

Technology Diffusion from Foreign Direct Investment through Supply Chains

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July 20, 2002

Abstract

This paper examines how the technology that accompanies foreign direct investment (FDI) diffuses in the host economy. We ask if local vendors that sell to multinational entrants acquire technology through supply chain linkages. Using a panel dataset of Indonesian manufacturing establishments from 1988 to 1996, we measure the effect of downstream FDI on local firm productivity and find strong evidence that *vertical* supply chains are a channel for technology transfer. In contrast, prior studies that measure the *horizontal* spillover of technology from foreign entrants to domestic competitors find mixed evidence of technology transfer. We conclude that considering only horizontal spillover underestimates technology transfer from FDI. This finding is consistent with the incentives of multinational enterprises: whereas they attempt to minimize technology leakage to competitors, they often deliberately transfer technology to suppliers with the aim of reducing the price and raising the quality of inputs.

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1. Introduction

Policymakers often cite technology diffusion to host country firms as a benefit of foreign direct investment (FDI). This belief proliferates in part because of impressive claims of technological development from FDI, such as those of the [World Bank 1993](#), p. 1, which writes that “[FDI] brings with it considerable benefits: technology transfer, management know-how, and export marketing access. Many developing countries will need to be more effective in attracting FDI flows if they are to close the technology gap with high-income countries, upgrade managerial skills, and develop their export markets.” These claims have encouraged developing countries to adopt costly programs, such as tax holidays, subsidized industrial infrastructure, and duty exemptions, to attract multinational enterprises.

Is this enthusiasm for FDI warranted? A number of recent empirical studies, which find mixed evidence of technology transfer from FDI, have prompted many observers to conclude it is not. [Rodrik \(1999, p. 37\)](#), in a summary of the evidence, comments, “today’s policy literature is filled with extravagant claims about positive spillovers from FDI, [but] the hard evidence is sobering.” The studies to which Rodrik refers ask if local competitors benefit from a positive externality, or “technology spillover,” generated by multinational entry in the same industry. When one considers the incentives of foreign firms and the nature of the markets they enter, however, it is not surprising that evidence of technology spillover is weak. Multinationals will attempt to minimize technology leakage to competitors by limiting the mechanisms, such as labor mobility and imitation, through which spillover occurs. Further, multinationals with non-protectable technology will likely choose not to enter overseas markets at all. Even if local firms can observe the technology brought with FDI, they may lack the absorptive capacity to adopt it because of the often wide gap in human capital and product development capabilities between multinational and local firms.

In contrast, we argue that technology diffusion from FDI is more likely to occur with local suppliers than with local competitors, because of multinationals’ strategies to build efficient supply chains overseas. Although multinational enterprises may invest overseas initially to obtain low-wage labor or to avoid costly barriers to foreign markets, they realize the full benefit of expansion only if the cost and quality of inputs abroad match those of their home manufacturing base. To build efficient supply chains abroad, many multinationals will deliberately transfer technology to local vendors to improve supplier productivity. This strategy suggests that supply chains, rather than within-industry spillover, may be a conduit for

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technology transfer from FDI. Furthermore, because multinationals initially tend to procure inputs requiring relatively simple production technology, the capacity of local suppliers to learn from supply chain linkages may be greater than the capacity of local competitors to learn from spillover. Indeed, anecdotal evidence from interviews we conducted with multinational and local firm managers in Indonesia shows close cooperation through vertical linkages. Such cooperation, described in the next section, exemplifies the mechanisms through which learning from FDI can occur vertically.

This study measures the effect of FDI on local supplier productivity by estimating a production function using a rich panel dataset on local- and foreign-owned Indonesian manufacturing establishments. We identify vertical supply chains using the Indonesian input-output table. The estimation employs fixed-effect estimation to admit only variation within a factory over time, thereby controlling for time-invariant unobservable factory attributes. Further, we use semi-parametric estimation to control for time-variant unobservable factory shocks that could simultaneously influence both FDI and factory productivity. The results indicate that local firms do acquire technology from FDI through vertical supply chains. This finding suggests that *considering only horizontal spillover may underestimate the true benefit of technology transfer from FDI*.

The paper proceeds as follows. The next section reviews the extant literature on technology transfer and the mechanisms by which it may occur. Section 3 provides some background on manufacturing and FDI in Indonesia. Section 4 describes the data and details the econometric identification strategy. Section 5 discusses the results and Section 7 concludes.

2. Technology Transfer

Most of the literature recognizes two major channels for technology transfer from FDI: horizontal flows to local competitors (sometimes called “spillover” because it is largely an externality), and vertical flows to backwardly linked suppliers. We define technology broadly to mean the managerial practices, production methods, and other tacit and codified know-how by which a firm transforms capital, labor, and materials into a product. Below we describe the mechanisms by which local firms could learn through each channel and summarize the empirical evidence.¹

¹Kumar 1996, Blomstrom and Kokko 1997, Keller 2001 and Moran 2001 provide extensive literature reviews.

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We first discuss horizontal transfer, which has been the focus of most empirical work, and suggest why recent studies have found mixed evidence of transfer through this channel. We next discuss vertical transfer, the emphasis of this paper, and argue that the incentives of multinational investors would promote technology transfer through this channel. Finally, we suggest a refutable empirical test of technology transfer through supply chains. round

2.1. Horizontal Technology Transfer

Multinational entry may provide positive technological externalities to local competitors through a number of mechanisms. First, the local firm may be able to learn simply by observing and imitating the multinationals. Second, employees may leave multinationals to create or join local firms. Third, multinational investment may encourage the entry of international trade brokers, accounting firms, consultant companies, and other professional services, which then may become available to local firms as well.

Multinational entry may also hurt local firms. First, foreign firms may hire talent away from local firms, thereby creating a “brain drain.” Second, foreign firms, which often pay higher wages, may raise wages for all firms in competitive labor markets (Aitken, Harrison, and Lipsey 1996). If the higher wages do not reflect an improvement of employee capabilities, which may be the case if the multinational faces public pressure in its home market to improve overseas workers’ conditions, then firms may substitute capital for labor in an otherwise (prior to the wage increase) inefficient manner.

Empirical studies of technology spillover find mixed results. The studies, which regress local firm productivity on within-sector FDI, fall into two categories: those that use cross-sectional data, e.g., Caves 1974, Globerman 1979, and Blomstrom and Wolff 1994, and those that use panel data, e.g., Haddad and Harrison 1993, Kokko 1994, Aitken and Harrison 1999, and Haskel, Pereira, and Slaughter 2002. The former typically find positive correlation between local firm productivity and FDI. However, cross-sectional analysis cannot distinguish whether FDI actually increases local firm productivity, or whether multinational investors simply invest in inherently more productive sectors. Studies using panel data, which can control for investor selection bias, find mixed results. On one hand, Aitken and Harrison’s examination of Venezuelan factories finds net negative benefits to local firms, a result they attribute to the effect of foreign competition. On the other hand, Haskel, Pereira, and Slaughter employ similar methods with a panel dataset of

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factories in the United Kingdom and reach the opposite conclusion.

Host economy heterogeneity and limitations of production function estimation likely explain the mixed results. First, the technology gap between foreign and domestic firms likely varies by country and industry. In cases in which the gap is wide, local firms may lack the absorptive capacity needed to recognize and adopt the new technology. Similarly, the degree to which foreign and domestic firms actually compete in the same market will also vary. Domestic firms may produce for the local market while multinationals produce for export. Because of differences in quality and other attributes, exported and domestically consumed goods may entail different production methods which reduce the potential for technology transfer. Second, multinationals may enact measures to minimize technology leakage to local competitors. In particular, multinationals with non-protectable technology may not enter the market at all if they rely on a technological advantage to sustain rents. Again, the level of technology multinationals bring to the host economy and the degree to which it can be protected will vary widely. Last, production function estimation may confound the productivity gains from technology transfer with the efficiency losses from increased competition. If multinationals capture market share, then local firms may under-utilize existing capacity in the short run. Although local firms will eventually redeploy slack resources, production function estimation will interpret non-utilized resources as a productivity loss in the short run.

2.2. Vertical Technology Transfer

Vertical technology transfer could occur through both *backward* (from buyer to supplier) or *forward* (from supplier to buyer) linkages. Because most multinationals in Indonesia are export-oriented and generally do not supply Indonesian customers, we focus here on technology transfer through backward linkages. That is, we examine the effect of vertical FDI, the presence of multinational buyers *downstream*, on the performance of local suppliers.

Two arguments suggest that supply chains may be a conduit for technology transfer. First, whereas multinationals seek to minimize technology leakage to competitors, they do have incentives to improve the productivity of their suppliers through training, quality control, and inventory management, for example. To reduce dependency on a single supplier, the multinational may establish such relationships with multiple vendors, which benefits all firms which purchase their output. Second, while the technology gap between foreign and domestic producers

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may limit within-sector technology transfer, multinationals likely procure inputs requiring less sophisticated production techniques for which the gap is narrower.

Evidence of technology transfer through vertical supply chains is well documented in case studies. For example, [Kenney and Florida \(1993\)](#) and [Macduffie and Helper \(1997\)](#) provide a rich description of technology transfer to U.S. parts suppliers following the entry of Japanese automobile makers. Empirical analysis, however, is generally limited to small samples, such as that by [Lall \(1980\)](#), which documents technology transfer from foreign firms through backward linkages in the Indian trucking industry. A rare large-sample empirical study is [Kugler \(2000\)](#), which shows that FDI in one sector of Columbian manufacturing can Granger-cause productivity gains in another. Kugler, however, does not identify backward linkages or any particular causal mechanisms for the inter-sector spillover. This study aims to partly fill that gap in the literature.

Anecdotal evidence from interviews with multinational and Indonesian firms exemplifies the specific mechanisms through which vertical technology may occur.² An American firm reported that its process of qualifying domestic suppliers involved several stages over a few years. First, the American firm's engineers would visit the local factory to inspect their facilities and suggest needed modifications. Next, sample product was sent to a testing facility in the United States. If the product was approved, the suppliers were sent to overseas training classes to learn the multinational's systems for inventory control, quality control, and cost accounting. Thereafter, the supplier would be asked to produce a small amount of the total production demand. Only after the supplier had successfully established a record of delivering on-time and within-specification would the multinational qualify it as a large-scale supplier.

Managers from a Japanese multinational reported a similar process. They added that it was common for them to introduce good suppliers to affiliate companies in their industrial group, both in Indonesia and in other countries. By doing so, they added, they could increase their suppliers' economies of scale and smooth their capacity utilization. Likewise, the same Japanese firm reported that it often used suppliers in Malaysia and Thailand that were referred to it by affiliate companies. This reduced the dependence on local suppliers and ensured that Indonesian vendors were competitive within the region. The goal, noted the manager, was to guarantee a reliable supply of parts from a handful of the best local firms in Southeast Asia.

²We interviewed managers from two American, two Japanese, and two Indonesian firms in Jakarta during the July, 2000.

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Not all of the foreign firms reported success in local procurement. Another Japanese firm noted that it bought very little from local suppliers, other than cardboard boxes and paper packaging. The manager said that, although he would like to buy more locally and faced some pressure to do so, it was just not practical. Most local firms could not meet his requirements for quality, price, and delivery performance. Instead, he preferred to buy from the firm's established vendors in Japan. He added, however, that many of those vendors were themselves producing in Indonesia and surrounding countries.

Indonesian suppliers cited some benefits from selling to foreign customers. One vendor reported that his relationship with a large Japanese firm was valuable because the customer sent engineers from Japan annually to review his production methods and suggest improvements for cost reduction. He added that the Japanese firm's desire for extremely consistent product attributes had prompted him to invest in new machinery imported from Switzerland. In contrast, however, he stated that his relationship with an American buyer had been less successful. The Americans, he complained, had unobtainable goals for cost reduction, did not provide him with sufficient lead time for orders (necessitating that he pay expensive overtime wages), and offered no technical support to meet their requirements. In the end, the American firm rejected much of his supply on quality grounds (he disputed their evaluation), and he voluntarily severed the relationship.

Many of the reported mechanisms for technology transfer through supply chains would apply equally to exports. One Indonesian firm reported that it exported 100 percent of its output to Germany. Its main customer, a large German consumer goods company, reportedly sent efficiency experts to advise on how best to expand production capacity. In fact, during the day of the interview, four product designers from the German customer were at the plant advising how to adapt the product appearance to suit new consumer trends. The Indonesian manager observed that the increased sales, which were largely driven by lower labor costs following the massive devaluation of the rupiah in 1997, had strained his accounting resources. He complained that the higher volume made it difficult for his planners to know if production was on schedule. Consequently, he could not respond quickly to customer requests for time-critical orders. To solve the problem, he had just ordered inventory control software from Europe. When financing the purchase, one of the largest capital investments since building the factory, he had borrowed from the Jakarta branch of an American bank using the German customer's letter of intent to order as evidence of his creditworthiness.³

³A number of interviewed managers mentioned the role of foreign firms in helping Indonesian

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2.3. Testable Implications of Technology Transfer through Supply Chains

Although the specific mechanisms for technology transfer described above are typically unobservable in the data, one can identify technology transfer indirectly by otherwise unexplained productivity gains. If vertical supply chains are a conduit for technology transfer, then one would expect, *ceteris paribus*, that local firms in industries and regions with growing levels of downstream vertical FDI would show greater productivity growth than other local firms. Further, one would expect to see this productivity gain in intermediate goods industries, for which there is variation in downstream FDI, but not for final goods industries. The methodology for testing this hypothesis is described in detail in Section 4.2 and is preceded by some background on Indonesian manufacturing and a description of the data in the following two sections.

3. Indonesian Manufacturing and Foreign Investment Policy

Indonesia's manufacturing sector is an attractive setting for research on FDI and technology transfer for several reasons. First, with the fourth largest population in the world and thousands of islands stretching over three time zones, the country has abundant labor and natural resources to support a large sample of manufacturing facilities in a wide variety of industries. Further, the country's size and resources support a full supply chain, from raw materials to intermediate and final goods, and both export and domestic markets. Second, rapid and localized industrialization provides variance in manufacturing activity in both time and geography. Third, the country's widespread island archipelago geography and generally poor transportation infrastructure create a number of local markets, each of which can support independent supply chains. Fourth, a number of institutional reforms of investment law have dramatically increased the amount of FDI and export activity in recent years. In particular, the nature and timing of these reforms provide exogenous variation in FDI by region, industry, and time that will be exploited in the econometric identification. Last, Indonesian government agencies employ a number of well trained statisticians who have collected exceptionally rich manufacturing data for a developing country. The remainder of this section provides some background on Indonesian manufacturing and foreign investment

suppliers obtain credit during the Asian financial crisis. Because 1996 is the last year of empirical analysis for this study, this role does not affect the results here.

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policy with the intent of highlighting institutional changes that contribute to the longitudinal variation we exploit in the econometric identification. Readers not interested in this background may skip ahead without loss of continuity.

3.1. Growth in Manufacturing

The Indonesian economy and the manufacturing sector have grown dramatically since the late 1970's until the recent financial crisis.⁴ Indonesia enjoyed an average annual GDP growth rate of 6-7 percent and much of this growth was driven by manufacturing, which expanded from 11 percent of GDP in 1980 to 25 percent in 1996 (Nasution 1995). Government initiatives to reduce dependency on oil and gas revenue in the mid-1980's, principally liberalization of financial markets and foreign exchange, a shift from an import-substitution regime to export promotion, currency devaluation, and relaxation of foreign investment laws, facilitated the large increase in manufacturing output (Goeltom 1995).

3.2. Foreign Investment Policy

Over the past 40 years, government regulation has shifted dramatically from a policy antagonistic to FDI to a policy actively encouraging it (Wie 1994a; Hill 1988; Pangestu 1996). Following independence from the Netherlands in 1945, the Sukarno government nationalized many of the former Dutch manufacturing enterprises. Weak property rights and socialist rhetoric kept foreign investment at a trickle throughout the 1950's and 1960's.

The first reforms came in 1967 as part of the "New Order" economic regime of Suharto, who had purged the government of left-wing elements in his rise to power. Many of the assets nationalized after independence were returned and the enactment of Foreign Investment Law No. 1 in 1967 established a licensing procedure for foreign operations that remains the basis of current policy. Although, in principle, Foreign Investment Law No. 1 allowed FDI with few restrictions, the process of obtaining an operating license was onerous in practice. Nevertheless, FDI, primarily from Japan, did begin to flow into labor-intensive sectors, such as textiles.

Negative nationalistic reaction to the foreign investment and complaints from local firms prompted the government to impose restrictions, particularly on en-

⁴Hill (1988) and Pangestu and Sato (1997) provide detailed histories of Indonesian manufacturing from the colonial period to the present.

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trants that produced for the local market. Opposition to FDI culminated in violent protests during the 1974 visit to Jakarta of Japanese Prime Minister Kakuei Tanaka. Suharto responded with a presidential decree restricting the sectors open for new foreign investment and limiting the maximum allowable foreign equity in manufacturing operations. Most notably, all new investment had to take the form of a joint venture with Indonesian partners, who were required to own at least 20 percent of equity initially and 51 percent within 10 years of operation.

Because of the restrictions on equity holdings, foreign firms adopted other mechanisms for controlling their operations. Japanese investors, for example, would maintain effective control of joint ventures in which they had minority equity stakes by increasing the debt-to-equity ratio and licensing or leasing production technology and equipment (Wie 1994b). Embedded in such an arrangement was the option to withhold the financing, equipment, and know-how needed for the plant's viability if the foreign investor believed it did not have effective control.

Following the collapse of oil prices in the mid-1980's, the government began to seek outside investment more actively. From 1986 to 1994, it introduced a number of exemptions to the 1974 regulations. The exemptions were targeted to multinationals investing in particular locations, notably a bonded zone on the island of Batam (only 20 kilometers from Singapore), government sponsored industrial parks, and undeveloped provinces of east Indonesia. The new policy also granted exemptions to investment in capital-intensive, technology-intensive, and export-oriented sectors. The exemptions typically allowed a lower minimum initial Indonesian equity stake, a lower long-term Indonesian equity target, and a longer period to achieve that target (often as long as 20 years). Moreover, the reforms reduced or eliminated import tariffs for certain capital goods and for materials that would be assembled and exported.

Finally, in 1994 the government lifted nearly all equity restrictions on foreign investment. Multinationals in most sectors were allowed to establish and maintain in perpetuity operations with 100 percent equity. In a handful of sectors deemed strategically important, a nominal 5 percent Indonesian holding was required with no further requirement to divest.

Changes in Investment Following Initiation of Reforms The reforms have been accompanied by large increases in both the absolute and the relative value of foreign production in Indonesian manufacturing. Figure 1 shows the real value added by foreign firms in 1996 by province. The map indicates significant regional variation and shows the absolute level of foreign output to be very large. For ex-

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ample, the value added by multinational manufacturing in the province of Riau (the closest province to Singapore and home to the Batam bonded zone) is 2,335 billion rupiah, or about 10 percent of the province GDP. Large foreign investment from 1988 to 1996 in chemicals, plastics, electronics assembly, textiles, garments, and footwear dramatically increased the foreign output in many areas. Figure 2 shows the foreign share of manufacturing value added in 1988 and 1996, respectively, by province. In many regions the foreign share of value added increased dramatically from 1988 to 1996 and accounted for more than half of the total in 1996.

4. Data and Measurement

The analysis is based on data from the Republic of Indonesia’s *Budan Pusat Statistik* (BPS), the Central Bureau of Statistics.⁵ The primary data are taken from an unpublished annual survey of manufacturing establishments with more than 20 employees conducted by *Biro Statistik Industri*, the Industrial Statistics Division of BPS. Additional data include the input-output table and several input and output price deflators. The remainder of this section describes each dataset and the measurement of firm learning from vertical FDI.

4.1. Sources

The principal dataset is the *Survei Tahunan Perusahaan Industri Pengolahan* (SI), the Annual Manufacturing Survey conducted by the Industrial Statistics Division of BPS. The SI dataset is designed to be a complete annual enumeration of all manufacturing establishments with 20 or more employees from 1975 onward. Depending on the year, the SI includes up to 160 variables covering industrial classification (5-digit ISIC), ownership (public, private, foreign), status of incorporation, assets, asset changes, electricity, fuels, income, output, expenses, investment, labor (head count, education, wages), raw material use, machinery, and other specialized questions.

BPS submits a questionnaire annually to all registered manufacturing establishments, and field agents attempt to visit each non-respondent to either encourage compliance or confirm that the establishment has ceased operation.⁶ Because

⁵We identify names in Bahasa Indonesia, the language of most government publications, with italics. Subsequently, we use the English equivalent or the acronym.

⁶Because some firms may have more than one factory, we henceforth refer to each observation

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field office budgets are partly determined by the number of reporting establishments, agents have some incentive to identify and register new plants. In recent years, over 20,000 factories have been surveyed annually. Government laws guarantee that the collected information will only be used for statistical purposes. However, several BPS officials commented that some establishments intentionally misreport financial information out of concern that tax authorities or competitors may gain access to the data. Because the fixed-effect analysis admits only within-factory variation on a logarithmic scale, errors of under- or over-reporting will not bias the results provided that each factory consistently misreports over time. Further, even if the degree of misreporting for a factory varies over time, the results are unbiased provided the misreporting is not correlated with other factory attributes in the right-hand-side of the regression.

Not surprisingly, particularly in a developing country environment, there is a high level of non-reporting and obvious erroneous responses to many of the survey questions, particularly questions that require some accounting expertise, such as the replacement and book value of fixed assets. We have cleaned key variables to minimize noise due to non-reporting, misreporting, and obvious mistakes in data keypunching as described in Appendix B.

The analysis here starts from 1988, the first year data on fixed assets are available. To avoid measurement error in price and other uncertainties introduced by the 1997-1998 Asian financial crisis, the last year of analysis is 1996. The key variables are described in Appendix A and summarized for 1988 and 1996 in Table 1.⁷ The table indicates a large increase in the number of foreign factories, which increases from 118 in 1988 to 322 in 1996. On average, foreign factories are bigger (as measured by value added, employees, and capital), more capital intensive (as measured by capital per employee), more productive (as measured by value added per employee), and more export-oriented (as measured by percentage of production exported).

We derived inter-industry supply chains using input-output (IO) tables that BPS published in 1990 and 1995. The tables show the value added of goods and services produced by economic sector and how this value is distributed to other

as an establishment, plant, or factory. BPS also submits a different questionnaire to the head office of every firm with more than one factory. Although these data were not available for this study, early analysis by BPS suggests that less than 5 percent of factories belong to multi-factory firms.

⁷The descriptive statistic tables show the data actually used in the analysis. Observations removed in the data cleaning and plants in finished goods sectors are not included.

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economic sectors. The IO tables divide manufacturing activity into 89 sectors and BPS provides concordance tables linking the 1990 and 1995 IO codes to 5-digit ISIC codes as described in Appendix B.

We deflated output, materials, and capital to express values in real terms. The deflators are based on *Indeks Harga Perdagangan Besar* (IHPB), wholesale price indexes (WPI), published by BPS. Appendix B describes the deflator calculation in detail.

4.2. Measurement

The analysis estimates a production function to reveal the effect of changes in downstream vertical FDI on establishment productivity over time. A positive contribution from vertical FDI suggests a transfer of technology through supply chains.

Below we describe the calculation of vertical FDI, a proxy for supply chain transactions, and the econometric identification of technology transfer.

We use the IO tables together with the SI to calculate vertical FDI, the proportion of an industry’s output purchased by downstream multinational manufacturers, or equivalently, the percentage of foreign ownership in downstream industries. The measure of vertical FDI varies by industry, region, and time. The approach appeals to Indonesia’s vast island geography and poor inter-region transportation infrastructure in assuming local markets, i.e., that intermediate goods output is consumed by firms in the same region. We consider each of Indonesia’s 27 provinces to be a separate region, thereby not confounding vertical FDI with the unlikely flow of goods between distant provinces. However, by-province does not capture the flow of goods between factories close to the border of neighboring provinces. To ensure this restriction does not substantially affect the analysis, we have also calculated vertical FDI without the assumption of local markets. The results do not fundamentally change, but the effect of vertical FDI is more muted.

We determine vertical FDI by industry and region, rather than by factory, for two reasons. First, estimation with industry and region measures of vertical FDI avoids the endogeneity of a particular factory’s decision to sell to multinational customers. Second, the data do not reveal which specific factories supply multinational manufacturers.

We calculate *Vertical_FDI* by summing the output shares purchased by manufacturing sectors multiplied by the share of foreign output, *Foreign_Share*, in those sectors. For example, suppose that half of the wheat flour sector output is

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purchased by the bakery industry and the other half is purchased by the pasta industry. Further, suppose that the bakery industry has no foreign factories but that foreign factories produce half of the pasta sector output. The calculation of vertical FDI for the flour sector would yield $0.25 = 0.5(0.0) + 0.5(0.5)$. Equations 1 and 2 express the calculation for sector j , region r , at time t .

$$Foreign_Share_{jrt} = \frac{\sum_{i \in jrt} Foreign_OUTPUT_{it}}{\sum_{i \in jrt} OUTPUT_{it}} \quad (1)$$

$$Vertical_FDI_{jrt} = \sum_k \alpha_{jkt} Foreign_Share_{jrt} \quad (2)$$

where $i \in jrt$ indicates a factory in a given sector, region, and time, $OUTPUT_{it}$ is the output of factory i , and $Foreign_OUTPUT_{it}$ is the output of factory i if the factory is foreign, and zero otherwise, and $0 \leq \alpha_{jkt} \leq 1$ is the proportion of sector j output consumed by sector k . Values of α_{jkt} before and including 1990 follow from the 1990 IO table, values of α_{jkt} from 1991 through 1994 are linear interpolations of the 1990 and 1995 IO tables, and values of α_{jkt} from 1995 on are from the 1995 IO table. Recall that α_{jkt} does not have a region r subscript because the IO table is generated for the entire national economy.

Table 2 shows the values of $Vertical_FDI$ in 1988 and 1996 and the between- and within-factory standard deviation for the 39 industries (described later in this section) analyzed. To reduce its size for display, Table 2 reports $Vertical_FDI$ at the national level (removing the local market assumption by collapsing all regions into one). The standard deviations in the table and the values of $Vertical_FDI$ using in the analysis, however, are calculated at the regional level (assuming that intermediate goods are purchased in the region in which they are produced).

We obtain establishment-level productivity measures by estimating a translog production function.

$$\begin{aligned} \ln Y_{it} = & \beta_0 Vertical_FDI_{jrt} + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 \ln M_{it} + \\ & \beta_4 \ln^2 K_{it} + \beta_5 \ln^2 L_{it} + \beta_6 \ln^2 M_{it} + \\ & \beta_7 \ln K_{it} \ln L_{it} + \beta_8 \ln K_{it} M_{it} + \beta_9 \ln L_{it} M_{it} + \\ & \alpha_i + \gamma_t + \varepsilon_{it} \end{aligned} \quad (3)$$

where Y_{it} , K_{it} , L_{it} , and M_{it} are the amounts of production output, capital, labor, and raw materials for establishment i at time t , α_i is a fixed effect for factory i , and γ_t is a dummy variable for year t . A positive coefficient on $Vertical_FDI_{jrt}$

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indicates that downstream vertical FDI is associated with higher productivity. Output, capital, and materials are nominal rupiah values deflated to 1983 rupiah. Labor is the total number of production and non-production workers. We initially assume that ε_{it} is *i.i.d.*, but we later control for simultaneity bias that may arise if ε_{it} is correlated with other right-hand-side variables.

We estimate Equation 3 on a sample of locally owned factories in intermediate goods industries. Final goods industries, by definition, could not benefit from supply chain linkages to foreign manufacturers because they do not sell to other manufacturing sectors.

A sample of intermediate goods industries has two advantages over a sample of all industries. First, it reduces truncation of *Vertical_FDI* that occurs if industries do sell to foreign buyers that are not manufacturers. For example, the concrete industry may sell to foreign construction firms, or the garment industry may sell to foreign retailers. However, because the data do not reveal the level of foreign ownership outside of manufacturing sectors, this downstream FDI cannot be observed. Second, a sample of intermediate industries allows better matching of the treatment industry-region groups (those industry-regions groups with growing downstream FDI) and the control industry-region groups (those industry-region groups without growing downstream FDI). In particular, the value of *Vertical_FDI* is upwardly bound by $\sum_k \alpha_{jkt}$, the fraction of a sector's output consumed by other manufacturing sectors. Because the upward bound on *Vertical_FDI* is low for final goods industries, they are necessarily control groups and would be compared with treatment groups that are necessarily intermediate goods industries. Fundamental differences in final and intermediate goods industries, such as exposure to export markets (finals goods in Indonesia are often exported), suggest that the two groups are not well suited for comparison. A sample of just intermediate goods sectors allows comparison of treatment and control industry-region groups that are more closely matched.

We define intermediate goods industries as the 39 sectors that sold 50 percent or more of their output to other manufacturing sectors as indicated in either the 1990 or 1995 IO table. The results are robust to percentage definitions of intermediate goods sectors. As the sample becomes more inclusive, the coefficient on *Vertical_FDI* becomes less pronounced, but remains statistically significant even on a sample of all industries.

5. Results

Table 3 reports the results of estimating Equation 3 using an establishment-level fixed-effect estimator.⁸ To remain consistent with prior studies, which generally use a Cobb-Douglas production function, we first adopt the same functional form by constraining the coefficients of the higher-order terms, β_4 - β_9 , to be zero. Column (1) shows the Cobb-Douglas estimation results with a sample of both local and foreign establishments, with a variable indicating the proportion of foreign establishment equity, *Foreign_Equity*, added to control for the direct effect of FDI within a factory. Column (2) shows the results with only domestic establishments, a sample that removes any technology transfer from foreign buyers to foreign suppliers, e.g., learning by Japanese suppliers that may have followed Japanese buyers in expanding production to Indonesia. Not surprisingly, the coefficient on *Foreign_Equity* is positive and significant, indicating that an increase in foreign ownership is correlated with an increase in factory productivity. The positive and significant coefficient on *Vertical_FDI* in both indicates that greater productivity is associated with downstream FDI.

We next estimate the translog functional form on a sample of all factories and only domestic factories, respectively. That is, the coefficients of the higher-order terms, β_4 - β_9 , are no longer constrained to be zero. Because the translog functional form relaxes the assumptions of unitary elasticity of substitution and linear returns to scale imposed by the Cobb-Douglas, it more accurately reflects the production possibility frontier. This flexibility allows the translog estimation to more fully control for economies of scale—which might otherwise be false attributed to productivity gains if the added demand from foreign buyers increases local supplier output. Columns (3) and (4) show the results of the translog estimation, again with the populations of all factories and only domestic factories, respectively. The higher-order input terms are jointly significant, indicating that the Cobb-Douglas estimation is not fully specified, and the coefficient of *Vertical_FDI* also indicates a positive effect on productivity.

Although the correlation between the level of downstream vertical FDI and plant productivity is consistent with the hypothesis that supply chain linkages are a conduit for technology transfer, there are a number of possible alternative explanations. First, the analysis could be biased by unobserved error terms that simultaneously determine both measured productivity and FDI. That is, FDI

⁸A Hausman test showed significant correlation between individual establishment effects and the other regressors, thereby rejecting a random-effects model.

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could be the *result* of, not the *cause* of changes in supplier productivity. Second, productivity gains could be the result of non-technological externalities, such as the provision of roads, ports, and other public goods. Third, the same results could be obtained if the mechanism for technology transfer were exposure to export markets, which might be correlated with downstream FDI. We address each alternative explanation below. Further, we decompose the effect of vertical FDI on local firm output volume into gains from productivity improvement and gains from increased factor use. The decomposition shows that vertical FDI increases local firm output both by greater demand and by higher productivity.

5.1. Simultaneity Bias in Vertical FDI and Olley-Pakes Estimation

The positive correlation between vertical FDI and domestic factory productivity could result from multinationals selectively locating in areas where supplier productivity was improving. That is, productivity shocks could simultaneously determine vertical FDI and measured performance. Fixed-effect estimation allows some establishments to be inherently more productive than others, but assumes that conditions that make some factories “better” remain unchanged. Suppose, however, that establishments were affected by productivity shocks during the interim of the panel. Such a shock, *e.g.*, the hiring of a skilled manager or the discovery of a better production technique, is potentially observable to both the supplier and potential investors, but would remain unobservable to the econometrician. If either local factories or multinationals reacted to those shocks by adjusting inputs or investment, then the error term in Equation 3 would not be independent of other right-hand-side variables. Of particular concern, such simultaneity would introduce correlation between the error term ε_{it} and $Vertical_FDI_{it}$.

The error term in Equation 3 can be decomposed to show the potential sources of productivity shocks:

$$\varepsilon_{it} = \epsilon_i + \epsilon_{jt} + \epsilon_{rt} + \epsilon_{it}$$

One can consider the error term for factory i at time t to consist of four (and potentially more) sources of error: ϵ_i , a static “fixed-effect for factory i ,” ϵ_{jt} , a shock to industry j at time t , ϵ_{rt} , a shock to region r at time t , and a fully idiosyncratic shock, ϵ_{it} , affecting factory i at time t . The fixed-effect estimator controls for the error term ϵ_i by only admitting variation about a factory’s mean. We control for the industry and region shocks, such as sudden price changes in key inputs, political strife, or government intervention, by including dummy variables for the interaction of year and industry or the interaction of year and

region. The results with each set of dummy variables were largely unchanged, but the interactive terms were jointly non-zero and suggest that industry and region shocks have significant effects.

Other variation in the error terms, such as a factory-specific shock or a shock to a particular industry in a particular region, is captured in the idiosyncratic error term, ϵ_{it} . In practice, it seems unlikely that ϵ_{it} would be correlated with *Vertical_FDI*; the long lead time and high transaction costs of investment and contracting with suppliers suggest that multinationals would invest in industries and regions which offered long-term productivity growth potential rather than chasing transient boosts to supplier performance. Further, if supply markets are competitive, shocks affecting just one supplier may have little effect on market prices. Nonetheless, the possibility of bias remains. Moreover, unobserved productivity shocks could be correlated with other inputs, such as capital, although the direction of such a simultaneity bias on the *Vertical_FDI* coefficient is not clear.

A number of recent papers have proposed using proxies for productivity shocks to correct for simultaneity bias. Possible proxies include investment (Olley and Pakes 1996) and intermediate input use, such as electricity (Levinsohn and Petrin 2000). Both the Olley-Pakes and Levinsohn-Petrin estimators identify the contribution of productivity shocks, first by showing that the shock proxy (investment or intermediate inputs) is monotonically increasing with respect to the shock, and second by proposing that some inputs, like labor, will respond immediately to a shock while other variables, like capital, will respond only after an adjustment lag. Appendix C summarizes the Olley-Pakes estimation approach.

Column (7) of Table 3 shows the results of the Olley-Pakes estimation using a Cobb-Douglas production function. Because the estimation uses investment as a proxy for productivity shocks, it is only properly identified for observations with investment greater than zero. Hence, the sample is reduced by about half to retain only observations with positive investment.⁹ Simultaneity in fixed-effect regression typically biases the coefficient of capital downward. Indeed, the Olley-Pakes estimation shows a much higher return to capital compared to the fixed-effect estimation. The coefficient on *Vertical_FDI* is larger, although not significantly different than that of the fixed-effect estimation. The larger coefficient likely reflects the attenuation bias of fixed-effect estimation in the presence of measurement

⁹An advantage of the Levinsohn-Petrin estimator is that it uses intermediate inputs, which is positive for nearly all observations, as the proxy for the shock and therefore does not reduce the sample size.

error.

5.2. Public Goods

The correlation between vertical FDI and local plant productivity could be explained by multinationals' provision of public goods rather than by technology transfer. For example, if multinational entry leads to the building of new roads or the installation of more reliable electricity-generating facilities, then local firm productivity may increase *without* any transfer of technology. Since the provision of these public goods would likely be correlated with downstream FDI, analysis could erroneously attribute local firm gains from public goods to technology transfer.

To test for the role of public goods, we assume that all plants would benefit from the provision of roads, bridges, ports, etc. Although some industries would benefit more than others, this proposition seems reasonable on the grounds that public goods are non-excludable. To separate the effects of vertical FDI from public goods, we include only finished goods sectors, which were dropped in the general analysis, in the sample. Because establishments in finished goods sectors sell nearly all of their output to non-manufacturing sectors, they cannot benefit from vertical FDI in manufacturing. Hence, any benefit from FDI would likely derive from public goods. We then estimate Equation 3 substituting $Region_FDI_{rt}$, the share of foreign firm share of industrial output in all industries, for $Vertical_FDI_{jrt}$. Column (5) of Table 3 shows the insignificant coefficient on $Region_FDI$, indicating that public goods do not have a major impact on local firm productivity.

5.3. Exports

The results so far reveal only the effect on local firms supplying multinationals that operate *within* Indonesia. Many of the mechanisms for technology transfer, however, would also benefit local firms that exported. Indeed, one would expect some correlation between local firms that supply multinationals within the country and local firms that export. To the extent that local exporters produce products of international quality and price, in-country multinationals would be likely to select them as suppliers. Further, to the extent that local suppliers learn from multinational customers and improve quality and price, they are more able to export successfully to global markets. Indeed, the interviews suggested that

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multinational customers may sometimes assist their local suppliers in accessing export markets.

To remove any effects of exporting, we estimated Equation 3 on a sample of only *never-exporting* domestic firms. Column (6) of Table 3 shows that the positive effect of vertical FDI holds and suggests that exports are not a viable alternative explanation to technology transfer through supply chains.

5.4. Decomposition of the Effect of FDI

Policymakers may be interested not only in the productivity gains from FDI, but also in the production volume gains. To reveal the full impact of FDI on local factory output, we totally differentiate the production function to decompose the effect of FDI into four components: the contributions through demand-driven changes in capital, labor, and materials usage, and the contribution through technology acquisition. Consider the following Cobb-Douglas production function (dropping factory and year subscripts, and factory and year fixed effects for simplicity):

$$\ln Y = \beta_1 \ln K + \beta_2 \ln L + \beta_3 \ln M + \beta_4 \textit{Vertical_FDI} + \varepsilon \quad (4)$$

Now estimate reduced-form regressions of the effect of vertical FDI on output and inputs (rewriting *Vertical_FDI* as *VFDI*).

$$\ln Y = \lambda_{Y0} + \lambda_{Y1} VFDI + \epsilon_Y \quad (5)$$

$$\ln K = \lambda_{K0} + \lambda_{K1} VFDI + \epsilon_K \quad (6)$$

$$\ln L = \lambda_{L0} + \lambda_{L1} VFDI + \epsilon_L \quad (7)$$

$$\ln M = \lambda_{M0} + \lambda_{M1} VFDI + \epsilon_M \quad (8)$$

Totally differentiating Equation 4 with respect to *VFDI* yields:

$$\frac{d \ln Y}{d VFDI} = \beta_1 \frac{\partial \ln K}{\partial VFDI} + \beta_2 \frac{\partial \ln L}{\partial VFDI} + \beta_3 \frac{\partial \ln M}{\partial VFDI} + \beta_4 d VFDI \quad (9)$$

Recognizing that $\frac{d \ln Y}{d VFDI} = \lambda_{Y1} d VFDI$ by differentiating Equation 5, $\frac{\partial \ln K}{\partial VFDI} = \lambda_{K1} d VFDI$ by differentiating Equation 6, and so on, we can rewrite Equation 9

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as

$$\begin{aligned}\lambda_{Y1}dVFDI &= \beta_1\lambda_{K1}dVFDI + \beta_2\lambda_{L1}dVFDI + \beta_3\lambda_{M1}dVFDI + \beta_4dVFDI \\ \lambda_{Y1} &= \beta_1\lambda_{K1} + \beta_2\lambda_{L1} + \beta_3\lambda_{M1} + \beta_4\end{aligned}$$

Taking the coefficient values from the reduced form regressions gives:

$$.348 = .091(.217) + .297(.089) + .613(.308) + .114$$

The value of β_4 , 0.114, is about a third of the total effect of *Vertical FDI*, 0.348. Extrapolating from the mean (an approximation, since the coefficients are for the neighborhood about the mean), these coefficients indicate that domestic firms, on average, experience about 35 percent growth in output as the share of output sold to foreign buyers goes from zero to 100 percent. A substantial portion of this output growth, about a third, is due to gains in technology rather than increased demand.

In many of the intermediate goods industries in the analysis sample, the increase in *Vertical FDI* from 1988 to 1996 is substantial. Table 2 shows the level of vertical FDI, calculated at the national level, by industry for 1988 and 1996. The table shows increases of over 20 percent for vertical FDI in the pulp, knitting mills, electrical appliances, textile, prime movers and engines, electric generator, and electrical motor sectors. Extrapolating from the mean again, the results estimate that the output of these sectors grew over 1.6 percent based on productivity gains from vertical FDI and over 3.2 percent based on increased demand.

6. Industry Effects

The section examines which industries are the likely recipients of technology transfer from vertical FDI by dividing the pooled sample of all intermediate goods industry factories into groups belonging to similar sectors. A division offers two benefits: it reveals the which industries are the largest beneficiaries from vertical FDI and it relaxes the constraint, imposed by the pooled regression, of uniform returns to inputs across industries.

The analysis above pools factories in all industries. The advantage of a pooled cross-industry sample is that provides high variation in vertical FDI. Recall that the vertical FDI is calculated by industry, region, and year. Because the estimation uses fixed-effect estimation, only the variation about a factory's mean, or within variation, is admitted. If the estimation sample was limited to firms in just one

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industry, the only between observation variation in vertical FDI would be by region. That is, one would take factories in regions with changes in vertical FDI over time as the treatment group, and other provinces with no changes in vertical FDI as the control group. In practice, we use Indonesia’s 27 provinces as regional indicators and many industries are concentrated in only a few provinces. Thus, there is insufficient variation between provinces for a statistically powerful test. Further, if there is little change in vertical FDI in the industry, there may be insufficient within variation. To increase variation, we have pooled all industries together. The estimation then takes some industries as treatment groups and some industries as control groups.

A pooled sample, however, has two disadvantages. First, because the effect of vertical FDI is also constrained to be uniform across industries, one cannot see *which* industries benefiting from vertical FDI. Rather, one can only observe the overall effect. Second, it constrains the return to inputs to be constant across industries. It may be unreasonable to assume that the marginal product of capital or labor is uniform across industries as varies as fish processing and electronics assembly. Such a constraint could bias the results, although it is not obvious in what direction.

To balance the need for variation in vertical FDI and the desire to have industries with similar technologies in the treatment and control group, we have divided the full sample into three groups: a food group, a textile group, and an electronics group.¹⁰ Each group comprises several of the 39 input-output table industry codes upon which the calculation of vertical FDI was based. Industries without sufficient variation, either within or between, in vertical FDI, or with few observations were not included. Hence, a number of industries, such as paper, chemicals, or metals could not be included in a group. Table 4 show the results of estimating Equation 3 on the three samples.

The results indicate a strong benefit from vertical FDI in the food and electronics sector. The effect for the textile sector is positive, but not statistically significant.

7. Summary and Implications

Both the econometric analysis and the manager interviews suggest that vertical supply chains are a conduit for technology transfer from FDI. Indonesian factories

¹⁰These groups correspond to the 31, 32, and 38 2-digit ISIC codes respectively, which span several IO codes each.

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in industries in regions with growing downstream vertical FDI experience greater productivity growth, *ceteris paribus*, than other factories. This finding is consistent with the incentives of multinational enterprises, which only realize the full benefit of investment abroad if they can procure high-quality inputs at low cost. To build efficient supply chains overseas, many multinationals will strategically transfer technology to local vendors. We conclude that considering only horizontal spillover underestimates technology transfer from FDI.

To the extent that evidence from Indonesia can be generalized, vertical technology transfer has a clear implication for multinational firm expansion strategy: foreign manufacturers that locate near clusters of other multinationals procuring similar inputs may benefit from a supply chain externality. Much of what local suppliers have learned from their foreign customers will allow them to provide higher-quality goods at lower prices to new customers as well. Although some multinationals may seek to limit this externality by vertically integrating with suppliers or negotiating exclusive contracts, such behavior is likely to be limited. Rather, as suggested by the manager interviews, many multinationals will encourage their suppliers to transact with other foreign buyers because doing so may further improve the suppliers' productivity, increase their economies of scale, and smooth demand.

The implication for policymakers is that technology transfer is a real benefit of FDI. One should be more agnostic, however, with respect to policies that *encourage* FDI—all of the technology transfer identified in this study is internal to supply chain transactions, and the benefits are realized by the supplier and the buyer. The private returns equal the public returns, and there is no need for government intervention in principle. In practice, however, policymakers may wish to encourage FDI for other reasons. Further, government intervention may be sensible in cases in which market failures prevent private contracting from capturing the benefits of vertical technology transfer. For example, if local suppliers benefit from FDI, then collectively they should be willing to entice multinational entry with payment up to the value of the technology they anticipate acquiring. The coordination mechanisms, contracts, and access to credit needed to organize such a deal and prevent free-riding, however, may be absent, particularly in an emerging market, and government intervention may be needed to correct market failures.

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A. Industrial Survey

A.0.1. Product Class, Location, and Age

The main product class of each establishment is identified by 5-digit International Standard of Industrial Classification (ISIC) codes published by the United Nations Industrial Development Organization (UNIDO). The ISIC standard divides manufacturing activity into 329 codes at the 5-digit level.¹¹ The data include plant age and location at the province and *kabupaten* district level. The province and district codes divide the country into 27 and 304 areas respectively. The analysis in this paper uses province to identify region.¹²

A.0.2. Ownership

Two survey questions relate to establishment ownership. First, establishments report whether they operate under a domestic or a foreign investment license. All new enterprises in Indonesia must obtain an operating license from *Badan Koordinasi Penanaman Modal* (BKPM), the Investment Coordinating Board. Establishments funded with any foreign investment operate under *Penanaman Modal Asing* (PMA), foreign capital investment licenses. Establishments with only domestic investment obtain *Penanaman Modal Dalam Negeri* (PMDN), wholly domestic capital investment licenses. Second, each establishment reports the percentage of foreign equity.¹³ Establishments with more than 20 percent foreign equity were defined as foreign. This definition yielded a sample of foreign factories very similar to those operating with PMA licenses. Estimation with foreign plants defined as those with any foreign equity, or those with more than 50 percent foreign equity, yielded nearly identical results.

A.0.3. Capital

The survey asks for the book value and current replacement value of fixed assets. Respondents report assets in five categories: land, buildings, machinery and

¹¹ISIC codes are revision 1 codes prior to 1990 and revision 2 codes thereafter. The method of concordance between the two revisions is discussed in Appendix B.

¹²Following the independence of East Timor, there are now 26 provinces and 291 districts.

¹³The source country of foreign capital is reported only in the 1988 survey. Although the survey instruments asked for this information in most years, BPS keypunched the responses in just 1988. Sadly, BPS has destroyed the original paper survey responses, so this information cannot be retrieved.

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equipment, vehicles, and other assets. The value of investment is also reported yearly.

A.0.4. Labor and Wages

The numbers of production and non-production workers are reported in all years. Workers are categorized as either paid or unpaid (*e.g.*, family members). In many years, the labor force is broken down by gender. In 1995-1997, the highest level of education obtained by all workers is available. In 1996, the highest degree and field of specialization for research and development workers is recorded.

Cash and in-kind wages are available for production and non-production workers in all years. In most years, wage payments are detailed in four categories: normal wages, overtime, gifts and bonuses, and other payments.

A.0.5. Materials

The value of all consumed materials is reported every year. The data also indicate the quantity and price of consumed petroleum products, *e.g.*, gasoline and lubricants, and purchased and self-generated electricity.

A.0.6. Output

The nominal rupiah value of production output is available every year.

B. Data Processing

This section provides more detail on the construction and cleaning of the dataset.

B.1. Construction of Price Deflators

Output, materials, and capital are deflated to express values in real terms. The deflators are based on *Indeks Harga Perdagangan Besar* (IHPB), wholesale price indexes (WPI), published monthly in BPS's *Buletin Statistik Bulanan Indikator Ekonomi*, the Monthly Statistical Bulletin of Economic Indicators. To calculate WPI, BPS field officers interview representative firms in all provinces to collect prices for five categories of commodities: agriculture, manufacturing, mining and quarrying, imports, and exports. In total, prices are available for 327 commodities, 192 of which are manufactured commodities.

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B.1.1. Output and Materials Deflators

Nominal rupiah output and materials values are deflated using the WPI for the nearest corresponding manufactured commodity. BPS officials provided an unpublished concordance table mapping the 192 WPI commodity codes to the 329 5-digit ISIC product codes.

B.1.2. Capital Deflators

Fixed assets are deflated using the WPI for manufactured construction materials and imported machinery. Specifically, the capital deflator combines the WPI for construction materials, imported electrical and non-electrical machinery, and imported transportation equipment. I weighted these price indexes by the average reported value shares of building and land, machinery, and vehicle fixed assets in the SI survey to obtain an annual capital deflator.

B.2. Correction for Outliers and Missing Values in Industrial Survey

I have cleaned key variables to minimize noise due to non-reporting, misreporting, and obvious mistakes in data keypunching. A three-stage cleaning process was used for capital, labor, materials, and labor. First, the earliest and latest years in which a plant reported were identified and interpolation was used to fill-in up to two subsequent missing years within the reporting window. If more than two subsequent years of data were missing, the factory was dropped from the sample. The first stage of cleaning removed about 15 percent of the total sample. Second, sudden jumps or drops in key data values likely attributed to keypunch error (often due to a spurious or omitted zero) were corrected with interpolation. Third, plants with remaining unreasonably large jumps or drops in key variables that were accompanied by corresponding movement in other inputs (for example, enormous increases in labor not accompanied by any increase in output) were dropped. This third stage removed about 10 percent of the sample.

The replacement value of fixed assets is used as the measure of capital stock for most factories. For the few factories that reported only the book value of fixed assets, those figures were used instead.

The percentage of foreign equity in the establishment was cleaned to remove spurious or omitted zeros from keypunch error. For example, a factory with foreign equity reported over time as 100, 100, 10, and 100 percent was cleaned to show 100 percent in all years.

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B.3. Concordance of Rev. 1 and Rev. 2 ISIC Codes

The industrial survey reports revision 1 ISIC codes prior to 1990 and revision 2 codes thereafter. Attempts to create a concordance table at the 5-digit level from rev. 1 to rev. 2 codes yielded disappointing results. Comparing code changes for the same establishment before and after 1990 showed that the concordance table predictions were incorrect as often as half the time. Rather than accept the noise introduced by these mistakes, the analysis attempts to assign each establishment's actual rev. 2 code to its observations in 1988-1989. Specifically, for each establishment that appears in either 1988 or 1989, the analysis looks for the earliest appearance of the same establishment in 1990 and later years. In most cases, the rev. 2 code from the 1990 observation could be used. If the establishment did not appear in 1990, the rev. 2 code from 1991 or 1992 was used. If the establishment did not appear between 1990 and 1992, it was dropped. This process greatly improved the precision of ISIC code assignments at the cost of dropping about 5 percent of the 1988-1989 sample. Since the dropped establishments appear in only one or two years anyway, the 5 percent loss has little effect on the results.

B.4. Concordance of Input-Output Table Code and ISIC Codes

The IO table was published in 1990 and 1995 with four variants: domestic transactions at producer prices, domestic transactions at purchaser prices, domestic and export transactions at producer prices, and domestic and export transactions at purchaser prices. The analysis here considers domestic transactions at producer prices.

Both the 1990 and 1995 IO tables classified industrial production into 89 categories. To merge the IO table with the SI, first the 1995 IO table codes were concorded with the 1990 IO table codes. Next, the 1990 IO table codes were concorded with the 329 5-digit ISIC codes reported in the SI. The 1990 IO codes were used to define industry in the paper analysis.

C. Olley-Pakes Estimation

Although a full description of Olley-Pakes estimation is beyond the scope of this paper (interested readers are referred to [Olley and Pakes 1996](#)), the steps implemented here are briefly outlined below.¹⁴

The Olley-Pakes estimation consists of three stages. First, investment is used as a proxy for idiosyncratic shocks to determine the contribution of variable inputs (labor and materials) conditional on the shock and state variables (capital and vertical FDI). Second, the effect of state variables on factory exit is estimated with a probit model to control for self-selection bias in plant closings. The concern here is that factories with certain state attributes, such as low levels of capitalization, may be more likely to close if they experience a negative shock. Third, the contribution of state variables is calculated conditional on the prior period's shock and the likelihood of closure. The assumption driving the identification in this stage is that state variables respond to shocks in lagged manner. That is, the unexpected portion of the current period shock is does not immediately affect capital or vertical FDI. Rather, only investment in the current period, which yields capital or vertical FDI in the subsequent period, is affected.

STAGE 1

The estimation starts with a Cobb-Douglas production function

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_m m_{it} + \beta_k k_{it} + \beta_v \text{Vertical_FDI}_{jrt} + \omega_{it} + \eta_{it} \quad (10)$$

where ω_{it} is the factory's idiosyncratic productivity shock (that could affect the factory's choice of freely variable inputs) and η_{it} is measurement error (or error that does not affect the factory's choice of inputs), and lower case variable names represent logs. Olley and Pakes show that investment is monotonically increasing in ω_{it} and can hence be used as a proxy for the shock conditional on state variables. That is, investment, i , can be expressed as function of the state variables and the shock.

$$i_{it} = i_{it}(\omega_{it}, k_{it}, \text{Vertical_FDI}_{jrt}) \quad (11)$$

Provided that $i_{it} > 0$, investment can be inverted to reveal ω_{it} .

$$\omega_{it} = h_{it}(i_{it}, k_{it}, \text{Vertical_FDI}_{jrt}) \quad (12)$$

¹⁴The analysis here follows the Olley-Pakes estimation implementation in [Pavcnik 2001](#).

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Conditioning output on ω_{it} and the state variables yields the following semi-parametric estimation.

$$y_{it} = \beta_l l_{it} + \beta_m m_{it} + \phi_{it}(i_{it}, k_{it}, Vertical_FDI_{jrt}) + \eta_{it} \quad (13)$$

where

$$\begin{aligned} \phi_{it}(i_{it}, k_{it}, Vertical_FDI_{jrt}) = & \beta_0 + \beta_k k_{it} + \beta_v Vertical_FDI_{jrt} + \\ & h_{it}(i_{it}, k_{it}, Vertical_FDI_{jrt}) \end{aligned} \quad (14)$$

Since the error term η_{it} is uncorrelated with the inputs, estimation of Equation 13 provides unbiased estimates of β_l and β_m . I use a third-order polynomial expansion in i_{it} , k_{it} , and $Vertical_FDI_{jrt}$ to estimate ϕ_{it} .

STAGE 2

The second stage considers factories' decision each period of whether to continue operation or exit the market, and then calculates the returns to the quasi-fixed inputs. Factories will continue operation only if the expected value of continuing operation exceeds the liquidation value of the assets. Conditional on the state variables, the expected value of a continued operation will increase monotonically with the factory's productivity. Hence, the factory's decision to continue or exit can be expressed in terms of its productivity: the factory will operate only if its productivity is greater than a threshold level, $\varpi_{it}(k_{it}, Vertical_FDI_{jrt})$, that is revealed at the beginning of each period. Otherwise, the factory will sell its assets and exit. Letting $\chi_{it} = 1$ if factory i survives in period t and $\chi_{it} = 0$ if it exits, one can estimate survival probabilities.

$$\begin{aligned} Pr\{\chi_{it+1} = 1 | \varpi_{it}(k_{it}, Vertical_FDI_{jrt})\} & \\ = Pr\{\omega_{it+1} > \varpi_{it}(k_{it}, Vertical_FDI_{jrt}) | \varpi_{it+1}(k_{it}, Vertical_FDI_{jrt}, \omega_{it})\} & \\ = \rho_{it}\{\varpi_{it+1}(k_{it}, Vertical_FDI_{jrt}, \omega_{it})\} & \\ = \rho_{it}(i_{it}, k_{it}, Vertical_FDI_{jrt}) & \\ \equiv P_{it} & \end{aligned} \quad (15)$$

The third equality follows from the fact that both the factory's exit productivity threshold, ϖ_{it+1} , and productivity shock, ω_{it} , are functions of i_{it} , k_{it} , and $Vertical_FDI$. I estimate P_{it} by performing a probit regression of χ_{it} on a third order polynomial expansion of i_{it} , k_{it} , and $Vertical_FDI_{jrt}$.

I must still obtain estimates β_k and β_v conditional on ω and survival. Consider the expectation of $y_{t+1} - \beta_l l_{t+1} - \beta_m m_{t+1}$, the output less the contribution of labor

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and materials (calculated in the first stage), conditional on capital, vertical FDI, and survival.

$$\begin{aligned}
& E[y_{t+1} - \beta_l l_{it+1} - \beta_m m_{it+1} | k_{it+1}, \text{Vertical_FDI}_{jrt+1}, (\chi_{it+1} = 1)] \\
&= \beta_0 + \beta_k k_{it+1} + \beta_v \text{Vertical_FDI}_{jrt+1} + E[\omega_{it+1} | \omega_{it}, \chi_{it+1} = 1] \\
&= \beta_0 + \beta_k k_{it+1} + \beta_v \text{Vertical_FDI}_{jrt+1} + g(\varpi_{it+1}, \omega_{it})
\end{aligned} \tag{16}$$

where $g(\varpi_{it+1}, \omega_{it})$ is the expectation of ω_{it+1} conditional on the prior period productivity and survival. Inverting ρ_{it} to reveal ϖ_{it+1} gives:

$$\begin{aligned}
g(\varpi_{it+1}, \omega_{it}) &= g[\rho_{it}^{-1}(P_t, \phi_{it} - \beta_k k_{it} - \beta_v \text{Vertical_FDI}_{jrt}), \phi_{it} \\
&\quad - \beta_k k_{it} - \beta_v \text{Vertical_FDI}_{jrt}] \\
&\equiv g(P_t, \phi_{it} - \beta_k k_{it} - \beta_v \text{Vertical_FDI}_{jrt})
\end{aligned} \tag{17}$$

Recall from Equation 13 that $\omega_{it} = \phi_{it} - \beta_k k_{it} - \beta_v \text{Vertical_FDI}_{jrt}$. I can substitute (17) into (16) to yield:

$$\begin{aligned}
y_{t+1} - \beta_l l_{it+1} - \beta_m m_{it+1} &= \beta_k k_{it} - \beta_v \text{Vertical_FDI}_{jrt} \\
&\quad + g(P_t, \phi_{it} - \beta_k k_{it} - \beta_v \text{Vertical_FDI}_{jrt}) + \xi_{t+1} + \eta_{it+1}
\end{aligned} \tag{18}$$

where ξ_{t+1} is the unanticipated portion of the shock, $\xi_{t+1} = \omega_{it+1} - E[\omega_{it+1} | \omega_{it}, \chi_{it+1} = 1]$, (that affects the factory's choice of inputs) and η_{it+1} is measurement error (that does not affect input choices). The key identifying assumption here is that the state variables (capital and vertical FDI) in time $t + 1$ respond only to the lagged productivity shock, ω_{it} , that is calculated in the first stage. So, the error terms in Equation 18 are independent of the state variables and non-linear least squares estimation will reveal unbiased estimates of β_k and β_v . Again, I use a third order polynomial expansion in P_t and $\phi_{it} - \beta_k k_{it} - \beta_v \text{Vertical_FDI}_{jrt}$ to estimate

I calculated standard errors for the coefficients obtained above using bootstrap methods.

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D. Tables

All rupiah values are in thousands (000's) of rupiah, unless otherwise indicated. All regressions have YEAR dummy variables, although the coefficients are not reported.

	Obs.	1988		Obs.	1996	
		Mean	S.d.		Mean	S.d.
Province vertical FDI	3615	0.06	0.101125	5300	0.13	0.13
log(output)	3615	12.12	1.99	5300	12.75	2.07
log(labor)	3615	140.81	368.51	5300	172.52	521.07
log(capital)	3615	11.41	2.11	5300	11.93	2.23
log(materials)	3615	11.47	2.13	5300	12.01	2.24
Value added per worker	3615	2994.69	7156.93	5300	9649.14	45165.27
Capital per worker	3615	8998.10	160147.50	5300	11489.95	183749.80
Percent of output exported				5300	0.10	0.26
Province vertical FDI	118	0.12	0.14	332	0.22	0.14
log(output)	118	15.21	1.59	332	15.63	1.65
log(labor)	118	388.28	515.28	332	435.68	636.12
log(capital)	118	14.19	1.90	332	14.68	1.87
log(materials)	118	14.45	1.76	332	14.81	1.95
Value added per worker	118	17655.85	24369.53	332	45200.74	150280.70
Capital per worker	118	28029.46	83209.69	332	42299.95	316118
Percent of output exported				332	0.41	0.41

Table 1: Descriptive statistics for 1988 and 1996, domestic establishments (top) and foreign establishments (bottom).

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IO Code	Intermediate Goods Industry	VFDI 1988	VFDI 1996	Between s.d.	Within s.d.
129	Musical instruments	0.93	0.76	0.368	0.240
105	Basic iron and steel	0.46	0.15	0.190	0.077
72	Leather tanneries and leather finishing	0.44	0.48	0.192	0.098
124	Motor cycles	0.38	0.09	0.253	0.138
56	Peeled grain, chocolate and sugar confectionery	0.32	0.14	0.145	0.103
128	Jewelry	0.32	0.32	0.098	0.064
84	Basic chemical except fertilizer	0.27	0.30	0.118	0.031
96	Smoked and crumb rubber	0.23	0.28	0.104	0.053
93	Other chemical products	0.21	0.17	0.072	0.012
87	Synthetic resins, plastic and fiber	0.20	0.26	0.090	0.036
90	Native medicine	0.17	0.02	0.107	0.046
113	Prime movers and engines	0.17	0.64	0.199	0.084
52	Non-wheat flour, milled cereals, and root	0.17	0.26	0.085	0.044
99	Plastic products	0.16	0.16	0.061	0.012
31	Drying and salting of fish	0.15	0.25	0.170	0.043
98	Other rubber products	0.14	0.13	0.055	0.016
66	Yarn and cleaning kapok	0.14	0.20	0.144	0.061
55	Sugar	0.14	0.14	0.042	0.031
107	Non-ferrous basic metal products	0.13	0.21	0.032	0.051
49	Copra, animal and vegetable oil	0.12	0.12	0.042	0.035
78	Goods made of wood, bamboo, rattan and cork	0.11	0.14	0.050	0.010
127	Measuring, photo, and optical equipment	0.11	0.29	0.102	0.043
58	Processed tea	0.10	0.17	0.090	0.052
119	Other electrical appliances	0.09	0.31	0.104	0.068
81	Paper and cardboard products	0.08	0.13	0.077	0.035
115	Electric generator and electrical motor	0.08	0.62	0.148	0.162
69	Knitting mills	0.08	0.29	0.104	0.066
59	Soya bean product	0.06	0.07	0.036	0.015
51	Wheat flour	0.06	0.23	0.085	0.080
71	Carpet, rope, twine, and other textile	0.06	0.20	0.064	0.025
46	Dairy products	0.06	0.18	0.045	0.047
107	Non-ferrous basic metal	0.05	0.11	0.032	0.050
120	Battery	0.04	0.22	0.099	0.043
64	Tobacco products	0.03	0.06	0.070	0.002
67	Textiles	0.03	0.30	0.126	0.142
82	Cardboard	0.02	0.09	0.141	0.017
74	Sawmill and preserved wood	0.01	0.11	0.043	0.033
80	Pulp	0.00	0.20	0.045	0.059
125	Other transportation equipment	0.00	0.10	0.098	0.055

Table 2: Downstream vertical FDI (VFDI) by intermediate goods industry in 1988 and 1996 calculated nationally (by collapsing all regions into one). Between- and within-factory standard deviation is calculated at the regional level (by assuming output is sold to buyers in the same region).

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dependent var.: log(output)	fixed-effect						Olley-Pakes
	(1)	(2)	(3)	(4)	(5)	(6)	
Province vertical FDI	0.121 (4.89)	0.114 (4.54)	0.105 (4.59)	0.095 (4.13)	0.063 (2.46)		0.138 (3.06)
Factory foreign equity	0.226 (7.04)		0.161 (5.43)				
Province FDI in all industries						-0.028 (0.82)	
log(capital)	0.089 (30.76)	0.091 (30.52)	0.186 (13.40)	0.158 (10.74)	0.223 (12.99)	0.159 (12.82)	0.185 (46.25)
log(labor)	0.302 (53.57)	0.297 (51.68)	0.849 (29.63)	0.845 (28.64)	0.581 (15.24)	0.684 (25.46)	0.232 (8.92)
log(materials)	0.608 (251.87)	0.613 (247.77)	0.345 (25.97)	0.331 (23.94)	0.437 (26.80)	0.243 (20.64)	0.668 (26.72)
log(K)*log(K)			0.008 (10.04)	0.010 (11.14)	0.008 (7.64)	0.008 (11.51)	
log(L)*log(L)			0.012 (3.28)	0.007 (1.91)	0.025 (4.88)	0.045 (13.51)	
log(M)*log(M)			0.053 (71.95)	0.053 (69.37)	0.054 (59.38)	0.052 (76.67)	
log(K)*log(L)			0.047 (17.51)	0.047 (16.86)	0.061 (17.52)	0.040 (16.87)	
log(K)*log(M)			-0.042 (33.77)	-0.042 (32.34)	-0.050 (33.06)	-0.037 (33.66)	
log(L)*log(M)			-0.103 (43.90)	-0.100 (40.87)	-0.105 (35.27)	-0.100 (43.78)	
Constant	2.940 (76.89)	2.858 (73.47)	2.460 (21.92)	2.675 (23.09)	2.192 (15.73)	3.854 (40.35)	
Observations	44047	42044	44047	42044	31219	66761	11743
No. of establishments	9252	8945	9252	8945	6950	14998	5391
R-squared	0.75	0.75	0.79	0.79	0.79	0.77	
Absolute value of t statistics in parentheses							

Table 3: Production function estimation for (1) and (3) all intermediate goods establishments, (2) and (4) only domestic intermediate goods establishments, (5) domestic never-exporting intermediate goods establishments, (6) domestic final goods establishments, and (7) intermediate goods establishments reporting positive investment.

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dependent var.: log(output)	(1)	(2)	(3)
Province vertical FDI	0.120 (1.98)	0.042 (1.22)	0.233 (1.83)
log(capital)	0.059 (2.15)	0.168 (5.80)	0.151 (2.10)
log(labor)	0.607 (15.04)	1.184 (17.10)	0.443 (2.61)
log(materials)	0.854 (39.69)	-0.014 (0.40)	0.321 (4.87)
log(K)log(K)	0.023 (13.61)	0.001 (0.71)	0.013 (3.56)
log(L)log(L)	-0.002 (0.42)	0.058 (6.48)	-0.006 (0.29)
log(M)log(M)	0.042 (30.49)	0.061 (32.68)	0.049 (12.24)
log(K)log(L)	0.051 (10.87)	0.027 (4.16)	0.046 (3.04)
log(K)log(M)	-0.063 (27.29)	-0.019 (6.60)	-0.049 (6.91)
log(L)log(M)	-0.088 (22.19)	-0.135 (23.81)	-0.055 (3.65)
Constant	0.480 (2.54)	3.910 (16.41)	3.695 (6.99)
Observations	12108	9232	1811
No. of establishments	2477	1925	377
R-squared	0.83	0.78	0.86
Absolute value of t statistics in parentheses			

Table 4: Translog production function estimation for local factories in (1) food processing (2) textiles, and (3) electronics.

E. Figures

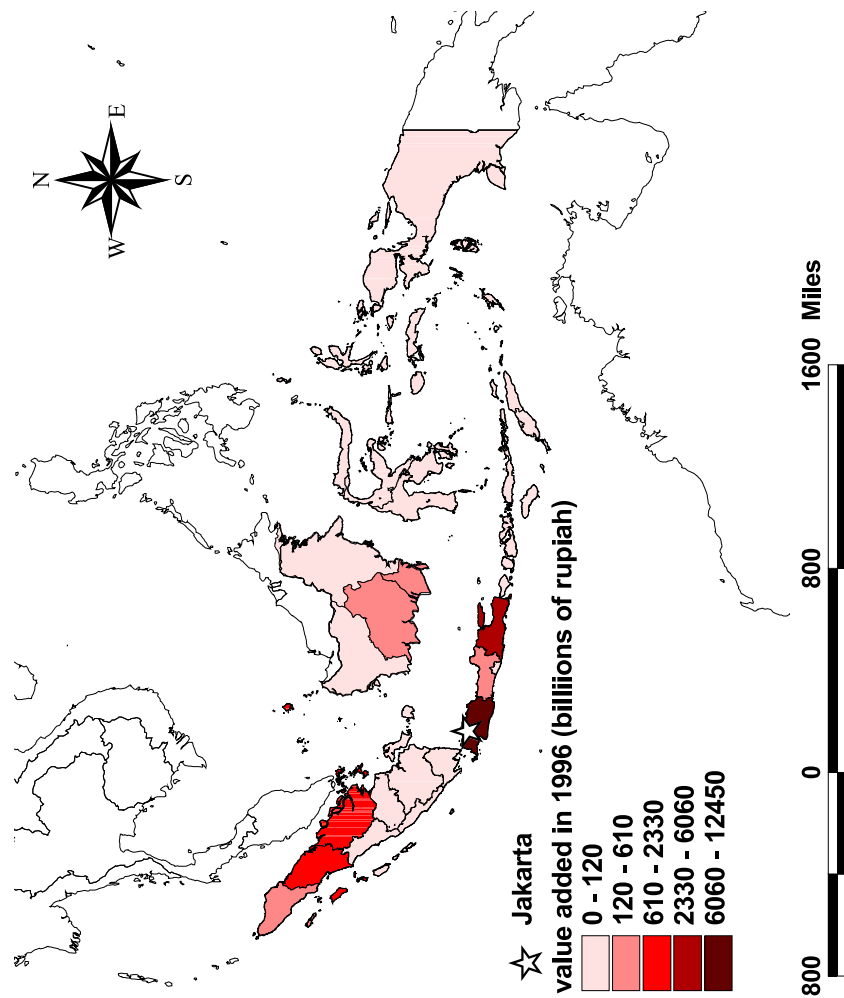


Figure 1: Value added in manufacturing, 1996, by province.

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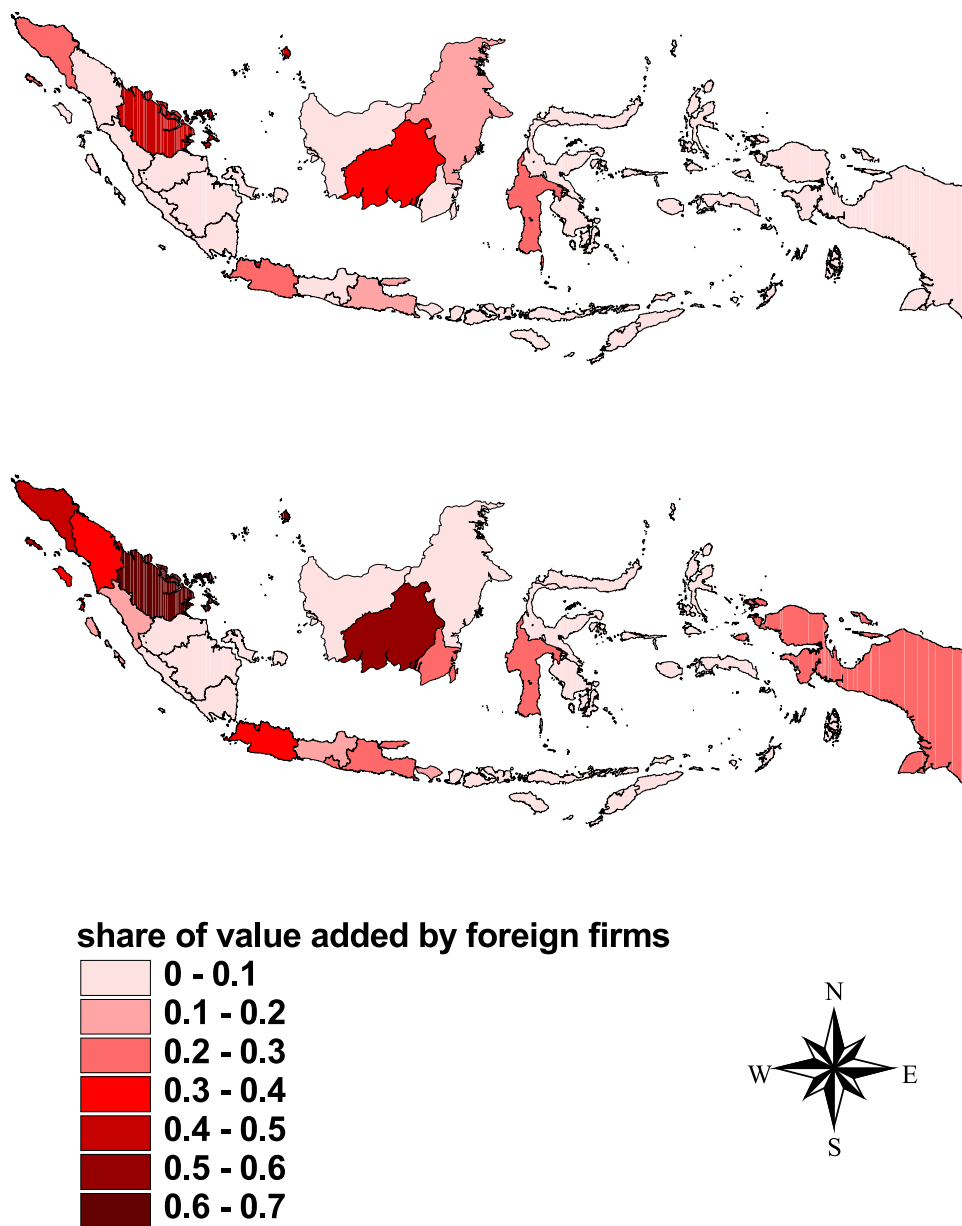


Figure 2: Share of manufacturing value added by foreign firms, by region, 1988 (top) and 1996 (bottom).