

Firm Capabilities and Technology Adoption: Evidence from Foreign Direct Investment in Indonesia

Garrick Blalock ^{*} Paul J. Gertler ^{† ‡}

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Abstract

We explore how firm capabilities affect innovation by observing the diffusion of technology brought with foreign direct investment (FDI). Using a panel dataset of Indonesian manufacturers from 1988 to 1996, we measure how the productivity of differing local firms responds to the entry of multinational competitors. We find that firms with greater absorptive capacity, as measured by prior investment in research and development, and firms with highly educated employees are able to adopt more technology from foreign entrants than others. In contrast, firms that have a narrow 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.

^{*} Cornell University, Department of Applied Economics and Management,
garrick.blalock@cornell.edu

[†]University of California, Haas School of Business, and NBER, gertler@haas.berkeley.edu

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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 technology, defined here as the managerial practices, production methods, and other tacit and codified knowhow by which a firm transforms inputs into a product. This technology may then diffuse throughout the host economy. For example, local incumbents may imitate the new technology or workers trained by the multinational may leave to create or join domestic firms. To the extent that the technology can be observed and adopted in this manner, it is a public good with a positive externality for local firms. 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 whatever technology is brought with FDI. Understanding the determinants of technology adoption has implications for both policy and management strategy. Policy makers evaluating the cost of programs to attract FDI must consider whether there are benefits to FDI overall and which firms are the likely recipients. Indeed, the empirical evidence on technology spillovers from FDI is mixed.² One reason for the conflicting results may be firm heterogeneity—if only certain firms can benefit from FDI, then the overall benefit may vary with the composition of firm types in the economy. Managers also have an interest in understanding technology diffusion from FDI. If firm attributes affect technology adoption, managers have an obvious incentive to promote the capabilities that facilitate adoption.

We propose three firm capabilities that may influence technology adoption. First, a firm’s

¹See Moran (2001) and Saggi (2002) for excellent surveys of the literature on technology transfer from FDI.

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

investment in absorptive capacity, the “ability to recognize the value of new 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 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 external technology, its ability to adopt or imitate may be contingent upon having skilled personnel with sufficient training and educational background to learn quickly. We measure human capital as the percentage of a firm’s workers with college or higher degrees.

Third, a firm’s technology gap, the distance between the level of a firm’s technology and that of the international best practice frontier, could affect technology adoption. The direction of such an effect is unclear. On one hand, firms with a wide gap could innovate quickly since they could initially adopt “low hanging fruit,” or technology with low marginal costs and high marginal returns. On the other hand, less technically competent firms could be too far behind best practice and lack the skills needed to catch up.

We test the three hypotheses described above using a panel dataset for Indonesian manufacturing facilities from 1988 to 1996, a period of foreign investment liberalization. This setting provides three advantages for our research. First, trade regime changes, such as that which occurred in Indonesia, introduce dramatic changes in foreign investment by industry, region, and year, and we can exploit this variation to identify technology diffusion. Second, unlike basic research and development, the technology brought with FDI is *already* commercialized by the multinational firms. In particular, multinationals tend to transfer more mature and stable technologies to their overseas operations (Mansfield and Romeo 1980).³

³Although the technology adopted by host economy firms is not necessarily new to the multinational, it is sufficient for our study if it is simply new to the host economy firms. Nelson (1992) points out that,

This means that there is not the long lag between basic research and commercialization that often complicates the identification of knowledge flows. Third, because the data capture FDI at the level of the multinational firm, we can precisely identify local firms in the same sector and region that potentially benefit from intra-sector technology spillover.

Our data are a rich panel of Indonesian manufacturing establishments with information on ownership, inputs, outputs, and a number managerial attributes. The data provide three advantages for identification. First, panel data allow the use of within-establishment estimation, which enables better identification of technology adoption than cross-sectional data. Second, the analysis can exploit large inter-temporal variation in FDI stemming from investment policy liberalization. Third, the dataset provides exceptionally rich descriptions of establishment attributes which allow identification of firm capabilities.⁴

The results suggest firm capabilities do affect technology adoption from FDI. In particular, firms with greater absorptive capacity, as measured by prior investment in research and development, and firms with well educated employees benefit more than others. In contrast, firms that have a narrow “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 of new knowledge is greater for firms that have more 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 identification strategy, respectively. Section 5 discusses the results and Section 6 concludes.

“innovation,” includes the implementation and mastery of new designs and processes, “whether or not they are new to the universe, or even to the nation.”

⁴Quantifying technology transfer and identifying to which firms it occurs is challenging because of methodological and data limitations (Griliches 1994). Researchers typically employ one of three approaches to overcome the inherent difficulty in observing intangible knowledge flows: survey results (e.g., Mansfield 1991), patent counts (e.g., Jaffe 1989), and production function estimation (e.g., Griliches 1962), the method used here. Griliches and Mairesse 1995 reviews the literature on measuring technology transfers. Studies identifying how firm attributes affect technology adoption, e.g. Cockburn and Henderson 1998 and Arora and Gambardella 1994, are few because of the richer firm-level data required, a constraint that our data allow us to overcome.

2. Indonesian Manufacturing and Foreign Investment Policy

We examine the above issues in a period just following the liberalization of foreign investment in Indonesia. Like many other emerging markets seeking inward technology transfer, Indonesia enacted a number of policies to encourage FDI in the late 1980's and early 1990's. The spillover of knowledge from FDI to local firms was part justification for the cost of these programs. We treat the knowledge accumulated from FDI as a public good and ask which firms benefited from it.

Indonesia's manufacturing sector 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. 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, which support our use of geographical variation in the analysis. Fourth, 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 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.

2.1. Growth in Manufacturing

The Indonesian economy and the manufacturing sector grew dramatically from the late 1970's until the recent financial crisis.⁵ 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).

2.2. 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 during 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

⁵(Hill 1988) and (Pangestu and Sato 1997) provide detailed histories of Indonesian manufacturing from the colonial period to the present.

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 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 arrangements was the option to withhold the financing, equipment, and knowhow 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 oper-

ations 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.

2.3. 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.

3. Data

The analysis is based on data from the Republic of Indonesia's *Budan Pusat Statistik* (BPS), the Central Bureau of Statistics.⁶ 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 the data.

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

⁶We identify names in Bahasa Indonesia, the language of most government publications, with italics. Subsequently, we use the English equivalent or the acronym.

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.⁷ Because field office budgets are partly determined by the number of reporting establishments, agents have some incentive to identify and register new plants. In recent years, over 20,000 factories have been surveyed annually. Government laws guarantee that the collected information will only be used for statistical purposes. However, several BPS officials commented that some establishments intentionally misreport financial information out of concern that tax authorities or competitors may gain access to the data. Because the fixed-effect analysis admits only within-factory variation on a logarithmic scale, errors of under- or over-reporting will not bias the results provided that each factory consistently misreports over time. Further, even if the degree of misreporting for a factory varies over time, the results are unbiased provided the misreporting is not correlated with other factory attributes in the right-hand-side of the regression.

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

The analysis here starts from 1988, the first year for which data on fixed assets are

⁷Some firms may have more than one factory. BPS also submits a different questionnaire to the head office of every firm with more than one factory. Although these data were not available for this study, analysis by BPS suggests that less than 5 percent of factories belong to multi-factory firms. We therefore generalize the results to firms.

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 1.⁸ The table indicates a large increase in the number of foreign factories, which increases from 276 in 1988 to 904 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 deflated output, materials, and capital to express values in real terms. The deflators are based on *Indeks Harga Perdagangan Besar* (IHPB), wholesale price indexes (WPI) published by BPS. Appendix B describes the deflator calculation in detail.

4. Identification and Measurement

Our objective is to identify and estimate the effect of FDI on firm productivity. We do so by estimating an establishment-level transcendental logarithmic (translog) production function. The translog production function is a second-order logarithmic approximation of production that places no functional form restrictions on the nature of input substitution or returns to scale. The production function controls for input levels and scale effects. In effect, we ask whether the residual in the production function is correlated with FDI. Further, we will interact firm attributes with changes in FDI to identify which firms benefit more from foreign firm presence.

Because our firm-level data are a panel, we can examine how changes in FDI over time affect changes in firm productivity. The advantage of this approach is that it allows us to control for static unobservable attributes. Further, as we explain below, our measure of FDI varies by time, industry, and region. We can thus exploit changes in FDI over time not

⁸The descriptive statistic tables show the data actually used in the analysis. Observations removed in the data cleaning are not included.

only between industries, but also within the same industry across different regions. That is, while controlling for firm-specific effects, our “treatment” group consists of firms in a particular industry in a region with changing FDI, versus a “control group” of firms in the same industry but in a region without changing FDI.

Our estimating equation is

$$\begin{aligned}
\ln Y_{it} = & \beta_0 FDI_{jrt} + \beta_1 CAPABILITY_i FDI_{jrt} + \\
& \beta_2 \ln K_{it} + \beta_3 \ln L_{it} + \beta_4 \ln M_{it} + \beta_5 \ln^2 K_{it} + \beta_6 \ln^2 L_{it} + \beta_7 \ln^2 M_{it} + \\
& \beta_8 \ln K_{it} \ln L_{it} + \beta_9 \ln K_{it} M_{it} + \beta_{10} \ln L_{it} M_{it} + \\
& \alpha_i + \gamma_t + \varepsilon_{it}
\end{aligned} \tag{1}$$

where Y_{it} , K_{it} , L_{it} , and M_{it} are the amounts of production output, capital, labor, and raw materials for establishment i at time t , α_i is a fixed effect for factory i , and γ_t is a dummy variable for year t . FDI_{jrt} is foreign direct investment, which we derive below, in industry j and region r and $CAPABILITY_i$ is a placeholder for the three firm capability variables, also discussed below. A positive coefficient on FDI_{jrt} indicates that FDI is associated with higher productivity overall. A positive coefficient on $CAPABILITY_i FDI_{jrt}$ indicates that the interaction of that capability with FDI is positive. In other words, firms with that attribute have a greater productivity response to FDI than other firms. Output, capital, and materials are nominal rupiah values deflated to 1983 rupiah. Labor is the total number of production and non-production workers. We assume the error term, ε_{it} , to be i.i.d.⁹

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), who found that the rate of knowledge diffusion, measured by patent citations,

⁹We assume the error term, ε_{it} , to be uncorrelated with the other right-hand-side variables. Our results would be biased if inputs, FDI, or capabilities were simultaneously determined by unobserved idiosyncratic shocks in ε_{it} (see Olley and Pakes 1996 and Levinsohn and Petrin 2003 for a full discussion). We have performed our analysis with the simultaneity corrections proposed by Olley and Pakes and Levinsohn and Petrin using investment and electricity as a proxies for idiosyncratic shocks. The results (not reported here but available from the authors) are virtually unchanged.

declined with distance. Indonesia’s vast island 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 2.

$$FDI_{jrt} = \frac{\sum_{i \in jrt} Foreign_OUTPUT_{it}}{\sum_{i \in jrt} OUTPUT_{it}} \quad (2)$$

$i \in jrt$ 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. We classify industrial sectors with four-digit ISIC codes.

As to the measures 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.¹⁰

Human capital is measured as the percentage of workers with college or higher degrees. 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.

We calculate the “technology gap,” the distance from a firm’s production competency to international best practice, using the fixed effect, α_i , obtained from estimating a translog production function. A technology gap measure for each local firm is obtained by subtracting its fixed effect from the mean fixed effect of foreign firms in the same 3-digit ISIC code. Recall that our estimation is all in logs and thus coefficients represent elasticities. The technology gap derived from fixed effect subtraction therefore has an intuitive interpretation as a percentage from the frontier. For example, a gap of 0.2 indicates that that firm was 20

¹⁰Estimation using continuous measures of R&D expenditures shows an effect only at the discontinuity from zero to a positive value.

percent less productive than the average of foreign firms in the same industry.

To avoid the obvious endogeneity of the technology gap measure—that the technology gap and firm performance are jointly determined—we have divided each firm’s duration in the panel into two periods. We calculate the technology gap using only the first three years of observations for each firm. We then estimate the effect of FDI interacted with the technology gap using only observations *after* the first three years a firm was in the panel.

Table 2 reports the correlation between all three capabilities. Overall, there is little correlation between the three measures, although firms with greater human capital and absorptive capacity have slightly narrower technology gaps. Table 3 displays descriptive statistics for the three capabilities by foreign and domestic firms. Although we include only domestic firms in our analysis, the difference between foreign and domestic firms is revealing. Only about 10 percent of local firms have absorptive capacity (positive R&D expenditures), compared with 28 percent for foreign firms. Likewise, only about 1 percent of local firm employees are college educated, compared with 4 percent for foreign firms. The average technology gap is .28 for domestic firms, suggesting that they are about 28 percent less productive than their foreign counterparts.¹¹

The capabilities above are likely correlated with other attributes of the firm. For example, firms with R&D expenditures and higher proportions of college-educated employees tend to be bigger, as measured by number of employees and capitalization, and more likely to export than other firms. Such correlations might lead one to suspect that effects attributed to the measured firms’ capabilities really stem from unobserved factory characteristics. Fortunately, because our analysis uses panel data, we can remove the effects of unobserved variables, provided that they are static—a reasonable assumption for the firm fundamentals likely to drive investment in human capital and absorptive capacity.

¹¹Since the average productivity of foreign firms is the “frontier” benchmark for the technology gap, the gap for foreign firms is not meaningful and is omitted from the table.

5. Results

Table 4 shows the results of estimating equation 1. The first two columns present the baseline case of overall technology adoption from FDI. Column (1) shows the estimation with both domestic and foreign firms, with the percentage of foreign equity added as a control. As one would expect, productivity increases with foreign ownership. Column (2) displays the results for just domestic firms, the population of interest here. The positive coefficient on FDI suggests that, overall, local firm productivity does increase with foreign entry.

Column (3) displays the results of estimating Equation 1 on a sample of local firms with 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 interaction term suggests that firms with greater absorptive capacity acquire more technology from FDI.

Column (4) displays the results of estimating Equation 1 on a sample of local firms with a measure of human capital, the percentage of employees with college or higher degrees, interacted with FDI. As with the R&D indicator, because human capital variable is time-invariant for each firm, its main effect is dropped from the fixed-effect estimation. The interaction term suggests that firms with greater human capital acquire more technology from FDI.

Column (5) displays the results of estimating Equation 1 on a sample of local firms with a measure of technical competency, the gap between the firm's productivity and international best practice, interacted with FDI. A wide technology gap indicates that the firm is far behind the average productivity of foreign competitors. The coefficient on the interaction term is positive, which suggests that firms with a wide gap benefit more. Such firms can innovate quickly whereas firms with narrow gaps may have less to learn and have a lower return to the new knowledge.

It is interesting to note that the technology gap coefficient is *opposite* in sign and significant if one does not correct for the endogeneity of the gap calculation. Recall that the

technology gap is calculated using the first three years an establishment is in the panel. Only observations for later years are then included in the estimation sample. If the two periods are pooled, thereby introducing simultaneity between firm performance and the technology gap measure, then the results are reversed. This outcome is intuitive—without correcting for the endogeneity, poorly performing establishments will have wide technology gaps by definition.

Column (6) shows all three capabilities tested jointly. The direction of the effects remains unchanged, but human capital is no longer significant, perhaps because this variable has the least variance of the data on the three capabilities. The joint test suggests that among the firms with a wide technology gap, it is those with absorptive capacity that are able to realize the high marginal returns of technology from FDI.

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, there is some concern 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 also 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 measures are driven by productivity gains in the early years of the panel. Such a scenario could explain the weak effect of the human capital variable in the joint estimation with the other capabilities.

6. Summary and Implications

This paper examines how firms innovate by analyzing host-economy adoption of technology brought with foreign direct investment (FDI). Our major result is to find that firm capabilities affect technology adoption in three ways. 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” idea 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. 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 heterogeneous pool of host-economy firms.

Finally, to the extent that evidence from Indonesia can be generalized, these results have a key implication for trade 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 further room to improve against international best practice stand to enjoy 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 can be applied to national innovation policy in general.

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A. Data Appendix

A.1. Product Class, Location, and Age

The main product class of each establishment is identified by 5-digit International Standard of Industrial Classification (ISIC) codes published by the United Nations Industrial Development Organization (UNIDO). The ISIC standard divides manufacturing activity into 329 codes at the 5-digit level.¹² 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.¹³

A.2. Ownership

Two survey questions relate to establishment ownership. First, establishments report whether they operate under a domestic or a foreign investment license. All new enterprises in Indonesia must obtain an operating license from *Badan Koordinasi Penanaman Modal* (BKPM), the Investment Coordinating Board. Establishments funded with any foreign investment operate under *Penanaman Modal Asing* (PMA), foreign capital investment licenses. Establishments with only domestic investment obtain *Penanaman Modal Dalam Negeri* (PMDN), wholly domestic capital investment licenses. Second, each establishment reports the percentage of foreign equity. 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.

¹²ISIC 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.

¹³Following the independence of East Timor, there are now 26 provinces and 291 districts.

A.3. Capital

The survey asks for the book value and current replacement value of fixed assets. Respondents report assets in five categories: land, buildings, machinery and equipment, vehicles, and other assets. The value of investment is also reported yearly.

A.4. Labor and Wages

The numbers of production and non-production workers are reported in all years. Workers are categorized as either paid or unpaid (e.g., family members). In many years, the labor force is broken down by gender. In 1995-1997, the highest level of education obtained by all workers is available. In 1996, the highest degree and field of specialization for research and development workers are 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.5. Materials and Energy

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.6. Output

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

B. Data Processing

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

B.1. Construction of Price Deflators

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

B.1.1. Output, and Materials Deflators

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

B.1.2. Capital Deflators

Fixed assets are deflated using the WPI for manufactured construction materials and imported machinery. Specifically, the capital deflator combines the WPI for construction materials, imported electrical and non-electrical machinery, and imported transportation equipment. 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 Surveys

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. First, the earliest and latest years in which a plant reported were identified, and interpolation was used to fill-in gaps of up to two missing years within the reporting

window. If more than two continuous 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 spikes in key data values likely attributable to keypunch error (often due to an erroneously added or omitted zero) were corrected with interpolation. Third, plants 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) 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 erroneously added or omitted zeros resulting 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. We applied the same correction to the percentage of output exported.

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.

C. Tables

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

	1988		1996	
Variable	Mean	Std. Dev	Mean	Std. Dev.
FDI	0.07	0.16	0.14	0.2
log(output)	12.01	1.87	12.5	1.93
log(capital)	11.3	1.99	11.73	2.02
log(materials)	11.21	2.12	11.61	2.21
Employees	128.08	552.56	154.82	559.07
Value added per employee	2901.44	8167.2	7934.07	32235.37
Capital per employee	7079.45	111992.18	10318.56	160494.48
No. establishments	8862		14935	
log(output)	15.18	1.73	15.72	1.62
log(capital)	14.06	1.97	14.68	1.72
log(materials)	14.36	1.9	14.88	1.86
Employees	367.21	466.74	609.4	1039.43
Value added per employee	16934.12	22412.09	40641.14	117916.27
Capital per employee	100527.92	1317417.08	35312.42	279424.8
No. establishments	276		904	

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

	Absorptive capacity	Human capital	Technology gap
Absorptive capacity	1.00		
Human capital	0.21	1.00	
Technology gap	-0.09	-0.12	1.0000

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

	Local establishments			Foreign establishments		
	No. obs.	Mean	Std. dev.	No. obs.	Mean	Std. dev.
Absorptive capacity	17701	.10	.30	907	.28	.45
Human capital	16644	.01	.03	860	.04	.06
Technology gap	23736	.28	.50			

Table 3: Mean and standard deviations for absorptive capacity (one if the establishment had R&D expenditures, zero otherwise), human capital (proportion of employees with college or higher educations), and technology gap (distance from establishment fixed effect to average of foreign establishments' fixed effects).

Dependent var.: log(output)		Fixed-effect					
		(1)	(2)	(3)	(4)	(5)	(6)
FDI		0.061 (5.64)	0.044 (3.90)	0.038 (3.02)	0.041 (3.18)	0.016 (0.97)	-0.004 (0.22)
Establishment foreign equity		0.140 (7.65)					
Absorptive capacity*FDI				0.091 (2.71)		0.095 (2.34)	0.105 (2.51)
Human capital*FDI					0.843 (2.46)		0.612 (1.16)
Technology gap*FDI							0.119 (2.42)
log(labor)		0.964 (57.23)	0.972 (54.97)	1.015 (55.65)	1.011 (54.65)	0.987 (36.76)	1.037 (38.13)
log(capital)		0.158 (17.50)	0.146 (15.34)	0.134 (13.05)	0.127 (12.12)	0.149 (9.96)	0.140 (9.04)
log(materials)		0.245 (29.13)	0.222 (25.39)	0.187 (20.24)	0.193 (20.39)	0.223 (16.47)	0.181 (13.02)
log(K)*log(K)		0.013 (28.80)	0.014 (28.56)	0.014 (27.57)	0.014 (26.69)	0.016 (21.07)	0.015 (19.96)
log(L)*log(L)		0.059 (29.13)	0.055 (26.08)	0.055 (25.38)	0.055 (25.04)	0.062 (20.39)	0.060 (19.71)
log(M)*log(M)		0.050 (103.80)	0.051 (101.80)	0.053 (101.18)	0.052 (97.33)	0.054 (73.62)	0.055 (74.05)
log(K)*log(M)		-0.033 (42.94)	-0.033 (41.36)	-0.033 (38.56)	-0.032 (36.24)	-0.038 (30.86)	-0.036 (28.81)
log(L)*log(M)		-0.097 (61.11)	-0.095 (57.42)	-0.099 (57.43)	-0.099 (56.37)	-0.104 (44.14)	-0.107 (44.99)
Constant		3.126 (43.99)	3.294 (44.73)	3.497 (44.72)	3.499 (43.77)	3.611 (29.97)	3.790 (30.58)
Observations		114146	108805	90436	85895	48813	43429
No. of establishments		24784	23943	17879	16812	12758	10196
R-squared		0.78	0.77	0.79	0.79	0.73	0.73

Absolute value of t statistics in parentheses

Table 4: Production function estimation for all establishments in column (1) and only domestic establishments in all other columns. A large technology gap in columns (5) and (6) indicates that the firm is far from international “best practice.” All estimations include but do not report year dummy indicators.

D. Figures

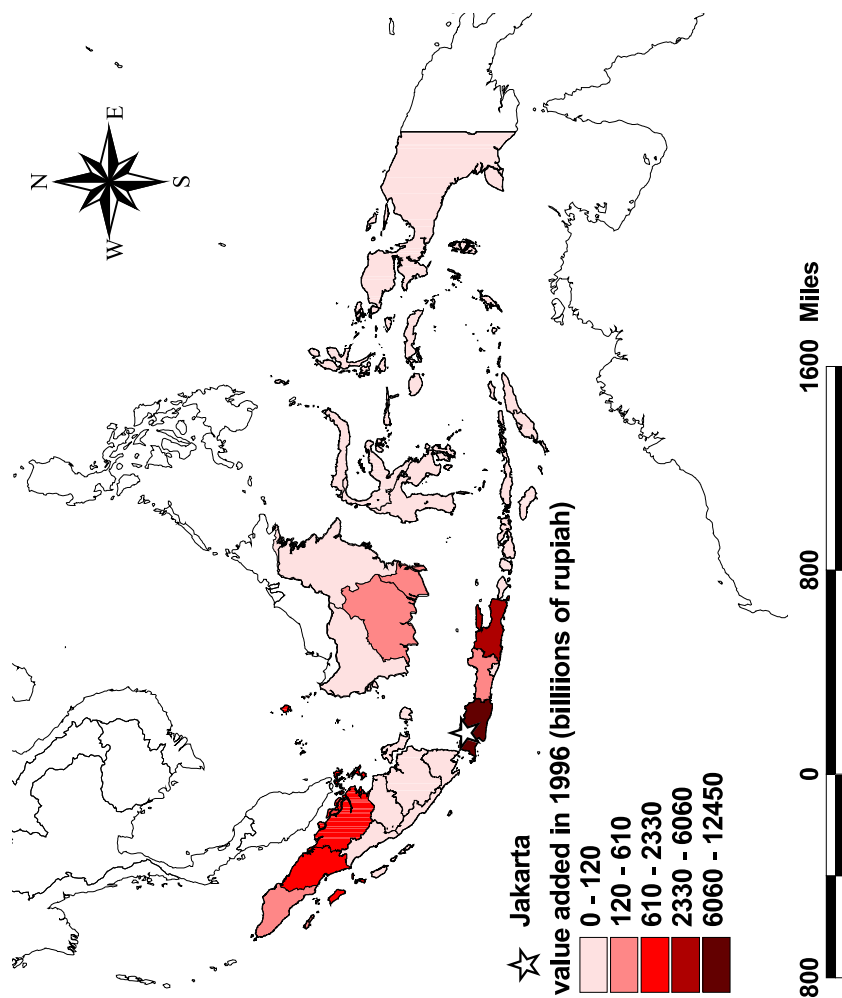


Figure 1: Value added by foreign firms in manufacturing, 1996, by province.

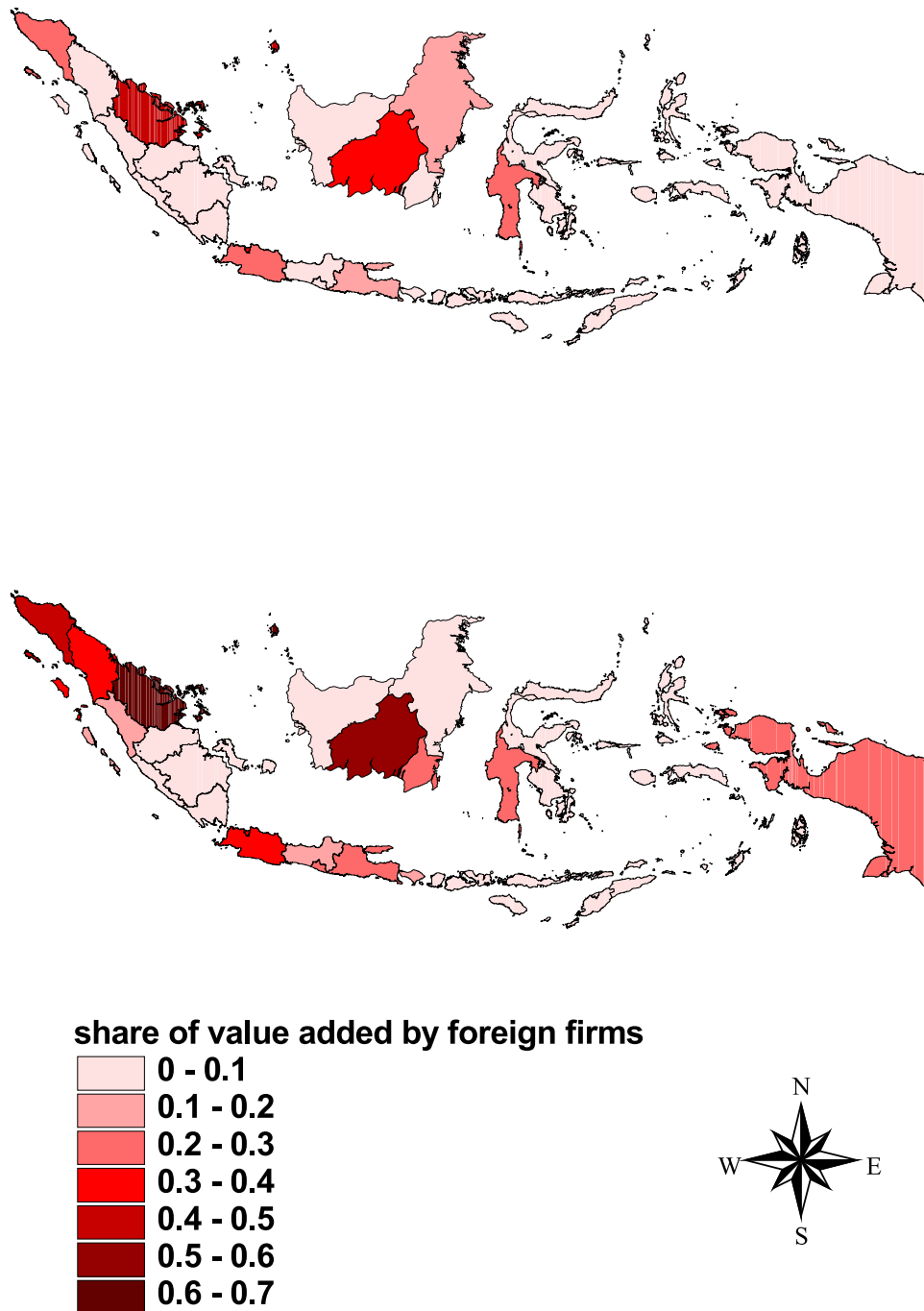


Figure 2: Share of manufacturing value added by foreign firms, by region, 1988 (top) and 1996 (bottom).