How Firm Capabilities Affect Who Benefits from Foreign Technology*

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Abstract

We explore how firm capabilities affect the diffusion of technology brought with foreign direct investment (FDI). Using a panel dataset on Indonesian manufacturers from 1988 to 1996, we measure how the productivity of differing domestic firms responds to the entry of multinational competitors. We find that firms with investments in research and development and firms with highly educated employees adopt more technology from foreign entrants than others. In contrast, firms that have a small "technology gap," meaning that they are close to the international best-practice frontier, benefit less than firms with weak prior technical competency. This finding suggests that the marginal return to new knowledge is greater for firms that have more room to "catch up" than it is for already competitive firms.

Keywords: technology transfer, foreign direct investment, firm capabilities
JEL classification: O32, O24, F14, L60

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1. Introduction

Policy makers have long believed that foreign direct investment (FDI) can be an important source of technology for developing economies (World Bank 1993). They argue that the technology employed by firms in emerging markets is inferior to that of their multinational counterparts based in developed economies. When multinationals enter an emerging market, they bring more advanced managerial practices, production methods, and other tacit and codified knowhow by which a firm transforms inputs into a product. This technology then diffuses throughout the host economy as local incumbents imitate the new technology and hire workers trained by the multinationals. This proposition has spawned a large literature seeking to identify "technology spillover" from FDI.[1]

This paper builds on this discussion by asking *which* host economy firms are most likely to adopt the technology brought with FDI. Understanding the determinants of technology adoption has important policy implications. Policy makers evaluating the cost of programs to attract FDI must consider whether there are benefits from FDI overall and, if so, what domestic firm characteristics maximize the benefit. Empirical evidence on the first question is mixed.[2] One reason for the conflicting results may be firm heterogeneity—if only certain firm types benefit from FDI, then the overall benefit may vary with the composition of firms in the economy. Policy makers may want to encourage domestic firms to adopt characteristics necessary to benefit from foreign technology.

We consider three firm capabilities that may influence technology adoption. First, a firm's investment in absorptive capacity, the "ability to recognize the value of new

[1] See Moran 2001, Saggi 2002, and Keller 2004 for excellent surveys of the literature on technology transfer from FDI.

[2] See Caves 1974, Globerman 1979, Blomstrom and Wolff 1994, Haddad and Harrison 1993, Kokko 1994, Aitken and Harrison 1999, and Haskel, Pereira, and Slaughter 2002.

information, assimilate it, and apply it to commercial ends" would likely influence its ability to exploit external knowledge (Cohen and Levinthal 1990). Cohen and Levinthal argue that a firm can build absorptive capacity by engaging in organizational activities requiring prior related knowledge, such as basic related skills, a common language, or familiarity with scientific and technical developments in the field. As a proxy for absorptive capacity, we will use a firm's investment in research and development.

Second, a firm's human capital may influence its adoption of technology for similar reasons. Even if a firm can observe technology, its ability to adopt the technology may be contingent upon having skilled personnel with sufficient training and educational background. We measure human capital as the percentage of a firm's workers with college or higher degrees.[3]

Third, a firm's technology gap, the distance between its technology level and that of typically more advanced multinational firms, could affect technology adoption. The direction of such an effect is unclear. On one hand, firms with a large gap have the most to gain and possibly the highest marginal returns from adoption. Firms with a small gap lack the incentive to alter existing practices. These firms may have already picked the "low-hanging fruit" technologies that have low cost and high returns, thereby making further cost-effective improvement more difficult. On the other hand, firms with a large gap are far behind best practice and could lack the technical competency needed to catch up. Firms with a small gap are technically proficient and could easily employ new technology. We measure a domestic firm's technology gap as the difference between its total factor productivity and that of foreign-owned firms in the period prior to our analysis.

[3] Arguably, employee education could also be considered absorptive capacity. Because Cohen and Levinthal 1990 stresses the role of organizational activities (in additional to individuals' experiences and activities) in their discussion of absorptive capacity, we use the term human capital instead.

We test the three hypotheses described above using a panel of Indonesian manufacturing facilities from 1988 to 1996. During this period Indonesia liberalized trade and foreign investment regulations stimulating a large increase in foreign investment. We exploit the variation in this investment as a measure of the available foreign technology by industry and by region over time. We then estimate the extent to which changes in the availability of foreign technology shifted domestic firms' productivity and how those shifts were mediated by the firms' capabilities.

Unconditional on firm capabilities, we find no overall effect of FDI on domestic firm productivity. But, looking for an overall effect masks wide variation in the impact of FDI on firms with differing capabilities. Suppose that the FDI in an industry-region increases by ten percentage points. Firms with absorptive capacity experience an 1.8 percent productivity gain relative to those without, and firms gain an additional 1.3 percent for each tenth of their workforce with a college degree. Further, firms with a large large technology gap increase productivity about 1.0 percent more than firms that are already near the best practice frontier, suggesting that the marginal return from new knowledge is greater for firms with room to "catch up" than it is for already competitive firms.

The paper proceeds as follows. Section 2 provides some background on foreign direct investment in Indonesia. Sections 3 and 4 detail the data and our methods, respectively. Section 5 discusses the results, and Section 6 concludes.

2. Indonesian Manufacturing and Foreign Investment Policy

Indonesia is an attractive setting for research on FDI and technology adoption 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. Second, the country's widespread archipelago geography and generally poor transportation infrastructure create a number of local markets, which support our use of geographical variation in the analysis. Third, a number of institutional reforms of investment law have dramatically increased the amount of FDI in recent years. In particular, the nature and timing of these reforms provide plausible exogenous variation in FDI by region, industry, and time.

The Indonesian economy and the manufacturing sector grew dramatically from the late 1970s until the recent financial crisis.[4] Indonesia enjoyed an average annual GDP growth rate of 6 to 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-1980s, 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).

Over the past 40 years, government regulation has shifted dramatically from a policy antagonistic to FDI to a policy actively encouraging it (Wie 1994; 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 1950s and 1960s. Gradual reforms began in 1967 as part of the "New Order" economic regime of Suharto. The reforms allowed investment in most sectors, but still required substantial minimum levels of Indonesian ownership in new ventures. After

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

the collapse of oil prices in the mid-1980s, the government introduced exemptions to the restrictions on foreign investment. The exemptions were targeted to 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. 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.

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 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.

3. Data

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 the *Survei Tahunan Perusahaan Industri Pengolahan* (SI), the Annual Manufacturing Survey. The SI dataset is a complete 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 (ISIC), location, ownership (public, private, foreign), status of incorporation, assets, asset changes, electricity, fuels, income, output, expenses, investment, labor (head count, education, wages), raw materials, machinery, and other specialized questions.

The analysis here starts from 1988, the first year for which 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 summarized for 1988 and 1996 in Table 1 and some details of their construction are in Appendix A. The table indicates a large increase in the number of foreign factories, which increases from 168 in 1988 to 464 in 1996. On average, foreign factories are bigger (as measured by employees and capital), and more productive (as measured by value added per employee). We deflate output, materials, and capital to express values in real terms as described in Appendix A.

4. Methods

In this section we describe the methods we use to estimate the effects of FDI on firm productivity and how firm capabilities mediate those effects. We examine the

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

extent to which changes in the availability of foreign technology shift a domestic firm's productivity and how those shifts are mediated by the firm's capabilities. We begin by specifying an empirical model, we then describe how we measure the key variables, and we end by discussing our econometric identification.

4.1. Empirical Specification

We follow a methodology similar to that of earlier work on the productivity effects of trade and investment, such as Pavcnik 2002 and Keller and Yeaple 2003, by regressing firm total factor productivity (TFP) on FDI and FDI interacted with firm capabilities. Specifically, we estimate

$$\ln TFP_{it} = \beta_0 FDI_{jrt} + \beta_1 CAPABILITY_i * FDI_{jrt} + \gamma_{jt} + \lambda_{rt} + \alpha_i \qquad (1)$$

where FDI_{jrt} is foreign direct investment during year t in industry j and region r, $CAPABILITY_i$ is a placeholder for the three firm capability variables, γ_{jt} is a industry-year fixed effect, λ_{rt} is a region-year fixed effect, and α_i is a firm fixed effect. A positive coefficient on FDI_{jrt} indicates that FDI is associated with higher total factor productivity and a positive coefficient on $CAPABILITY_i * FDI_{jrt}$ indicates that firms with that attribute have a greater productivity response to FDI than other firms. Because the firm capabilities are interacted with FDI, we capture their mediating effect on FDI. The main effect of these capabilities is captured in the firm fixed effect.

4.2. Measurement

The key variables used in the analysis are measures of TFP, FDI, and capabilities. We describe our measurement of each variable below.

4.2.1. TFP

Consistent with many prior studies (for example, see Schoar 2002, p. 2383), our firm-year measures of TFP are the residual of a Cobb-Douglas production function estimation. Specifically,

$$TFP_{it} = \exp(\ln OUTPUT_{it} - \beta_0 \ln CAPITAL_{it} - \beta_1 \ln LABOR_{it} - \beta_2 \ln MATERIALS_{it}) \tag{2}$$

in which the return to inputs, β_0, β_1, and β_2, are first determined by estimating the regression

$$\ln OUTPUT_{it} = \beta_0 \ln CAPITAL_{it} + \beta_1 \ln LABOR_{it} + \beta_2 \ln MATERIALS_{it} + \omega_{it} + \eta_{it}. \tag{3}$$

ω_{it} is a productivity shock observed by the firm but not by the econometrician and η_{it} is an error term uncorrelated with the other inputs. Because ω_{it} is observed by the firm, it may affect input choices and thus we would calculate inconsistent estimates of the production factors (Marschak and Andrews 1944). To avoid this potential simultaneity, we employ the production function estimation in Levinsohn and Petrin 2003 using the Stata `levpet.do` command documented in Levinsohn, Petrin, and Poi 2004. To allow the returns to inputs to vary across industries, we estimate the production function separately by 3-digit ISIC.

4.2.2. FDI

We calculate FDI by industry and provincial region. A regional measure captures the geographical localization of knowledge spillovers suggested by Jaffe, Trajtenberg, and Henderson 1993, which found that the rate of knowledge diffusion, measured by patent citations, declined with distance. Indonesia's vast archipelago geography and poor transportation and communications infrastructure further support the notion that firms are less likely to adopt knowledge if it is distant. We calculate FDI as shown in Equation 4.

$$FDI_{jrt} = \frac{\sum_{i \in jrt} FOREIGN\_OUTPUT_{it}}{\sum_{i \in jrt} OUTPUT_{it}} \tag{4}$$

$i \in jrt$ indicates a factory in a given industry, region, and year, $OUTPUT_{it}$ is the output of factory i, and $FOREIGN\_OUTPUT_{it}$ is the output of factory i if the factory is foreign, and zero otherwise. We define industries by four-digit ISIC codes and regions by Indonesia's then 27 provinces.[6]

4.2.3. Firm Capabilities

We next discuss our measurement of the three firm capabilities described above. Research and development expenditures, the proxy for absorptive capacity, are available in the 1995 and 1996 surveys. Experience with the SI data indicates that financial reporting is often noisy. Hence, and because the ratio of R&D expenditures to total costs is typically low, we do not distinguish between levels of expenditures. Instead, we use a discrete measure of one if the firm spent any amount on R&D in either 1995 or 1996, and zero otherwise.[7]

Human capital is measured as the percentage of workers with an education at or above the junior-college level. Data on employee educational attainment are available for 1995 and 1996. If firms reported educational attainment in both years, we used the highest percentage. We dropped firms that did not report educational attainment from the sample.

[6] Following the independence of East Timor and the recent division of some provinces, the current count is now 33.

[7] Estimation using continuous measures of R&D expenditures shows an effect only at the discontinuity from zero to a positive value.

We define "technology gap" as the distance from a domestic firm's technical competency level to that of international best practice. We use the first three years of TFP values as a baseline gap for analysis in later years. Specifically, we subtract the firm's average TFP in its first three years from the median foreign firm TFP in the same 3-digit ISIC sector, and then divide this difference by the average foreign firm TFP. For example, a gap of 0.20 would indicate that the firm's TFP was 20 percent lower than the median foreign firm TFP.

4.3. Identification

Our estimation relates firm TFP to FDI. To establish that any correlation is causal, we must consider the fact that multinationals can be expected to invest in the regions and industries that have the highest expected rate of return. A key factor in the expected rate of return is productivity and possibly expected growth in productivity. This concern is a variant of the endogeneity of program placement issue (Rosenzweig and Wolpin 1996).

We take several approaches to control for the potential endogeneity. First, we include firm fixed effects. This controls for unobserved firm-specific time-invariant productivity factors such as managerial capabilities and local characteristics (α_i in equation 1). Next, we include industry-year fixed effects, which control for changes over time in factors common to all firms in the same industry such as regulation and terms of trade (γ_{jt} in equation 1). Finally, we include region-year fixed effects, which control for changes in location specific factors that are common to all firms in the same region and might affect firm productivity, such as local regulation, infrastructure, and labor markets (λ_{rt} in equation 1). Thus, our specification is intended to measure the effect of an increase in FDI in industry j in region r on the change in a domestic firm's total factor productivity in the same industry and the same region, controlling for productivity shocks to the industry and to the region.

Finally, we must take special care when estimating the interaction of FDI and the technology gap measure. Consider, for example, the case that FDI conveys large benefits to technologically laggard firms, those with a large gap. Suppose that a firm had low productivity the first few years in the panel, was then exposed to FDI, and then had extremely high productivity in the remaining years. Since the average productivity of the firm over the entire panel would be high, our technology gap measure would be small if constructed over all years. We would thus falsely conclude that technologically advanced firms with small gaps benefit the most from FDI. To avoid this endogeneity problem, we split the sample into two groups: one with just the observations for firms' first three years in the panel and another containing the remaining observations. We use the first three years to construct the technology gap measure. We estimate the capability*FDI interaction effects using the subsequent years of data. Stated another way, our technology gap measure represents productivity in the period prior to the analysis.

5. Results

5.1. Descriptive Statistics of Capabilities

The descriptive statistics for the capability measures are reported in Table 2 by foreign and domestic firms. Although we include only domestic firms in our analysis, the differences between foreign and domestic firms are revealing. Only about 9 percent of domestic firms have absorptive capacity (positive R&D expenditures), compared with 23 percent for foreign firms. Likewise, only about 2 percent of domestic firm employees are college educated, compared with 7 percent for foreign firms. The average technology gap is 0.11 for domestic firms, suggesting that they are about 11 percent less productive than their foreign counterparts.[8] Consistent with our prior that foreign firms are more productive, 75 percent of domestic firms have productivity less than the foreign average.

Table 3 shows the breakdown of sample size, change in FDI, and capabilities by the 20 largest 3-digit ISIC codes.[9] The table reveals significant variation in FDI and firm capabilities across industries and, in some cases, large differences between nearby codes representing similar products. For example, the two chemical categories (ISIC codes 351 and 352) differ significantly in both FDI and the technology gap. Hence, at least some of the comparison between our treatment and control groups is across seemingly otherwise similar industries. The mean technology gap values in the last column again demonstrate the relatively low levels Indonesian firms' TFP. In most industries, the technology gap is in the range of 0.2–0.3, indicating that Indonesian firms' TFP is 20 to 30 percent lower that that of foreign firms.

The capability measures each seem to provide some independent information. Table 4 reports correlations between the capabilities. Absorptive capacity and human capital are positively correlated and both of these measures are negatively correlated with the technology gap. That is, firms with investments in R&D tend to have better educated employees and are closer to the technology frontier.

5.2. Estimation Results

Table 5 shows the results of estimating equation 1. Column (1) gives the results of estimating Equation 1 on all domestic firms with no capability interaction terms. The overall effect of FDI is near zero and insignificant. However, the overall effect

[8]Since the median productivity of foreign firms, by definition, is the "frontier" benchmark for the technology gap, the gap for foreign firms is not meaningful and is omitted from the table.

[9]In our regressions, we use changes in FDI by province. Because it is impractical to include a table for each of the 27 provinces, the table reports only country-wide changes in FDI. The table thus understates the true variation in localized FDI.

masks important differences in how how FDI affects firms with different capabilities. Column (2) includes an indicator of absorptive capacity, expenditures on research and development, interacted with FDI. Because the R&D indicator is time-invariant for each firm, its main effect is dropped from the fixed-effect estimation. The 0.185 coefficient on the interaction term suggests that domestic firms with greater absorptive capacity acquire more technology from FDI. If FDI in an industry-region were to grow from zero to nearly one (i.e., move from no foreign firms to nearly all foreign firms), then domestic firms with absorptive capacity would realize about an 18.5 percent point productivity gain relative to other firms. Although such a large change in FDI does not occur in practice, increases in excess of 20 percent are not uncommon in industry-regions cells occupied by hundreds of firms. Thus, the realized productivity effect of FDI differs by a non-trivial amount across firms with and without absorptive capacity.

Column (3) displays the results of estimating Equation 1 on a sample of domestic firms with a measure of human capital, the percentage of employees with degrees at or above the junior-college level, interacted with FDI. As with the R&D indicator, because the human capital measure is time-invariant for each firm, its main effect is dropped from the fixed-effect estimation. The positive coefficient on the interaction term suggests that local firms with greater human capital acquire more technology from FDI. Although the coefficient of 1.306 seems high, it must be multiplied by changes in FDI and the generally small changes in the share of employees with college degrees to calculate the realized productivity difference. For most firms, the realized effect of the human capital measure is an increase in productivity of one or two percent.

Column (4) shows the results of estimating Equation 1 on a sample of domestic firms with a measure of technical competency, the gap between the firm's productivity and international best practice, interacted with FDI. The coefficient of 0.106 shows that the benefit of FDI is greater for firms with larger technology gaps. That is, firms that that are further from the best practice frontier tend to benefit more from FDI.

As noted above, about 25 percent of the domestic firms have a negative technology gap, meaning that their productivity is higher than the average of foreign firms. One would expect the effect of FDI to differ for these firms. That is, whereas unproductive domestic firms might be able to learn from FDI, one might not expect more productive firms to "unlearn" or otherwise be dragged down. We therefore enter the technology gap semi-parametrically into the estimation. Firms with negative technology gaps were coded as such. We divide the remaining firms with a positive technology gap into three equal-sized groups: small, medium, and large, with a large gap indicating poor productivity far from the foreign firm median. In total, the four categorizations, negative, small, medium, and large, are mutually exclusive and negative is the omitted category in the estimation. The effect of FDI on firms with a negative technology gap is thus just the main effect of FDI. The estimation, shown in in column (5), indicates that only firms with a large technology gap have a statistically significant effect from FDI, about a 10.1 percent point productivity gain relative to firms with a negative gap.

Table 4 shows that the technology gap measure is correlated with the absorptive capacity and human capital, and thus our estimation may be confounding the three effects. I.e., the positive FDI coefficient for firms with a large technology gap might reflect that these less productive firms are also less likely to have absorptive capacity and high human capital. To separate the three effects, column (6) shows all three jointly estimated. The effect of absorptive capacity, human capital, and the technology gap remain similar magnitude and remain significant. The main effect of FDI is its effect on the omitted technology gap group, those firms with a negative gap. Because the coefficient of FDI is a statistically significant -0.089, one might be concerned that FDI is somehow "dragging down" the more advanced domestic firms. One must recall, however, that the more advanced firms are likely to have absorptive capacity and high human capital, and thus the interaction of those capabilities with FDI must also be considered. Evaluated at the mean values for absorptive capacity and human capital, the point estimate for the total effect of FDI (the sum of the main effect and the interaction effects) is -0.032. We used the "delta method"(for example, see Deaton 1997, p. 128) to calculate the variance of the summed total effect, is statistically insignificant (t-stat of 1.06). Thus FDI appears to have no adverse effect on the negative technology gap firms.

We should note that the data do not indicate changes in absorptive capacity or human capital over time. Rather, we have indications only from the end of the panel. Thus, a concern is that the decision for a firm to invest in absorptive capacity or human capital is endogenous to its prior performance. Although the endogeneity is not as obvious as that of the technology gap measure (for which prior performance actually determines the gap), it is non-remediable in our econometrics. We believe it reasonable to assume that firms with high absorptive capacity or human capital retain those attributes over time. However, we cannot rule out the possibility that investments in both capabilities are driven by productivity gains in the early years of the panel.

6. Summary and Implications

This paper examines how firms' capabilities influence the adoption of technology brought with foreign direct investment (FDI). Our chief finding is that firms with greater absorptive capacity, higher levels of human capital, but with lower prior technical competency, are the prime beneficiaries of technology from FDI.

The finding for prior technical competency is perhaps the most surprising. Whereas one might initially think that more competent firms could benefit the most from FDI, the evidence suggests that firms far from the best-practice frontier gain more. We believe the "low hanging fruit" concept explains this result: firms with poor initial technology are more likely to encounter new processes that yield high returns at low cost. This explanation is partly conditional on the idea that technology brought with FDI is relatively mature and can be adopted without extensive further development (Mansfield and Romeo 1980). In the case of less commercialized technology, such as that coming from universities or research laboratories, the impact of prior technical competency may differ significantly.

Our results add to a conflicting collection of results about technology adoption from FDI—whereas some studies find positive spillovers, others have found net negative effects from FDI. We argue that the conflicting evidence may, in part, be due to heterogeneity in the capabilities of host-economy firms. Understanding which firms benefit from FDI may be more informative than the mean benefit across a heterogenous pool of host-economy firms.

Finally, to the extent that evidence from Indonesia can be generalized, these results have an important implications for foreign investment policy in developing countries. Actions that promote FDI are more likely to benefit firms with investments in research and development and with highly educated employees. At the same time, firms that have more room to improve relative to international best practice stand to reap the greatest marginal return from exposure to the new knowledge. Further, to the degree that technology from FDI resembles technology from other sources, such as universities and research laboratories, the same implications apply to national innovation policy in general.

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A. Data Appendix

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

A.1. 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. Establishments with more than 20 percent foreign equity are defined as foreign. This definition yields a sample of foreign factories very similar to those operating with PMA licenses.

Surveys performed by BPS indicate that fewer than 5 percent of establishments belong to multi-establishment firms. We thus generalize our results to firms and refer to the observations as firms.

A.2. 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 equipment, vehicles, and other assets. When reported, we use the total replacement value of all five categories for our capital measure. However, if an establishment reported book values but not replacement values, we use the book values for our capital measure.

A.3. Labor

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) and our measures include both types. In 1995 to 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 are recorded

A.4. Construction of Price Deflators

Output, materials, and capital are deflated to express values in real terms. The deflators are based on *Indeks Harga Perdangangan 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.

A.4.1. 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.

A.4.2. 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 weight 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.

A.5. Correction for Outliers and Missing Values in Industrial Surveys

We have cleaned the output, labor, capital, and materials variables to minimize noise due to non-reporting, misreporting, and obvious mistakes in data keypunching. We removed observations with sudden spikes in values likely attributable to keypunch error (often due to an erroneously added or omitted zero). We also dropped observations with remaining unreasonably large jumps or drops in key variables not accompanied by corresponding movements in other variables (for example, large increases in labor not accompanied by any increase in output). Finally, after calculating our TFP measure for each firm-year, we dropped the top and bottom one percent values. The cleaning removed about a third of the sample, mostly due to non-reporting of capital.

B. Tables

All monetary values are given in 000's of 1983 rupiah.

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

	1988		1996	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
log(output)	11.74	1.63	12.38	1.72
log(capital)	11.01	1.79	11.58	1.74
log(materials)	10.05	1.88	11.51	1.99
Employees	88.25	513.00	119.27	527.69
Value added per employee	2212.45	5253.81	3674.12	8263.39
No. firms	7930		8540	
log(output)	14.67	1.79	15.45	1.64
log(capital)	13.44	2.00	14.32	1.54
log(materials)	13.81	1.95	14.63	1.88
Employees	287.69	456.71	591.35	1176.43
Value added per employee	15317.81	17468.13	22418.50	74824.63
No. firms	168		464	

Table 2: Mean and standard deviations for absorptive capacity (one if the establishment had R&D expenditures, zero otherwise), human capital (proportion of employees with junior-college or higher educations), and technology gap (distance from establishment fixed effect to average of foreign establishments' fixed effects).

	Domestic firms		Foreign firms	
	Mean	Std. dev.	Mean	Std. dev.
Absorptive capacity	0.09	0.27	0.23	0.42
Human capital	0.02	0.05	0.07	0.09
Technology gap	0.11	0.40		

Table 3: Distribution of firm count, industry change in FDI between 1988 and 1996, mean absorptive capacity indicator, mean human capital measure, and mean technology gap measure, for the 20 largest 3-digit ISIC rev. 2 industries. Note that zero values for the human capital measure (establishments with no highly educated workers) are included in the average. Among firms with at least one highly educated worker, the variation in the measure is much greater.

3-digit ISIC	Industry description	Firm count	FDI change 1988–1996	Mean absorptive capacity	Mean human capital	Mean tech. gap
311	Food 1	2,151	0.05	0.08	0.01	0.04
312	Food 2	1,507	0.10	0.07	0.01	0.41
314	Tobacco	1,016	0.02	0.03	0.00	0.34
321	Textiles	1,671	0.04	0.06	0.01	0.34
322	Apparel	1,884	0.19	0.06	0.01	0.02
324	Footwear	322	0.17	0.14	0.03	0.26
331	Wood	1,607	0.09	0.09	0.02	0.22
332	Furniture	1,170	0.05	0.06	0.02	0.42
341	Paper	219	0.07	0.09	0.04	0.16
342	Printing	549	0.00	0.08	0.06	0.32
351	Industrial chemicals	241	0.20	0.17	0.06	0.07
352	Other chemicals	463	0.01	0.24	0.07	0.33
355	Rubber	303	0.04	0.15	0.03	0.01
356	Plastic	759	0.06	0.06	0.03	0.17
363	Cement	618	0.00	0.08	0.01	0.45
364	Ceramics	851	0.21	0.04	0.00	-0.05
381	Metal	600	0.13	0.09	0.03	0.22
382	Machinery	260	0.15	0.13	0.05	0.44
383	Electronics	308	0.21	0.25	0.06	0.04
384	Transportation	437	-0.14	0.14	0.04	0.42

Table 4: Correlation between absorptive capacity (one if the establishment had R&D expenditures, zero otherwise), human capital (proportion of employees with education at or above the junior-college level), and technology gap (distance from the firm's total factor productivity to the median of foreign firms). Sample of domestic firms.

	Absorptive capacity	Human capital	Technology gap
Absorptive capacity	1.0000		
Human capital	0.1907	1.0000	
Technology gap	-0.0532	-0.0783	1.0000

Table 5: Productivity estimation. A negative technology gap is the omitted category in columns (5) and (6). All estimations include but do not report year indicators and firm fixed effects.

Dep. var: ln(TFP)	(1)	(2)	(3)	(4)	(5)	(6)
Province 4-digit ISIC HFDI	0.011	−0.005	−0.017	−0.005	−0.042	−0.089***
	(0.016)	(0.017)	(0.018)	(0.017)	(0.030)	(0.031)
Absorptive Capacity*FDI		0.185***				0.162**
		(0.062)				(0.064)
Human capital*FDI			1.306***			1.144***
			(0.295)			(0.301)
Technology gap*FDI				0.106**		
				(0.045)		
Small Technology Gap*FDI					0.032	0.055
					(0.064)	(0.065)
Medium Technology Gap*FDI					0.057	0.072*
					(0.038)	(0.039)
Large Technology Gap*FDI					0.101**	0.122***
					(0.041)	(0.042)
Overall R-squared	0.001	0.001	0.002	0.001	0.001	0.003
No. observations	32173	29374	27465	32173	32173	27465
No. firms	9778	8166	7477	9778	9778	7477
*p<0.10, **p<0.05, ***p<0.01						

C. Figures

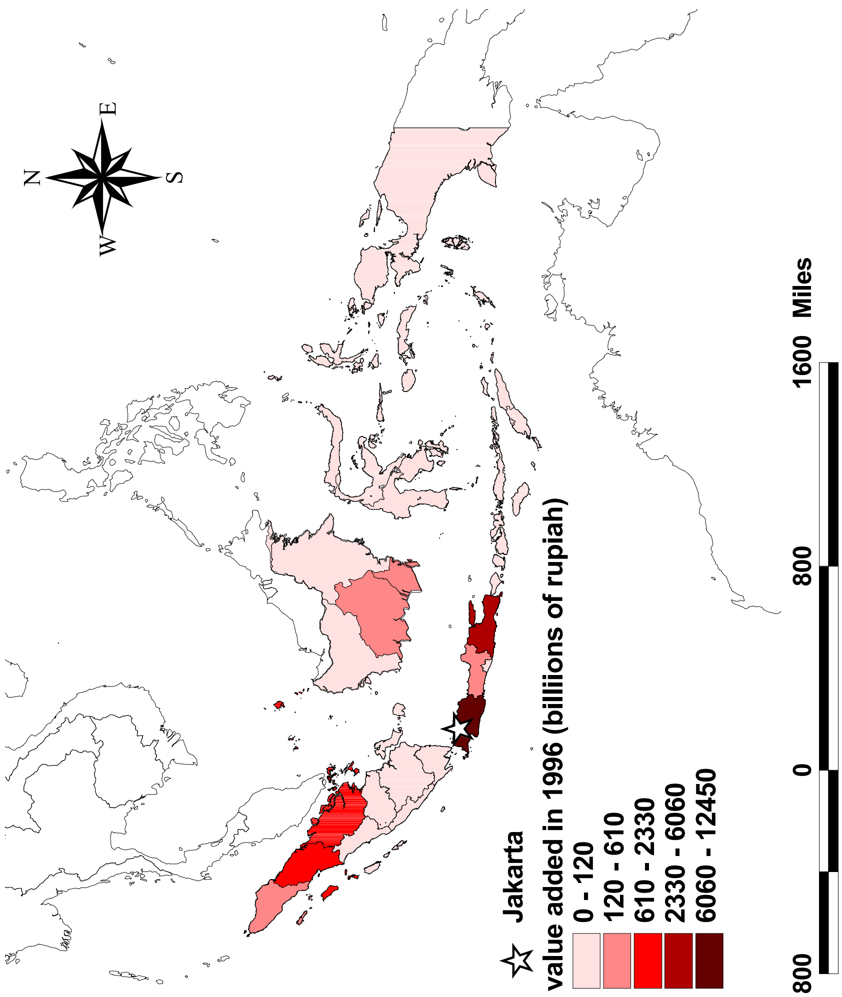

Figure 1: Value added by foreign firms in manufacturing, 1996, by province.

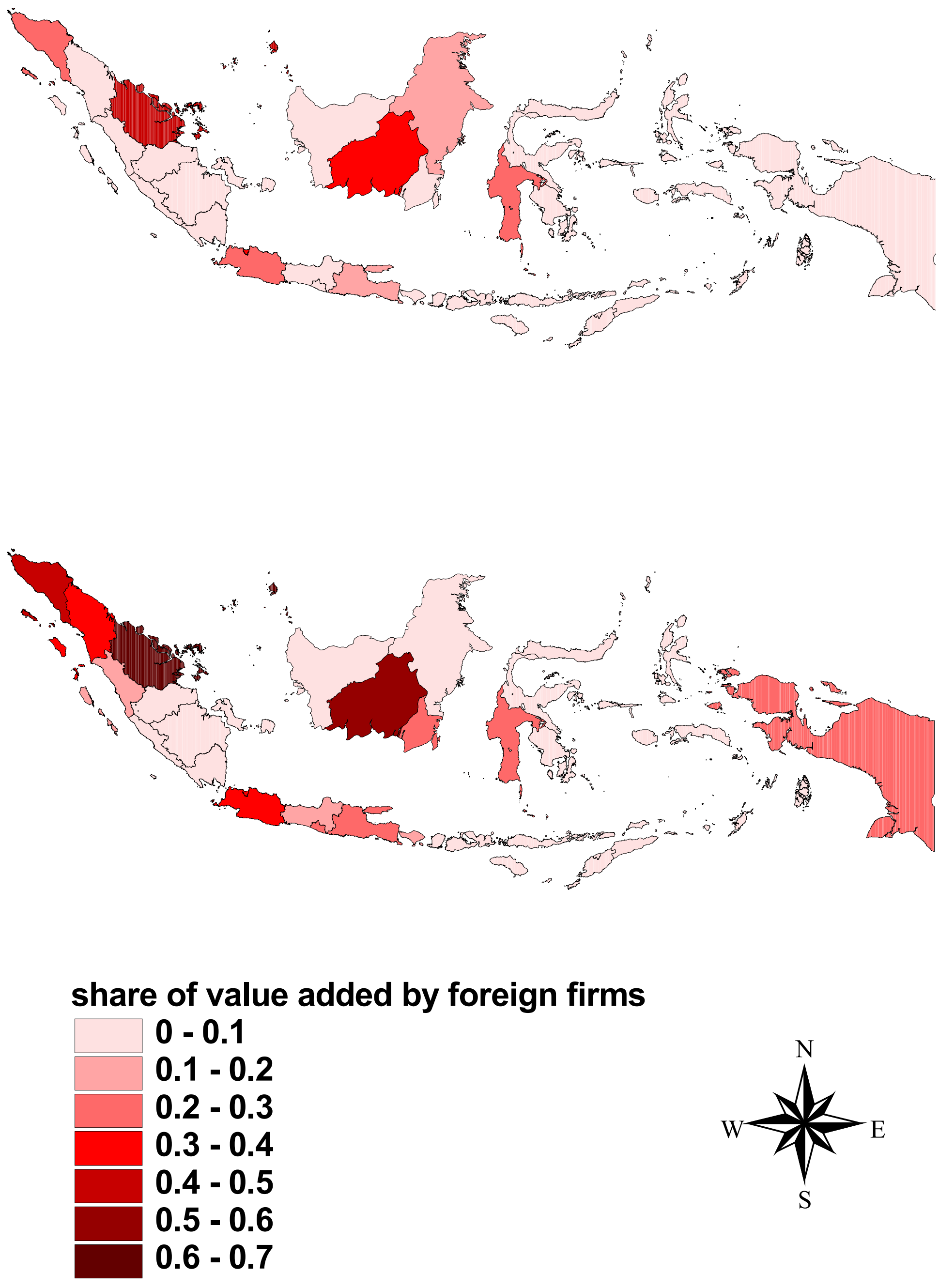

Figure 2: Share of manufacturing value added by foreign firms, by region, 1988 (top) and 1996 (bottom).