

Technology from Foreign Direct Investment and Welfare Gains through the Supply Chain

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April 27, 2003

Abstract

We measure the diffusion of technology brought with foreign direct investment (FDI) and the effect of that technology on competition and welfare in the host economy. Using a panel dataset of Indonesian manufacturing establishments from 1988 to 1996, we regress downstream FDI on local firm productivity and find strong evidence that *vertical* supply chains are a channel for technology transfer. In contrast, prior studies measuring the *horizontal* spillover of technology from foreign entrants to domestic competitors find mixed evidence of technology transfer. Our 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 prices and increasing competition in upstream markets. Indeed, we find that downstream FDI induces greater competition and lower prices, as well as higher output and valued added upstream. Further, these benefits also flow to sectors downstream of those receiving the original transfer of technology.

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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

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 direct competition in the end-product market. 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.

The primary motivation for multinationals to transfer technology to suppliers is to enable higher quality inputs at lower prices. If the enabling technology is only possessed by one vendor, however, then the multinational is vulnerable to hold-up. To mitigate holdup risk and to further competition and lower prices in the supply sector, the multinational may facilitate diffusion of the technology—either by direct transfer to other firms or by encouraging spillover from the original recipient.

The multinational may be concerned about losing the rents gained from lower input prices if they attract other buyers that free ride on the supply chain investment. Pack and Saggi 2001 demonstrate that this concern is not always justified. Provided that other buyers do not present too much competition to the multinational, the benefit of more demand downstream will further increase competition and output in the supply sector. Moreover, Pack and Saggi 2001 show that the original domestic recipient of the technology may benefit from enjoying a larger market into which it can sell its output. In short, diffusion of technology in the supply sector solves the so-called “double-marginalization” problem and can benefit both parties to the original technology transfer.

This study measures both the direct technology transfer from FDI as well as the changes in market competition and welfare induced by foreign entry. The analysis is in two parts.

The first part 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 establishment fixed effects 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 second part of the paper examines the subsequent effects of FDI technology diffusion as outlined in Pack and Saggi 2001. We estimate the effect of downstream FDI on upstream market concentration, prices, output, and value added. Further, we estimate the same metrics on firms in sectors downstream of sectors that supply multinational customers. We find that downstream FDI increases output and firm value added, and decreases prices and market concentration. Moreover, we find the same effects in markets downstream of markets supplying multinationals. This finding suggests strong competition and welfare effects—benefits captured by consumers as lower prices and to firms as greater value added—transmitted both up and down the supply chain from the adoption of technology brought with FDI.

We proceed 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 6 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 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 introduce some competition and welfare benefits that might arise from the technology diffusion.

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

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 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 differ-

ences 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 *downstream* FDI, 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 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.

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.

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

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

2.3. Competition and Welfare Effects of Vertical Technology Diffusion

The multinational transfers technology to its supplier largely to reduce input costs and increase quality. The presence of a single supplier with superior technology, however, is likely to increase market concentration upstream and may expose the multinational to hold-up. To overcome this vulnerability and to hasten fu-

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

ture competition and price reductions, the multinational may wish to provide the technology to other suppliers. We would thus expect to see direct technology transfer to several supplies, or encouragement of program that make the technology broadly available to the supply sector. Moreover, technology leakage between original local technology recipient and its rivals is possible as well. In fact, to the extent that we should expect to see horizontal technology transfer at all, it seems more likely to occur between local supply firms than between foreign and local firms in the end-product market.

Although the multinational has incentive to aid many suppliers, doing some may may inadvertently aid competitors if the more productive supply base is a non-excludable benefit. In a developing country setting, where generally export-oriented foreign firms may seldom compete with domestic makers, aiding local buyers may not concern multinationals. However, foreign firms may be concerned that their investment in local supply chain would eventually benefit later foreign entrants. One might think that foreign firms would thus be reluctant to transfer technology to suppliers under these conditions.

Provided that new competition is not too great, the benefits of a competitive supply base to the multinational buyer outweigh the rents lost to free-loading rivals. Perhaps surprisingly, technology diffusion and leakage to other local suppliers can also benefit the initial local recipient. Pack and Saggi 2001 outline the logic of this non-intuitive result. In the case of a single supplier and just one buyer with some market power, both parties set prices above marginal cost—the “double marginalization problem.” If technology diffusion to other upstream firms allows more capable suppliers to enter, then one would expect market concentration and input prices to fall. Further, given the benefit of lower priced inputs, firms downstream of the focal upstream sector will increase output and the likelihood of new firm entry and lower prices would rise. The stronger demand downstream would in, in turn, prompt higher output upstream. Lower prices and greater volume clearly generate a surplus which aids consumers. Pack and Saggi 2001 note that in most cases, firms are also able to capture some of the surplus because the benefit of input prices and higher volume outweigh the costs of greater competition for firms as well. Hence, we would expect to see firm value added—a proxy for profitability—rise. In summary, the competition and welfare benefits of the initial technology transfer should spread up and down the supply chain resulting in lower prices, lower concentration, higher output, and higher value added.

2.4. 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 lower concentration, lower prices, higher output, and more value added in this beneficiary sectors, as well as sectors downstream of them. 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 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 entrants that produced for the local market. Opposition to FDI culminated in violent protests during the 1974 visit to Jakarta of Japanese Prime Minister Kakuei

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

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 example, 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 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

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.

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. The table indicates a large increase in the number of foreign factories, which increases from 276 in 1988 to 888 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 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, energy, and capital to express values in real terms. Appendix B describes the deflator calculation in detail.

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 removed establishments with especially frequent non-responses to fundamental questions such as number of

study, early analysis by BPS suggests that less than 5 percent of factories belong to multi-factory firms. We thus generalize our results to firms in our discussion.

employees. In other cases, we imputed some variables to correct for non-reporting in just one or two years or to fix obvious clerical mistakes in data keypunching. We cleaned each variable independently and only removed establishments from the analysis for which the needed variables could not be constructed. For example, establishments with missing wage data could be used for output regression but not for value added regression. Thus, readers will notice slight differences in the sample count across different regressions. We also note that analysis on completely raw data yields very similar results to what we report here, although standard errors are slightly higher. Appendix B describes the process by which we prepared the data in more detail.

4.2. Measurement

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

We use the IO tables together with the SI to calculate downstream 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 downstream 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 23 provinces on the main island groups of Sumatra, Java and Bali, Kalimantan, and Sulawesi, to be a separate region. Because there is little industrialization in the rural outer islands of the nation, we have not included them in the sample.

We determine downstream FDI by industry and region, rather than by factory, for two reasons. First, estimation with industry and region measures of downstream 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 downstream FDI by summing the output shares purchased by manufacturing sectors multiplied by the share of intra-industry foreign output, horizontal FDI, in those sectors. For example, suppose that half of the wheat flour sector output is 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 .

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

$$Downstream_FDI_{jrt} = \sum_k \alpha_{jkt} Horizontal_FDI_{jrt} \quad (2)$$

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 α_{jkt} 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.

To capture the effect of being downstream of sectors that sell multinational buyers, we also calculate suppliers' downstream FDI, the value of downstream FDI in each of the upstream sectors weighted by the share of inputs provided by that sector.

$$Suppliers'_Downstream_FDI_{jrt} = \sum_k \alpha_{jkt} Downstream_FDI_{jrt} \quad (3)$$

where α_{jkt} is the share of sector j inputs obtained from sector k .

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

$$\begin{aligned} \ln Y_{it} = & \beta_0 Downstream_FDI_{jrt} + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 \ln M_{it} + \beta_4 \ln E_{it} + \\ & \beta_5 \ln^2 K_{it} + \beta_6 \ln^2 L_{it} + \beta_7 \ln^2 M_{it} + \beta_8 \ln^2 E_{it} + \\ & \beta_9 \ln K_{it} \ln L_{it} + \beta_{10} \ln K_{it} M_{it} + \beta_{10} \ln K_{it} E_{it} + \\ & \beta_{11} \ln L_{it} M_{it} + \beta_{12} \ln L_{it} E_{it} + \beta_{13} \ln M_{it} E_{it} + \lambda_{gt} + \alpha_i + \gamma_t + \varepsilon_{it} \end{aligned} \quad (4)$$

where Y_{it} , K_{it} , L_{it} , M_{it} and E_{it} are the amounts of production output, capital, labor, raw materials, and energy (fuel and electricity) for establishment i at time

t , and α_{gt} is a dummy indicator for the interaction of each four island groupings g and year t , λ_i is a fixed effect for factory i , and γ_t is a dummy variable for year t . A positive coefficient on downstream FDI indicates that it is associated with higher productivity. Output, capital, materials and energy 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 4 on a sample of locally owned factories.

Table 2 shows the shares of materials provided to and obtained from other sectors in 1995. Diagonal entries show materials provided to and obtained from within the same sector. We make two observations. First, there are large non-diagonal entries, suggesting that there is a large degree of inter-sector trade that we can use for identification. Second, the upstream and downstream shares from one sector to another are often not at parity. For example, although the cardboard products sector relies heavily on paper pulp, the paper pulp sector distributes a significant share of its output to other sectors. The non-parity of upstream and downstream shares is important to ensure that *Suppliers' Downstream FDI* and *Downstream FDI* is sufficiently disjoint to identify the effect of each separately.

Table 3 show mean values of horizontal FDI, downstream FDI and Suppliers' downstream FDI for foreign and domestic firms in 1988 and 1996, the first and last years of the panel.

To measure the welfare effects of FDI, we also estimate several reduced form models. Equation 5 measures the effect of FDI on concentration.

$$HI_{srt} = \beta_0 \text{Downstream_FDI}_{jrt} + \alpha_{sr} + \lambda_{gt} + \gamma_t + \varepsilon_{srt} \quad (5)$$

where HI_{srt} is the Herfindahl concentration index for 5-digit ISIC sector s in region r in time t . Note that we use the 89 IO Table codes, indicated by subscript j , to define sectors for supply chains. However, for calculating concentration indexes, which do not require the IO table, one can more narrowly define industries to the 329 ISIC codes, indicated by subscript s . λ_{gt} is intended to capture time-variant conditions affecting particular island groupings of the country and ε_{jrt} is a true error term.

Equation 6 measures the effect of FDI on prices.

$$\text{Price}_{st} = \beta_0 \text{Downstream_FDI}_{jt} + \alpha_s + \gamma_t + \varepsilon_{st} \quad (6)$$

Because prices are not available at the regional level, we use *Downstream FDI*

at the national level here. That is, downstream FDI is calculated as if the entire country was one region.

Equations 7 and 8 measure the effect of FDI on firm output and value added respectively.

$$Y_{it} = \beta_0 \text{Downstream_FDI}_{jrt} + \alpha_i + \lambda_{gt} + \gamma_t + \varepsilon_{it} \quad (7)$$

$$VA_{it} = \beta_0 \text{Downstream_FDI}_{jrt} + \alpha_i + \lambda_{gt} + \gamma_t + \varepsilon_{it} \quad (8)$$

We also estimate equations 5-8 replacing downstream FDI with suppliers' downstream FDI to gauge the welfare effects in sectors downstream of those sectors supplying multinationals. We calculate the effect of horizontal FDI on the same metrics to capture the effect of direct competition with foreign firms on domestic industry.

5. Results

We first discuss the results of estimating production functions to identify technology transfer. We next show the reduced form estimations that reveal the welfare effects of the technology diffusion.

5.1. Technology Transfer

Table 4 reports the results of estimating Equation 4 using an establishment-level fixed-effect estimator on a sample of domestic firms.⁷ Column (1) shows downstream FDI, column (2) shows horizontal FDI and column (3) shows the effect of both. The coefficient on horizontal FDI is close to zero, suggesting that there is little learning from direct foreign competitors. In contrast, the effect of downstream FDI is large and significant, indicating that firms with growing FDI downstream acquire technology through the supply chain.

Because the estimation is a log linear production function, the coefficients approximate elasticities and have intuitive interpretations. The 0.087 coefficient on downstream FDI suggests that firm output increases over eight percent as the share of foreign ownership downstream rises from zero to one. In practice, increases in share of downstream FDI of approximately 20 percent are common,

⁷A Hausman test showed significant correlation between individual establishment effects and the other regressors, thereby rejecting a random-effects model.

suggesting that the actual realized productivity gain might be close to 2 percent (.2 times .87).

We next perform several checks to examine the robustness of these results.

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

The positive correlation between downstream 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 downstream 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 4 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 *Downstream_FDI*_{*it*}.

The error term in Equation 4 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.

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 *Downstream_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 *Downstream_FDI* coefficient is not clear.

Olley and Pakes 1996 proposes using investment as a proxy for idiosyncratic shocks. The identifying assumption in Olley-Pakes estimation is that investment is monotonically increasing with respect to the shock, conditional on capital. Because capital responds to the shock only in a lagged fashion through contemporaneous investment, the return to the other inputs can be obtained by non-parametrically inverting investment and capital to proxy for the unobserved shock. Appendix C summarizes the Olley-Pakes estimation approach. Although it is possible to obtain the return to capital variables with an optional second stage of estimation, we do not implement that here since capital is not a variable on interest.

Column (4) of Table 4 shows the results of the Olley-Pakes estimation. The effect of downstream FDI is statistically identical to that measured without the Olley-Pakes correction, suggesting that simultaneity bias is not driving the contribution of downstream FDI to upstream supplier productivity.

5.1.2. 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 multinational customers may sometimes assist their local suppliers in accessing export markets.⁸

To remove any effects of exporting, we estimated Equation 4 on a sample

⁸See Clerides, Lach, and Tybout 1998, Bernard and Jensen 1999, and Aw, Chung, and Roberts 2000 for discussion of firm learning and exports

of only *never-exporting* domestic firms. Column (5) of Table 4 shows that the positive effect of downstream FDI holds and suggests that exports are not a viable alternative explanation for the observed productivity goods.

5.1.3. Public Goods

The correlation between downstream 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. We then estimate Equation 4 substituting $Region_FDI_{rt}$, the share of foreign firm share of industrial output in all industries, for $Downstream_FDI_{jrt}$. Column (6) of Table 4 shows the insignificant coefficient on $Region_FDI$, indicating that public goods do not have a major impact on local firm productivity.

5.2. Welfare Analysis

We next explore the effect of FDI on market competition and welfare. We estimate the effect of FDI on concentration and prices at the market level—province markets in the case of concentration and national markets in the case of prices, for which we do not have regional variation. The effect of FDI on output and value added is calculated at the firm level.

5.2.1. Concentration and Price

Table 5 shows the estimations of equations 5 and 6. Columns (1)-(7) show estimation of regional market concentration with a fixed effect for each 5-digit ISIC product and province cell. Both downstream FDI and suppliers' downstream FDI are significantly associated with a decrease in market concentration, measured by a Herfindahl index. This association suggests that foreign entry downstream will

lead to more competition in upstream supply markets. Likewise, other sectors downstream of those upstream markets also show increases in competition.

Columns (8)-(12) display the effect of FDI on prices estimated by Equation 6. Because we do not have regional variation in prices, the identifying estimation is by industry and year. Although one cannot assign causality from such a reduced form estimation, the results are consistent with the notion that FDI competition lowers prices. In fact, in-sector horizontal FDI, downstream FDI, and supplier's downstream FDI are all associated with a decline in prices. In other words, FDI competition lowers prices in the entry market, the supply markets, and other markets downstream of the supply markets.

5.2.2. Output and Value Added

We next estimate establishment output and value added. Given that FDI lowers prices, one also expects to see an increase in output. Indeed, columns (1)-(5) of Table 6 show the effect of FDI on domestic firm output by estimating Equation 7. Both downstream FDI and supplier's downstream FDI increase output, likely through the effect of FDI on prices and the demand added by the new entry. In isolation, in-sector horizontal FDI has no effect on volume. However, as noted in column (5), when horizontal FDI is considered together with downstream and suppliers' downstream FDI, it lowers output. This is likely to due to some correlation between the three measures of FDI. Whereas downstream and suppliers downstream FDI reflect the benefits of technology transfer, horizontal FDI also has competitive effect if foreign firms take away market share from domestic rivals. Columns (5)-(10) estimate Equation 8 to show whether domestic firms capture any of the surplus generated from lower prices and higher output. Again, both downstream FDI and supplier's downstream FDI lead to greater value added, suggesting that firms are capturing some of the welfare benefits of vertical technology transfer. Domestic firms, however, fare far worse when they compete directly with foreign entrants as evidenced the lower value added associated with horizontal FDI.

Table 7 estimates Equations 7 and 8 on the population of just foreign firms. To avoid the obvious endogeneity that an establishment's own foreign ownership adds to horizontal FDI, we have only included *other* firms foreign equity in the calculation. As was the case with domestic firms, an increase in downstream FDI and suppliers' downstream FDI is associated with both increases in volume and value added. As with domestic firms, there is no direct effect of horizontal FDI

isolation. However, when horizontal FDI is included together with downstream and suppliers' downstream FDI (thereby removing any part of horizontal FDI that might overlap with the vertical FDI measures), it significantly reduces both output and value added. We interpret this to mean that foreign firms benefit from the entry of other multinationals *provided* that the new entrants do not directly compete in the same sector.

6. 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 in industries in regions with growing downstream 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 mentioned in the 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.

We also find that FDI has strong welfare benefits for the host economy and that these gains diffuse up and down supply chains. The presence of foreign firms induces more competitive markets, lower prices, and greater output in the supplying sectors and other sectors downstream. Both domestic and foreign firms are able to capture some of this surplus as evidenced by the higher value added. In fact, with the possible exception of firms competing directly with multinational entrants, new FDI benefits existing domestic and foreign firms elsewhere on the

supply chain.

The implication for policymakers is that technology transfer is a real benefit of FDI and that the welfare benefits spread throughout the host economy. One should be agnostic, however, if prescribing policies that encourage FDI. It is important to note that the direct transfer of technology from the multinational buyer to the supplier is deliberate. Further, the subsequent diffusion of technology benefits both parties. Hence, although FDI generates an externality, it is not clear that public intervention is required to provide incentives.

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A. Data Appendix

A.0.3. 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.⁹ 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.¹⁰

A.0.4. 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.¹¹ 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.0.5. 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

⁹ISIC 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.

¹⁰Following the independence of East Timor, there are now 26 provinces and 291 districts.

¹¹The 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.

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

A.0.6. 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.0.7. 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.0.8. Output

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

B. Data Cleaning

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.

B.1.1. Output, Materials, and Energy 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. Energy is deflated with Indonesian petroleum prices.

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. We 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

We 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.

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.¹²

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

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_m m_{it} + \beta_k k_{it} + \beta_v \text{Vertical_FDI}_{jrt} + \omega_{it} + \eta_{it} \quad (9)$$

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.

$$i_{it} = i_{it}(\omega_{it}, k_{it}, \text{Vertical_FDI}_{jrt}) \quad (10)$$

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

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

¹²The analysis here follows the Olley-Pakes estimation implementation in Pavcnik 2001.

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

$$y_{it} = \beta_l l_{it} + \beta_m m_{it} + \phi_{it}(i_{it}, k_{it}, Vertical_FDI_{jrt}) + \eta_{it} \quad (12)$$

where

$$\begin{aligned} \phi_{it}(i_{it}, k_{it}, Vertical_FDI_{jrt}) = & \beta_0 + \beta_k k_{it} + \beta_v Vertical_FDI_{jrt} + \\ & h_{it}(i_{it}, k_{it}, Vertical_FDI_{jrt}) \end{aligned} \quad (13)$$

Since the error term η_{it} is uncorrelated with the inputs, estimation of Equation 12 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.

$$\begin{aligned} Pr\{\chi_{it+1} = 1 | \varpi_{it}(k_{it}, Vertical_FDI_{jrt})\} & \quad (14) \\ = Pr\{\omega_{it+1} > \varpi_{it}(k_{it}, Vertical_FDI_{jrt}) | \varpi_{it+1}(k_{it}, Vertical_FDI_{jrt}, \omega_{it})\} \\ = \rho_{it}\{\varpi_{it+1}(k_{it}, Vertical_FDI_{jrt}, \omega_{it})\} \\ = \rho_{it}(i_{it}, k_{it}, Vertical_FDI_{jrt}) \\ \equiv P_{it} \end{aligned}$$

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

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

$$\begin{aligned}
& E[y_{t+1} - \beta_l l_{it+1} - \beta_m m_{it+1} | k_{it+1}, \text{Vertical_FDI}_{jrt+1}, (\chi_{it+1} = 1)] \\
&= \beta_0 + \beta_k k_{it+1} + \beta_v \text{Vertical_FDI}_{jrt+1} + E[\omega_{it+1} | \omega_{it}, \chi_{it+1} = 1] \\
&= \beta_0 + \beta_k k_{it+1} + \beta_v \text{Vertical_FDI}_{jrt+1} + g(\varpi_{it+1}, \omega_{it})
\end{aligned} \tag{15}$$

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:

$$\begin{aligned}
g(\varpi_{it+1}, \omega_{it}) &= g[\rho_{it}^{-1}(P_t, \phi_{it} - \beta_k k_{it} - \beta_v \text{Vertical_FDI}_{jrt}), \phi_{it} \\
&\quad - \beta_k k_{it} - \beta_v \text{Vertical_FDI}_{jrt}] \\
&\equiv g(P_t, \phi_{it} - \beta_k k_{it} - \beta_v \text{Vertical_FDI}_{jrt})
\end{aligned} \tag{16}$$

Recall from Equation 12 that $\omega_{it} = \phi_{it} - \beta_k k_{it} - \beta_v \text{Vertical_FDI}_{jrt}$. I can substitute (16) into (15) to yield:

$$\begin{aligned}
y_{t+1} - \beta_l l_{it+1} - \beta_m m_{it+1} &= \beta_k k_{it} - \beta_v \text{Vertical_FDI}_{jrt} \\
&\quad + g(P_t, \phi_{it} - \beta_k k_{it} - \beta_v \text{Vertical_FDI}_{jrt}) + \xi_{t+1} + \eta_{it+1}
\end{aligned} \tag{17}$$

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 17 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

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

D. Tables

Capital, materials, energy, and value added are reported in thousands of 1988 Rupiah.

		domestic	foreign
1988	log(capital)	11.257	14.086
	employees	124	364
	log(materials)	11.171	14.421
	log(energy)	7.388	8.881
	log(value added)	10.438	14.068
	log(value added per worker)	6.447	8.765
1996	log(capital)	11.691	14.659
	employees	147	584
	log(materials)	11.588	14.893
	log(energy)	7.347	8.618
	log(value added)	11.039	14.580
	log(value added per worker)	6.973	8.967

Table 1: Descriptive statistics by foreign and domestic firms, 1988 and 1996.

insert Alpha Table here	insert Alpha Table here
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Table 2: Alpha table.

Year	No. Domestic Firms	No. Foreign Firms	Horizontal FDI	Downstream FDI	Suppliers' Downstream FDI
1988	8888	276	.131	.060	.074
1996	14912	888	.232	.094	.118

Table 3: Foreign and domestic establishment count, mean Horizontal, Downstream, and Suppliers' Downstream FDI, 1988 and 1996.

	(1)	(2)	(3)	(4)	(5)	(6)
	log(output)	log(output)	log(output)	log(output)	log(output)	log(output)
Downstream FDI	0.087 (4.33)		0.090 (4.40)	0.091 (4.48)	0.073 (3.12)	
Horizontal FDI		-0.004 (0.34)	-0.009 (0.88)	-0.010 (0.96)	-0.018 (1.52)	
FDI in all industries						-0.017 (0.58)
log(labor)	0.590 (29.98)	0.590 (29.94)	0.590 (29.98)	0.578 (28.77)	0.480 (17.50)	0.590 (29.94)
log(capital)	0.109 (12.67)	0.109 (12.66)	0.109 (12.66)		0.125 (12.22)	0.109 (12.66)
log(materials)	0.200 (21.76)	0.200 (21.71)	0.200 (21.76)	0.202 (21.87)	0.250 (22.53)	0.200 (21.72)
log(energy)	0.123 (17.98)	0.124 (18.17)	0.123 (17.99)	0.125 (18.14)	0.135 (16.59)	0.124 (18.17)
log(K)*log(K)	0.005 (9.57)	0.005 (9.57)	0.005 (9.58)		0.005 (9.91)	0.005 (9.56)
log(L)*log(L)	0.026 (10.53)	0.026 (10.52)	0.026 (10.53)	0.025 (10.40)	0.027 (7.60)	0.026 (10.52)
log(M)*log(M)	0.050 (89.47)	0.050 (89.53)	0.050 (89.45)	0.050 (89.36)	0.053 (80.58)	0.050 (89.53)
log(E)*log(E)	-0.010 (24.24)	-0.010 (24.24)	-0.010 (24.25)	-0.010 (24.22)	-0.009 (18.57)	-0.010 (24.24)
log(K)*log(L)	0.028 (16.35)	0.028 (16.41)	0.028 (16.35)		0.038 (17.47)	0.028 (16.41)
log(K)*log(M)	-0.028 (32.50)	-0.028 (32.51)	-0.028 (32.50)		-0.034 (34.09)	-0.028 (32.51)
log(K)*log(E)	0.006 (8.57)	0.006 (8.55)	0.006 (8.57)		0.005 (5.95)	0.006 (8.55)
log(L)*log(M)	-0.089 (49.64)	-0.089 (49.61)	-0.089 (49.64)	-0.089 (49.56)	-0.091 (40.57)	-0.089 (49.61)
log(L)*log(E)	0.023 (15.88)	0.023 (15.80)	0.023 (15.87)	0.023 (16.10)	0.025 (13.86)	0.023 (15.80)
log(M)*log(E)	-0.005 (6.52)	-0.005 (6.60)	-0.005 (6.51)	-0.005 (6.39)	-0.008 (9.60)	-0.005 (6.60)
Constant	3.882 (56.04)	3.885 (56.09)	3.883 (56.05)	3.830 (11.80)	3.663 (41.89)	3.887 (56.03)
Observations	108100	108100	108100	108100	81112	108100
Number of Establishments	23815	23815	23815	23815	18414	23815
R-squared	0.81	0.81	0.81	0.81	0.79	0.81
Absolute value of t statistics in parentheses						

Table 4: Production function estimation on domestic establishments. (4) Olley-Pakes estimation. (5) population of never-exporting firms. Establishment fixed effects, island-year and year dummy variables are included but not reported.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
			log(province	Herfindahl index)					log(national prices)			
Downstream FDI (prov.)	-0.076 (2.31)			-0.084 (2.48)		-0.057 (1.59)	-0.088 (2.39)					
Supplier's Downstream FDI (prov.)		-0.114 (2.15)			-0.144 (2.49)	-0.077 (1.34)	-0.079 (1.27)					
Horizontal FDI (prov.)			0.003 (0.31)	0.011 (0.94)	0.016 (1.28)		0.015 (1.18)					
Downstream FDI (nat.)								-0.462 (9.83)			-0.404 (8.21)	-0.282 (5.11)
Supplier's Downstream FDI (nat.)									-0.778 (9.95)			-0.453 (4.80)
Horizontal FDI (nat.)										-0.146 (6.66)	-0.090 (3.99)	-0.060 (2.56)
Constant	0.631 (148.84)	0.632 (138.78)	0.627 (148.92)	0.630 (144.13)	0.631 (137.59)	0.633 (137.55)	0.614 (122.05)	5.051 (708.15)	5.078 (556.01)	5.036 (692.29)	5.065 (633.67)	5.089 (542.35)
Obs	13592	13592	13592	13592	13592	13592	11766	2581	2581	2581	2581	2581
No. region-product groups	1982	1982	1982	1982	1982	1982	1671	307	307	307	307	307
No. product groups								0.78	0.78	0.77	0.78	0.78
R-squared	0.05	0.05	0.05	0.05	0.05	0.05	0.04					
Absolute value of t statistics in parentheses												

Table 5: Concentration and Prices. Region-product fixed effects (for concentration columns), product fixed effects (for price columns), and year fixed effects are included but not reported. FDI measures are calculated at the province level (as done for all other tables) in columns (1)-(7). Because we not have regional variation in prices, FDI measures for

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
			log(output)					log(value added)		
Downstream FDI	0.175 (3.94)			0.183 (4.08)	0.080 (1.73)	0.118 (1.73)			0.151 (2.21)	0.039 (0.55)
Supplier Downstream FDI		0.496 (7.75)			0.744 (9.28)		0.367 (3.78)			0.806 (6.65)
Horizontal FDI			-0.018 (0.81)	-0.030 (1.31)	-0.175 (6.29)			-0.121 (3.52)	-0.131 (3.78)	-0.284 (6.84)
Other firms' Horizontal FDI										
Constant	11.977 (1779.48)	11.958 (1637.08)	11.986 (1750.77)	11.980 (1707.96)	11.959 (1622.61)	10.449 (1022.91)	10.435 (944.57)	10.465 (1010.91)	10.460 (985.23)	10.437 (936.02)
Observations	108615	108615	108615	108615	108615	91616	91616	91616	91616	91616
Number of Establishments	23861	23861	23861	23861	23861	21377	21377	21377	21377	21377
R-squared	0.07	0.07	0.07	0.07	0.07	0.04	0.04	0.04	0.04	0.04
Absolute value of t statistics in parentheses										

Table 6: Value Added and Output, domestic firms. Establishment fixed effects, island-year and year dummy variables are included but not reported.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
			log(output)					log(value added)		
Downstream FDI	1.295 (6.12)			1.344 (6.19)	0.419 (1.76)	0.851 (2.73)			0.969 (3.03)	0.227 (0.63)
Supplier Downstream FDI		3.094 (9.92)			3.408 (8.96)		2.129 (4.42)			2.698 (4.48)
Other firms' Horizontal FDI			0.033 (0.36)	-0.095 (1.01)	-0.422 (4.24)			-0.139 (0.97)	-0.239 (1.63)	-0.508 (3.22)
Constant	14.810 (342.89)	14.575 (277.91)	14.941 (344.93)	14.828 (317.21)	14.596 (275.26)	13.646 (209.26)	13.478 (166.37)	13.767 (208.73)	13.691 (193.90)	13.506 (165.68)
Observations	5210	5210	5210	5210	5210	4120	4120	4120	4120	4120
Number of Establishments	1324	1324	1324	1324	1324	1096	1096	1096	1096	1096
R-squared	0.22	0.23	0.21	0.22	0.24	0.13	0.13	0.13	0.13	0.14
Absolute value of t statistics in parentheses										

Table 7: Value Added and Output, foreign firms. Establishment fixed effects, island-year and year dummy variables are included but not reported.

E. Figures

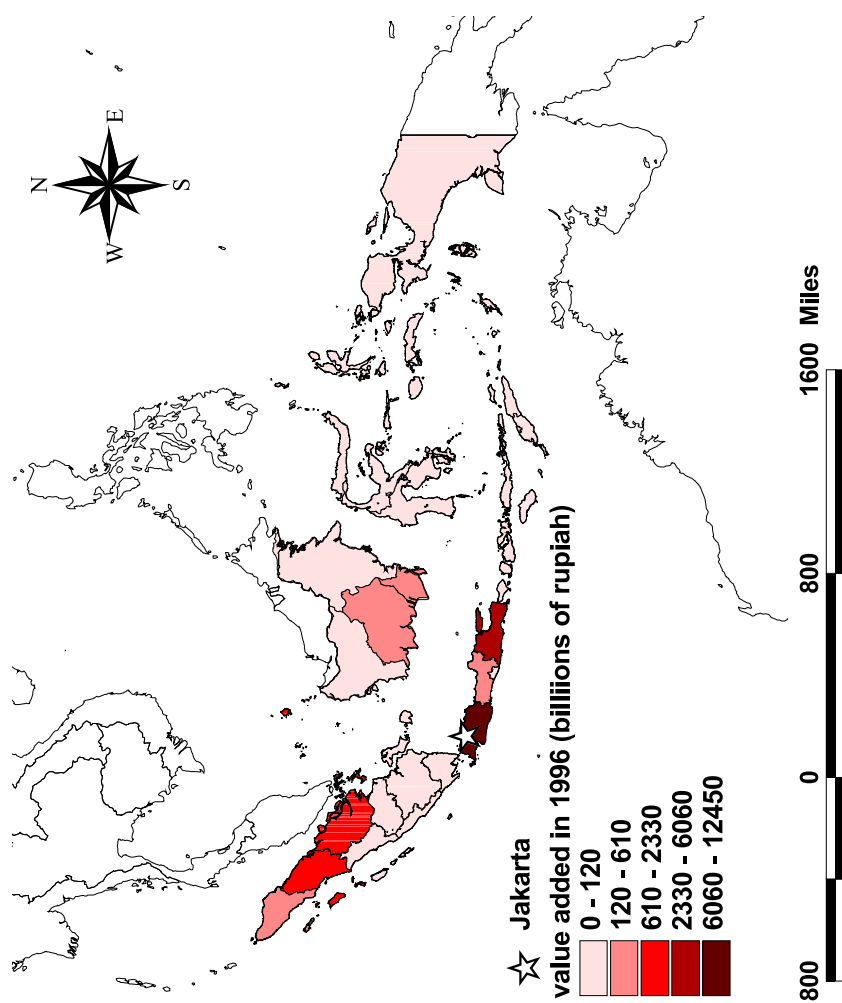


Figure 1: Value added in manufacturing, 1996, by province.

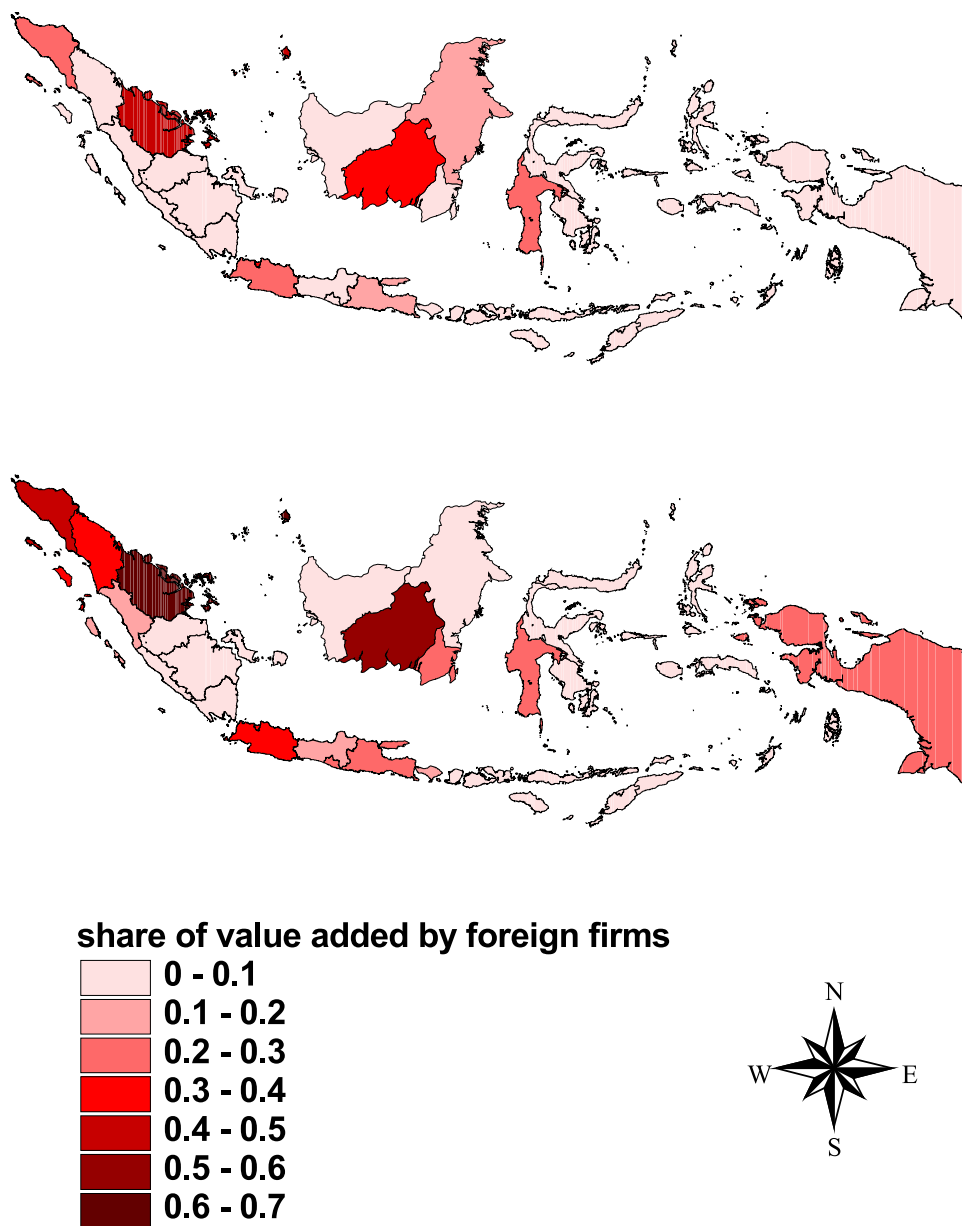


Figure 2: Share of manufacturing value added by foreign firms, by region, 1988 (top) and 1996 (bottom).