527)</td>
</tr>
</tbody>
</table>

Log-likelihood = -1158.09 -1158.43 -1158.22 -1158.59
AIC = 2344.18 2340.86 2344.44 2341.18
SC = 2421.87 2407.45 2422.13 2407.77
LR test for H_0: β = 0
p-value = 0.0174 0.0087 0.0189 0.0097

*** (**:*) : Significant at 1% (5%; 10%) level.
### Table 6-4 The Impact on R&D Employees

Dependent variable: \( d_{rea} \); Number of firms = 583; Period = 3; Observations = 1749

Random Effect Probit Estimations with Binary Choice Models (R-1 to R-4)

<table>
<thead>
<tr>
<th>Model</th>
<th>Coef. (Std Err.)</th>
<th>Coef. (Std Err.)</th>
<th>Coef. (Std Err.)</th>
<th>Coef. (Std Err.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-1</td>
<td>f_sal 0.0159 **  (0.0079)</td>
<td>f_tas 0.0158 **  (0.0079)</td>
<td>f_met 0.3686 *  (0.1944)</td>
<td>f_inf 0.6729 ***  (0.1825)</td>
</tr>
<tr>
<td></td>
<td>R-2</td>
<td>f_tas 0.0133 **  (0.0066)</td>
<td>f_met 0.3517 *  (0.1935)</td>
<td>f_inf 0.6779 ***  (0.1828)</td>
</tr>
<tr>
<td></td>
<td>R-3</td>
<td>f_tas 0.0158 **  (0.0066)</td>
<td>f_met 0.3509 *  (0.1937)</td>
<td>f_inf 0.6708 ***  (0.1828)</td>
</tr>
<tr>
<td></td>
<td>R-4</td>
<td>f_tas 0.0133 **  (0.0066)</td>
<td>f_met 0.3509 *  (0.1937)</td>
<td>f_inf 0.6708 ***  (0.1828)</td>
</tr>
<tr>
<td></td>
<td>f_tas 0.0133 **  (0.0066)</td>
<td>f_met 0.3509 *  (0.1937)</td>
<td>f_inf 0.6708 ***  (0.1828)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R-1</td>
<td>f_tas 0.0158 **  (0.0079)</td>
<td>f_met 0.3509 *  (0.1937)</td>
<td>f_inf 0.6708 ***  (0.1828)</td>
</tr>
<tr>
<td></td>
<td>R-2</td>
<td>f_tas 0.0133 **  (0.0066)</td>
<td>f_met 0.3509 *  (0.1937)</td>
<td>f_inf 0.6708 ***  (0.1828)</td>
</tr>
<tr>
<td></td>
<td>R-3</td>
<td>f_tas 0.0158 **  (0.0066)</td>
<td>f_met 0.3509 *  (0.1937)</td>
<td>f_inf 0.6708 ***  (0.1828)</td>
</tr>
<tr>
<td></td>
<td>R-4</td>
<td>f_tas 0.0133 **  (0.0066)</td>
<td>f_met 0.3509 *  (0.1937)</td>
<td>f_inf 0.6708 ***  (0.1828)</td>
</tr>
</tbody>
</table>

Log likelihood = -970.54 -970.87 -970.58 -970.90
AIC = 1969.08 1965.74 1969.16 1965.80
SC = 2046.77 2032.33 2046.85 2032.39
LR test for \( H_0: \beta = 0 \) p-value = 0.0004 0.0001 0.0004 0.0001

***(*, **): Significant at 1% (5%; 10%) level.
**Table 6-4 The Impact on R&D Employees (Continued)**

Dependent variable: d_rea; Number of firms = 583; Period = 3; Observations = 1749

Random Effect Probit Estimations with 3-Alternative Ordered Models (R-5 to R-8)

<table>
<thead>
<tr>
<th>Model: R-5</th>
<th>R-6</th>
<th>R-7</th>
<th>R-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Std Err.)</td>
<td>(Std Err.)</td>
<td>(Std Err.)</td>
<td>(Std Err.)</td>
</tr>
<tr>
<td>f_sal</td>
<td>-0.0037</td>
<td>-0.0037</td>
<td>(0.0030)</td>
</tr>
<tr>
<td>f_tas</td>
<td>(0.1670)</td>
<td>0.0065</td>
<td>(0.1660)</td>
</tr>
<tr>
<td>f_met</td>
<td>0.3054</td>
<td>0.2932</td>
<td>0.3001</td>
</tr>
<tr>
<td>f_inf</td>
<td>0.5051</td>
<td>0.4999</td>
<td>0.5037</td>
</tr>
<tr>
<td>f_liv</td>
<td>-0.1523</td>
<td>-0.1532</td>
<td>-0.1457</td>
</tr>
<tr>
<td>f_ing</td>
<td>0.1764</td>
<td>0.1707</td>
<td>0.1739</td>
</tr>
<tr>
<td>f_fpr</td>
<td>-0.1719</td>
<td>-0.1720</td>
<td>-0.1780</td>
</tr>
<tr>
<td>m_exp</td>
<td>-0.0820</td>
<td>-0.0778</td>
<td>-0.0804</td>
</tr>
<tr>
<td>m_cos</td>
<td>-0.0295</td>
<td>-0.0330</td>
<td>-0.0289</td>
</tr>
<tr>
<td>i_fdi</td>
<td>-0.1658</td>
<td>-0.1661</td>
<td>-0.1522</td>
</tr>
<tr>
<td>i_dom</td>
<td>0.0065</td>
<td>0.0067</td>
<td>0.0085</td>
</tr>
<tr>
<td>r_for</td>
<td>1.4464</td>
<td>1.4602</td>
<td>1.0156</td>
</tr>
<tr>
<td>r_dom</td>
<td>-0.0233</td>
<td>-0.0243</td>
<td>0.0246</td>
</tr>
<tr>
<td>v_tpi</td>
<td>-0.0279</td>
<td>-0.0221</td>
<td>(0.1342)</td>
</tr>
<tr>
<td>v_fpi</td>
<td>-0.1365</td>
<td>-0.1366</td>
<td>(0.2123)</td>
</tr>
<tr>
<td>γ0</td>
<td>0.9074</td>
<td>0.9110</td>
<td>0.8997</td>
</tr>
</tbody>
</table>

Log-likelihood = -1094.23 | -1094.44 | -1093.81 | -1094.02

AIC = 2216.46 | 2212.88 | 2215.62 | 2212.04

SC = 2294.15 | 2279.47 | 2293.31 | 2278.63

LR test for \( H_0: \beta = 0 \) p-value = 0.0041 | 0.0016 | 0.0031 | 0.0012

***(**;*): Significant at 1% (5%; 10%) level. [ ]: p-value
7 Conclusion

While the relocation of production processes by multinationals might yield higher productivity, there is a serious concern that it could also hurt domestic non-skilled workers. This has been confirmed by many studies on more developed countries; however, little research has focused on less developed countries. This paper tries to bridge this gap by using the data about Taiwanese multinationals, which are also active participants in foreign production activities.

Before investigating the issue, this paper borrows the theoretical considerations from the knowledge capital model, which infers that for a small and skilled labor abundant country like Taiwan, the vertical multinational, which is domestically headquartered and produces abroad, would be the prevalent type of organization, provided that the trade cost is not a dominant factor (As mentioned in Section 2, trade cost between Taiwan and China is not overly high since 1990). Based on this argument, skilled workers could survive or even benefit from the division of labor while non-skilled labor could suffer in the meantime. The prima facie evidence from the industry-level regression does suggest that in Taiwan, the non-skilled labor intensive jobs are more likely to be carried out abroad, while the skilled labor intensive jobs tend to be done domestically.

The above argument is further confirmed by the firm-level survey data for the Taiwanese multinationals. More specifically, this paper finds that while there is no significant evidence showing that manufacturing employees would be harmed if the multinationals have foreign affiliates in the developing countries, they do suffer from the multinationals’ increasing proportion of foreign output.

For more skilled workers like those in the R&D sectors, this paper finds that there is no significant evidence to conclude that they have been harmed by the increasing proportion of foreign output. On the contrary, the results show that having foreign affiliates in developing countries has a positive impact on domestic R&D employees, which suggests the geographical fragmentation of R&D and production activities. The empirical evidence also demonstrates that the positive impact on domestic
skilled labor employment seems to come from providing intangible input like R&D related services rather than producing tangible intermediates for the foreign affiliates.

More extension and refinement of this kind of study could be done in the future. For example, although this paper does consider whether the parent firm produces the intermediates for the foreign affiliate (and vice versa), due to the limitations of the data, the exact trade volume in these intermediates is not considered. Obviously, more accurate data on trade in intermediates would allow researchers to make better estimates.

Furthermore, in this paper, the sample is composed of relatively large multinationals. However, there are also many smaller firms that are headquartered domestically and moving their production activities abroad. Although the empirical evidence of this paper suggests that larger multinationals are less likely to hire new manufacturing labor, some anecdotal evidence from Taiwan shows that for the smaller multinationals not considered in this paper, the proportion of foreign output could be higher and thus the negative impact on domestic manufacturing employees could be stronger. If that is the case, this paper would underestimate the aforementioned negative impact.

Another point is that the only available dependent variable is simply the firm’s assessment of its employment status. However, it is plausible that a firm which reports the status “balance” for a specific kind of employee has already laid off or recruited some employees ex ante. Apparently, using the exact number of employees as the dependent variable would yield better estimates.

Finally, in Taiwan, despite the promising economic growth figures in recent years, many people have kept complaining that their salaries are almost stagnant. It seems that the economic improvement is only enjoyed by a small group of people, especially the most skilled employees who work in the high-tech sectors. In fact, this can be verified by the worsening income distribution in Taiwan during recent years.

Many empirical studies for other countries have found that the multinationals’ foreign production
activities could have a negative impact on the wage rates of domestic employees.\textsuperscript{30} Thus, in addition to studying the impact on domestic employment, the impact on wages is also worth investigating. However, although there are industry-level wage data for different categories of employees, there are no firm-level counterparts in MOEA's survey. More comprehensive surveys shall definitely benefit future studies.

\textsuperscript{30} For example, see Feenstra and Hanson (1996; 2001), Hsieh and Woo (2005), and Goldberg and Pavcnik (2007).
Appendix

A-01 Random Effect Probit Estimation with Binary Choice Model

Let us consider the following binary choice model with \( x_{it} \) being the \( K \times 1 \) vector of independent variables and \( \alpha_i \) representing the unobserved individual specific effect

\[
y_{it} = 1 \text{ if and only if } y_{it}^* = \alpha_i + x_{it}'\beta + u_{it} > 0 \tag{A01}
\]
\[
y_{it} = 0 \text{ if and only if } y_{it}^* = \alpha_i + x_{it}'\beta + u_{it} \leq 0
\]

In a random effect probit setting, \( \alpha_i \) is a random disturbance term under a normal distribution. By integrating over that distribution, \( \alpha_i \) can be cancelled out. Let us follow the assumption by Heckman and Willis (1976) such that in (A01): 1) \( \alpha_i \sim \text{IN}(0, \sigma_a^2) \); 2) \( u_{it} \sim \text{IN}(0, \sigma_u^2) \); and 3) both of them are mutually independent as well as independent of \( x_{it} \).\(^{31}\) Let us reformulate (A01) as:

\[
y_{it} = 1 \text{ if and only if } y_{it}^* = x_{it}'\beta + \epsilon_{it} \geq 0 \tag{A02}
\]
\[
y_{it} = 0 \text{ if and only if } y_{it}^* = x_{it}'\beta + \epsilon_{it} < 0
\]

where \( \epsilon_{it} = \alpha_i + u_{it} \sim \text{IN}(0, \sigma^2) \) with \( \sigma^2 = \sigma_a^2 + \sigma_u^2 \). The joint probability becomes:

\[
P(y_{i1}, y_{i2}, y_{i3}) = \int_{a_{i1}}^{b_{i1}} \int_{a_{i2}}^{b_{i2}} \int_{a_{i3}}^{b_{i3}} f(\epsilon_{i1}, \epsilon_{i2}, \epsilon_{i3}) d\epsilon_{i3} d\epsilon_{i2} d\epsilon_{i1} \tag{A03}
\]

where \( a_{it} = -x_{it}'\beta \) and \( b_{it} = \infty \) if \( y_{it} = 1 \) and \( a_{it} = -\infty \) and \( b_{it} = -x_{it}'\beta \) if \( y_{it} = 0 \). Following the approach proposed by Butler and Moffitt (1982), when conditioning on the random disturbance term \( \alpha_i \), the joint density function in (A03) can be decomposed into (A04) since \( \epsilon_{it} | \alpha_i \) and \( \epsilon_{i3} | \alpha_i \)

\(^{31}\) See Maddala (1987).
(t ≠ s) are independent: \(^{32}\)

\[
f(\varepsilon_{i1}, \varepsilon_{i2}, \varepsilon_{i3}) = f(\alpha_i) f(\varepsilon_{i1}, \varepsilon_{i2}, \varepsilon_{i3} | \alpha_i) = f(\varepsilon_{i1} | \alpha_i) f(\varepsilon_{i2} | \alpha_i) f(\varepsilon_{i3} | \alpha_i) \tag{A04}
\]

This implies (A03) can be expressed as:

\[
P(y_{i1}, y_{i2}, y_{i3}) = \int_{-\infty}^{\infty} f(\alpha_i) \int_{a_{i1}}^{b_{i1}} f(\varepsilon_{i1} | \alpha_i) d\varepsilon_{i1} \int_{a_{i2}}^{b_{i2}} f(\varepsilon_{i2} | \alpha_i) d\varepsilon_{i2} \int_{a_{i3}}^{b_{i3}} f(\varepsilon_{i3} | \alpha_i) d\varepsilon_{i3} \, d\alpha_i
\]

\[
= \int_{-\infty}^{\infty} \prod_{t=1}^{3} \left[ F(b_{it} | \alpha_i) - F(a_{it} | \alpha_i) \right] f(\alpha_i) \, d\alpha_i \tag{A05}
\]

Thus, the log-likelihood function becomes:

\[
\ln L = \sum_{i=1}^{N} \ln \left\{ \int_{-\infty}^{\infty} \prod_{t=1}^{3} \left[ F(b_{it} | \alpha_i) - F(a_{it} | \alpha_i) \right] f(\alpha_i) \, d\alpha_i \right\} \tag{A06}
\]

### A-02 Random Effect Probit Estimation with 3-Alternatives Ordered Model

Let us consider the following three-alternative ordered model:

\[
y_{it} = \begin{cases} 
1 & \text{if and only if } \gamma_0 < y_{it}^* = \alpha_i + x_{it} \beta + u_{it} \leq \gamma_1 \\
0 & \text{if and only if } \gamma_1 < y_{it}^* = \alpha_i + x_{it} \beta + u_{it} \leq \gamma_0 \\
-1 & \text{if and only if } \gamma_0 < y_{it}^* = \alpha_i + x_{it} \beta + u_{it} \leq \gamma_{-1}
\end{cases} \tag{A07}
\]

Note that in the above expression, \(\gamma_{-2} = -\infty\) and \(\gamma_1 = \infty\). Let us follow the assumption by Heckman and Willis (1976) such that in (A07): 1) \(\alpha_i \sim \text{IN}(0, \sigma_0^2)\); 2) \(u_{it} \sim \text{IN}(0, \sigma_u^2)\); and 3) both of them are mutually independent as well as independent of \(x_{it}\). Let us denote the probability that firm i

\[^{32}\text{Note that the variances of } \varepsilon_{it} | a_i \text{ and } \varepsilon_{is} | a_i \text{ only come from the contributions of } u_{it} \text{ and } u_{is}, \text{ respectively, and } u_{it} \text{ and } u_{is} \text{ are independent by assumption.}\]
chooses alternative \( j = J \) \((J = -1; 0; 1)\) in year \( t \) by \( P(y_{it} = J) \) and reformulate (A07) as:

\[
y_{it} = 1 \text{ if and only if } y_0 < y_{it} = x_{it}' \beta + \epsilon_{it} \leq y_1
\]

\[
y_{it} = 0 \text{ if and only if } y_{-1} < y_{it} = x_{it}' \beta + \epsilon_{it} \leq y_0 \quad \text{(A08)}
\]

\[
y_{it} = -1 \text{ if and only if } y_{-2} < y_{it} = x_{it}' \beta + \epsilon_{it} \leq y_{-1}
\]

where \( \epsilon_{it} = \alpha_i + u_{it} \sim N(0, \sigma^2) \) with \( \sigma^2 = \sigma^2_{\alpha} + \sigma^2_u \). Then, we have:

\[
P(y_{it} = j) = F(y_j - x_{it}' \beta) - F(y_{j-1} - x_{it}' \beta)
\]

(A08)

where \( F(\cdot) \) is the c.d.f. of \( \epsilon_{it} \). Note that for the same firm, the choices of different years are correlated since \( \epsilon_{i1}; \epsilon_{i2}; \epsilon_{i3} \) are correlated because of the presence of \( \alpha_i \). Thus, we need to use the approach proposed by Butler and Moffitt as in the binary choice case. Let us consider the conditional joint probability \( P(y_{i1}, y_{i2}, y_{i3} | \alpha_i) \). Since \( \epsilon_{i1} | \alpha_i; \epsilon_{i2} | \alpha_i; \epsilon_{i3} | \alpha_i \) are independent, we have:

\[
P(y_{i1}, y_{i2}, y_{i3} | \alpha_i) = \prod_{t=1}^{3} P(y_{it} = j | \alpha_i)
\]

(A08)

After integrating over \( \alpha_i \), we have:

\[
P(y_{i1}, y_{i2}, y_{i3}) = \int_{-\infty}^{\infty} [\prod_{t=1}^{3} P(y_{it} = j | \alpha_i)] f(\alpha_i) d\alpha_i
\]

(A09)

Thus, the log-likelihood function becomes:

\[
\ln L = \sum_{i=1}^{N} \ln \left\{ \int_{-\infty}^{\infty} [\prod_{t=1}^{3} P(y_{it} = j | \alpha_i)] f(\alpha_i) d\alpha_i \right\}
\]

(A10)
References


the Manufacturers, Department of Statistics, Ministry of Economic Affairs, Taiwan.

[37] ________________________ (2005) Declaration of Export to China Goes Up After Taiwan Opens Up the Direct Trade Between Taiwan and China (In Traditional Chinese), Department of Statistics, Ministry of Economic Affairs, Taiwan.


