Trade, Technology Transfer and Productivity Growth: The Neglected Role of Imports*

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Abstract

We present evidence that importing is a driver of international technology transfer. Using a detailed panel of Indonesian manufacturers, our analysis shows that firms in industries supplying import-intensive sectors have higher productivity than other firms. This finding suggests that linkages though vertical supply relationships are the channel through which import-driven technology transfer occurs. To our knowledge, these are the first firm-level results showing that imports play a role in technology adoption, measured by productivity gains. Taken together with the literature linking foreign direct investment and exporting to technology spillovers, we provide a third component to the argument that trade and openness promotes growth.

Keywords: Technology Transfer, Productivity, Imports, Indonesia, Supply Chain.

*We thank the participants in the seminars at Carnegie Mellon University, the Academy of Management, and the annual meeting of the Portuguese Society for Research in Economics for their valuable comments. We especially acknowledge the suggestions of Peter Thompson and Robert Lowe. Errors remain our own.

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1. Introduction

The international economics literature has had a lasting interest in the relationship between trade and technology transfer (Keller 2000; Saggi 2002; Werner 2002). Research has mostly focused on two avenues for knowledge transfer: exports and foreign direct investment. Much less effort has been devoted to the export counterpart, imports, which are the focus of this paper. We show that imports are a significant mechanism for acquiring knowledge from international markets and warrant greater attention from the research community.

Studies using aggregate country-level data suggest trade to be an important driver of economic growth. These findings have prompted further research on the mechanisms that support these aggregate findings. Most existing work has focused on two mechanisms: exports by local firms and foreign direct investment (FDI). Despite some conflicting evidence, the majority of research associates both mechanisms with greater increases in productivity, although the direction of the causality is still under scrutiny. Few studies have looked at the role of imports as a mechanism for technology transfer and none has been able to show that imports can be a significant driver of local productivity enhancement.

This paper asks whether imports can impact firm technological capabilities, as measured by productivity gains. Using a rich panel dataset of Indonesian manufacturers from 1988 to 1996, the paper examines factory productivity growth and its relation with imports. It finds strong evidence that firms selling to sectors that rely more on imports have higher levels of productivity than other firms. The findings also suggest that linkages through vertical supply relationships are the relevant mechanism through which import-driven technology transfer occurs. To our knowledge, these are the first firm-level results showing that imports play a role in the enhancement of technological capabilities, measured by total factor productivity. This is an important contribution towards establishing the existence of international knowledge spillovers, a critical component in the argument that trade promotes growth.

The paper is organized as follows. The next section discusses the theory and empirical literature on the relationship between trade, technology and productivity growth, discussing in particular the potential role of imports, the importance of the supply chain structure and Indonesia’s trade liberalization patterns. Section 3 discusses the data sources and measurement issues, Section 4 presents the results and Section 5 concludes.
2. Trade, Technology Transfer and Firm Productivity

2.1. Trade and Technology Transfer: What do we know?

Most north-south models of endogenous economic growth emphasize a product
life cycle perspective of trade (see, for example, Grossman and Helpman 1995). They posit that innovative products are created in the North and, due to the lower relative wages, Southern firms can successfully undercut Northern producers’ price if they are able to acquire the relevant technology. Hence, there is an incentive for firms in catch-up economies to invest in acquisition of advanced technologies created elsewhere. But, motivation alone is insufficient Southern firms need a channel through which they can acquire technology. In fact, international spillovers of knowledge are necessary conditions for technology migration from the more developed world into the developing countries (see Keller 2001; Saggi 2002 for recent reviews of these issues). However, empirical evidence of international knowledge flows and their impact on the technological capabilities in the less developed environment is weak.

The early and perhaps most well known literature exploring international knowledge spillovers uses country-level data to aim at correlating economic growth with increased openness to trade. Nevertheless, despite many papers addressing this issue, no consensus exists. For example, Sachs and Werner (1995) find empirical support for the view that open economies grow faster, while Rodriguez and Rodrik (1999) present a lengthy discussion of the problems with existing empirical work relating trade openness and growth and argue that the positive relationship between the two is far from being established. A more specific line of research has addressed directly the potential effect of international knowledge spillovers. Analyzing data for the OECD, Eaton and Kortum (1996) find that more than 50% of the growth in some countries derives from innovation in the United States, Germany, and Japan. Likewise, again using country-level data, Coe and Helpman (1995) and Coe, Helpman, and Hoffmaister (1997) suggest that international technology spillovers can be substantial and that trade plays an important role in these spillovers. Connolly (2001) specifically identifies imports in high technology sectors as a major source of productivity and economic growth. In contrast, Keller (1998) performs a similar analysis to Coe and Helpman (1995) and Coe, Helpman, and Hoffmaister (1997) but finds no statistical support for the positive relation between trade and technology diffusion. More recent estimates that either used industry level data (Keller 1997, 2000) or that separated general trade from capital goods trade (Xu and Wang 1999) again showed imports to play a
role in country productivity growth. A limitation of these studies is that, by using country-level data, they are inherently limited in the number of observations and often cannot establish causality. In addition, it is difficult to isolate the channels that can contribute to technology transfer and results are very dependent on the particular definitions of the variables in the analysis.

The limitations of country-level data have placed a greater emphasis on the use of firm-level data to evaluate the role of trade on growth and international knowledge spillovers. An early example is Irwin and Klenow 1994, which looked at the semiconductor industry and found technological externalities to be as large internationally as they were in the firm’s home economy. In this new firm-level research approach, two aspects have caught most of the attention of the researchers: exports and foreign direct investment (FDI). A number of authors have investigated whether entering a foreign market through exports may work as a mechanism through which firms learn (for example, Clerides, Lach, and Tybout 1998, Roberts and Tybout 1997, and Bernard and Jensen 1999). So far, there have been mixed results, with the positive effect depending on the characteristics of the market and the initial conditions of the firms that decide to export to a foreign market. Likewise, a growing body of research on the role of FDI as a determinant for technology transfers and productivity growth has produced conflicting evidence (see Blomstrom and Kokko 1998; Keller 2001; Kumar 1996 for extensive reviews).

Recent work by Blalock and Gertler (2003) examines this contradicting evidence. The authors’ empirics distinguish horizontal spillovers, an externality generated by foreign entry in the same industry, from vertical technology transfer, the often deliberate sharing of technology with clients and/or suppliers of the foreign entrant. They note that most of the conflicting empirical results have focused on the former notion of horizontal spillovers and explain how multinationals’ efforts to minimize technology leakage may explain the varying empirical results. On the contrary, the authors argue that vertical technology transfer is more likely because foreign entrants have incentives to encourage technology diffusion to suppliers.

But while research looking at firm-level spillover effects of FDI and exports mounts, another important element has been virtually left out the discussions on trade as a mechanism for technology transfer: the role of imports. To our knowledge, only two on-going research efforts have looked at the potential role of imports as a learning mechanism. Using data from French firms, Macgarvie (2003) shows that firms that import cite more foreign patents than non-importers, suggesting that this may indeed be an important learning mechanism. But the research falls short of demonstrating that such learning impacts firm performance.
In the only attempt to measure such effect, Keller and Yeaple (2003) find that imports influence the productivity of US multinationals, but the result goes away once they control of endogeneity in the estimation.

2.2. The Argument: Imports, Technology Transfer and Supply Chains

Existing models of productivity gains from importing (see Connolly 2001, Keller 2001, and Rivera-Batiz and Romer 1991), emphasize two mechanisms. Learning occurs either through direct observation of foreign technology, or through the incorporation of new intermediate products invented abroad in the local production chain. In the first case, an original design invented in a particular region is learned elsewhere (for example by reading a patent, reverse engineering a product, or licensing a technology). Since productivity is assumed to depend on the local stock of knowledge, learning the new design will increase the local knowledge pool and, as a result, increase local productivity. In the second case, use of the foreign intermediate product conveys the embodied technological capability and R & D of the foreign producer. If this intermediate good can be obtained for less than the full value of the technology embodied in it, there may be a productivity gain for the local producers. Because of both substantive reasons and measurement issues detailed below, this paper will focus on the first mechanism and not the second. Moreover, our findings suggest that productivity enhancement happens along the domestic supply chain, i.e., to local suppliers of products equivalent to the imports, instead of to the importers themselves.

When considering the technology transfer process, it is important to recognize that the purchase of foreign intermediate goods is by no means a guarantee that there will be local learning. There are at least three obstacles to such learning. First, the relevant knowledge necessary to produce the new product (or implement a new process) is only partially embedded in the product itself, even if substantial reverse engineering is used (Bresman, Birkinshaw, and Nobel 1999; Madhok and Osegowitsch 2000). Simply working with or looking at the product, blueprints, patents or other forms of codified knowledge do not necessarily uncover what might be needed to appropriate the technology (Cohen, J., R., and R 2002). Much of the required know-how may tacit and can only be conveyed through experience or apprenticeship. Second, the foreign owner of the relevant knowledge may not interested in transferring it elsewhere, in particular if the local companies are seen as potential lower cost competitors. In fact, the owner may actively discourage transfer by minimizing the availability of relevant know-how.
For example, the proprietor might withhold some product specifications, decline to sell the latest-generation products, or embed proprietary knowledge into process innovation rather than more visible product innovation. Third, even if the possibility to transfer technology from abroad exists, the local firm importing the intermediate product might not be interested in acquiring the technology necessary to produce it. For example, a car assembler is interested in having high quality and low cost parts, not in learning how to manufacture them.

Reconciling the potential for learning from imports with the difficulties highlighted above requires further exploration of the incentives and the nature of buyer-supplier or supply chain relations. Although importing firms may be uninterested in acquiring the technology supporting the products they bring from abroad, local suppliers of equivalent intermediate products have strong incentives to capture technologies that enable them to better compete with and eventually displace foreign suppliers. In other words, local suppliers competing with international rivals are more likely to seek best practice technology embodied in imported supplies than the direct importer. Failure to imitate the foreign import may threaten local supplier profitability, market share and even survival. In addition, ceterus-paribus on ability, a domestic client would prefer a local supplier to a foreign one because of reduced transportation costs and greater delivery reliability. Therefore, local clients have an incentive to help local suppliers in finding and transferring relevant technologies to try to displace foreign suppliers. The role that vertical supply chain relations play in transferring knowledge and capabilities to suppliers has long been acknowledged and documented in the management literature (Womack, Jones, and Roos 1990; R. 1993; Nishiguchi 1994). This is especially relevant in regional and local contexts and in more complex supply chains such as the automotive or machinery (J.H. and W.G. 1993; Cohen, J., R., and R 2002; Tendler J 1996).

One may question why a profit-maximizing domestic supplier would not adopt the most efficient means of production available, even in the absence of international competition? Three reasons may, in part, offer an explanation. First, in a context confined to local competition, there may be a lack of knowledge about the latest technologies and business methods. Second, in the absence of outside pressure, the benefits of adopting a new technology may not justify the personal uncertainty and cost of the effort incurred by non-owner managers—a form of x-inefficiency. Third, in a context of local competition, the additional local market returns (losses) from (the absence of) investing in a new technology may be very small. But this situation could dramatically change if a foreign supplier enters
the local market and starts taking share away from local suppliers based on superior technologies. These incentives support the base hypothesis that we explore: that learning from imports will occur among local suppliers upstream of import-intensive sectors.

Although the specific mechanisms for technology transfer described above are typically unobservable in the data, one can identify technology transfer by looking at individual firm productivity gains. Moreover, if supply chains are the relevant conduit for technology transfer from imports, then one would expect, ceteris paribus, that local firms supplying industries and regions with higher levels of inputs purchased in foreign markets would show greater productivity growth than other local firms.

Conversely, the same reasons that support supply chain learning also suggest that learning and technology transfer to the firms that buy the foreign intermediate goods will be of less importance, a conclusion that is supported by the results of Keller and Yeaple (2003). Still, recent research (Macgarvie 2003) suggests that firms might actively increase the incorporation of foreign knowledge once they begin importing. Moreover, as argued above, theory suggests that one could find indirect or passive learning in the importers through embodied technology in the goods they purchase. But an impact on productivity would require the price of the goods to be below the value of the embedded technology, an assumption that may not be easy to sustain. Furthermore, learning by direct importers is potentially subject to significant endogeneity problems, as the decision to import is likely to be correlated with productivity shocks (Keller and Yeaple 2003). These reasons discourage a potential focus on the impact of imports on the buyers of foreign products and reinforce the interest in understanding the impact of imports in the upstream suppliers, the object of this paper.

2.3. Indonesian Manufacturing and Trade Policy

Indonesias manufacturing sector is an attractive setting for research on technology transfer from importing 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, Indonesian government agencies employ a number of well trained statisticians who have collected exceptionally rich manufacturing data for a developing country. Further, the countrys size and resources support a full supply chain, from raw materials
to intermediate and final goods. Third, rapid and localized industrialization provides variance in manufacturing activity in both time and geography. Fourth, 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. Last, the Indonesian government legislated a major reform of the trade regime in the mid and late 1980s, shifting from a policy of import substitution to one of export promotion. In 1986, Indonesia substantially reduced import tariffs, reformed customs administration, and introduced a generous duty drawback scheme, thus prompting an overall growth in the import market. The overall share of imported materials in Indonesian manufacturing has grown from 28 to 35 percent, an increase likely driven by the liberalization of the trade regime.

3. Data, Sample Selection, and Measurement

3.1. Sources

The analysis is based on data from the Republic of Indonesia’s Badan Pusat Statistik (BPS), the Central Bureau of Statistics\(^1\). The primary data are taken from an annual survey of manufacturing establishments with more than 20 employees conducted by Biro Statistik Industri, the Industrial Statistics Division of BPS. Additional data include several input and output price deflators. The remainder of this section describes each dataset and the measurement of firm learning from imports.

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 (89 input-output table codes), ownership (public, private, foreign), exports, status of incorporation, assets, asset changes, electricity, fuels, income, output, expenses, investment, labor (head count, education, wages), raw material use, national and imported, 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 com-

\(^1\)We identify names in Bahasa Indonesia, the language of most government publications, with italics. Subsequently, we use the English equivalent or the acronym.
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pliance or confirm that the establishment has ceased operation. 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 used here 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. Inter-industry supply chains are estimated 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.

The analysis considered in the paper starts in 1988, the first year data on firm capital 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. Values for 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 by BPS.

### 3.2. Measurement

The analysis estimates a production function to reveal the effect of changes in within-industry on establishment productivity over time. A positive contribution from imports suggests that firms are learning through this mechanism. Our main interest is in evaluating the impact of downstream imports on firm productivity. This variable is calculated in two steps. First, we use Equation 1 to estimate

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2 Some firms may have more than one factory, we 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 study, early analysis by BPS suggests that less than 5 percent of factories belong to multi-factory firms. We therefore generalize the results to firms.
own sector imports, i.e., how much does a sector rely on imported materials. The measure varies by industry, time and region, with \( i \) representing a factory, \( j \) an industry, \( r \) a region and \( t \) the time (year). \( \text{Purchases}_{it} \) is the amount of materials purchased by factory \( i \) at time \( t \) and \( \text{Foreign Purchases}_{it} \) are the corresponding values for purchases made from foreign suppliers. The data includes the 89 different industrial sectors, as defined by the Input Output Table for the country. The region definitions are the 14 Indonesian provinces on most industrialized islands of Sumatra and Java (and neighboring Bali). We have excluded the provinces located in Indonesia's outer islands and the former Portuguese colony of East Timor because what little industrial activity that occurs is largely based on natural resource extraction and processing rather than the production of new goods. The regional approach appeals to Indonesia's vast island geography and poor inter-region transportation infrastructure in assuming local markets, i.e., firms in the same region are more likely to consume that intermediate goods output. We determine imports by industry and region, to avoid the endogeneity of a particular factory's decision to buy from foreign suppliers.

\[
\text{Own Sector Imports}_{jrt} = \frac{\sum_{i \in jrt} \text{Foreign Purchases}_{it}}{\sum_{i \in jrt} \text{Purchases}_{it}}
\]

(1)

\[
\text{Downstream Imports}_{jrt} = \sum_{k} \alpha_{jkt} \text{Own Sector Imports}_{jrt}
\]

(2)

The estimates of own sector imports are then used to estimate our critical variable, the presence of imports in client sectors. Potential for supply chain learning is measured using the \( \text{Downstream Imports}_{jrt} \) variable. As shown in equation 2, this variable is calculated by summing the output shares purchased by client manufacturing sectors multiplied by the share of own sector imports 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 purchases but that pasta sector buys half of the inputs from abroad. The calculation of downstream import penetration for the flour sector would yield 0.25 = 0.5(0.0)+0.5(0.5). So, \( \alpha_{jkt} \) is the proportion of output of sector \( j \) consumed by sector \( k \) at time \( t \). The coefficient \( \alpha_{jkt} \) is calculated from the national Input Output (IO) Tables. Values before and including 1990 follow from the 1990 IO table, values of \( \alpha_{jkt} \) from 1991 through 1994 are linear interpolations of the 1990 and 1995 IO tables, and values of \( \alpha_{jkt} \) from 1995 on are from the 1995 IO table. Recall that \( \alpha_{jkt} \) does not have a region
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$r$ subscript because the IO table is generated for the entire national economy.

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

$$\ln Y_{it} = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 \ln M_{it} + \beta_4 \ln E_{it} +$$

$$\beta_5 \ln^2 K_{it} + \beta_6 \ln^2 L_{it} + \beta_7 \ln^2 M_{it} + \beta_8 \ln^2 E_{it} +$$

$$\beta_9 \ln K_{it} \ln L_{it} + \beta_{10} \ln K_{it} M_{it} + \beta_{10} \ln K_{it} E_{it} +$$

$$\beta_{11} \ln L_{it} M_{it} + \beta_{12} \ln L_{it} E_{it} \beta_{13} \ln M_{it} E_{it} + \alpha_i + \gamma_t + \varepsilon_{it}$$

(3)

where $Y_{it}$, $K_{it}$, $L_{it}$, and $M_{it}$ are the amounts of production output, capital, labor, and materials for establishment $i$ at time $t$, $\alpha_i$ is a fixed effect for factory $i$, $\gamma_t$ is a dummy variable for year $t$, and $\varepsilon_{it}$ is an error term. A positive coefficient on $\text{Downstream Imports}_{jrt}$ indicates that downstream imports are associated with higher productivity. Output, capital, and downstream imports are nominal rupiah values deflated to 1983 rupiah. Labor is the total number of production and non-production workers.

3.3. Estimates and Sample Selection

We used several criteria to select the sample for the estimation of Equation 1 to test the robustness in our results. First, because foreign owned firms are more likely to import than wholly Indonesian-owned firms, it would be easy to confound changes in importing behaviour with changes in foreign ownership. To avoid this potential confounding effect, the sample used to calculate own imports is limited

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3 A joint F-test on the quadratic terms in the translog production function reject the hypothesis that the terms are jointly equal to zero. Hence, we reject a simpler Cobb-Douglas production function in favor of the more flexible translog functional form. The translog also allows us to allow non-unitary elasticity of substitution between inputs and thereby better condition on economies of scale.

4 A Hausmann test reject the use of random effect estimation.

5 Finally, we note that the error term, $\varepsilon_{it}$, is assume to be uncorrelated with downstream imports. Our results would be biased if, in fact, upstream firm productivity and downstream imports were simultaneously determined by unobserved idiosyncratic shocks (see Olley and Pakes 1996 and Levinsohn and Petrin 2000 for a full discussion). Although we know of know no particular economic justification for simultaneity concerns in our data, we have also performed our analysis with the corrections proposed by Olley and Pakes (using investment as a proxy for idiosyncratic shocks.) The results are virtually unchanged.
to wholly Indonesian owned firms over the entire panel period. A related concern is that downstream imports are a proxy for downstream foreign direct investment (FDI), a factor known to influence own and upstream firm productivity (Blalock and Gertler 2003; Blomstrom and Kokko 1998). If downstream FDI is highly correlated with downstream imports, it will be crucial to control for FDI to avoid falsely attributing the effect of one to the other. Finally, because some sectors supply themselves, downstream imports may be correlated with the direct own-sector imports described above. We control for this possibility by also including the own-sector import variable. Again, because of the potential endogeneity problems with the with own-sector imports, we do not assign causality to this variable. Rather, we use it simply as a control.

Table 1 shows descriptive statistics for the dependent variables for all the factories in the cleaned dataset.

Note that downstream imports represent a small proportion of the downstream supply chain. On average, less than 7% of the inputs consumed by downstream firms were imported goods. The value for this variable is important for subsequent interpretations of the estimation results and policy implications thereof. While a positive and significant coefficient on downstream imports in equation (3) would imply that imports may have a positive impact on local productivity, it can hardly be interpreted as a mandate for full fledge opening of the domestic economy. Results are for deviations of downstream imports around the rather low 7% average. This means that we are mostly seeing the effect of mild—perhaps first time—exposure to foreign markets, rather than large movements toward foreign purchases. Table 2 shows the correlations between the variable of interest. Downstream imports, own-sector imports, and downstream FDI are surprisingly uncorrelated which aids us separating their effects.

Another set of issues to be considered is how might the base hypothesis be adjusted by the nature of the firm. We consider three firm attributes: location in the supply chain, size, and private or government ownership.

First, an immediate corollary from the hypothesis of the upstream learning is the idea that firms in intermediate goods ought to learn more through this

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6The results presented subsequently are unchanged if the complete sample of firms is used to estimate imports.

7Downstream FDI is calculated much like downstream imports. First, the share of foreign output in a given industry, sector and time is calculated through the ratio of foreign owned firms’ output to total sector output. Then, for each sector, time and region, downstream FDI is estimated by summing the output shares purchased by client manufacturing sectors multiplied by the share of sector foreign output.
mechanism than firms in final goods sectors. With a few exceptions, final goods companies have little access to clients that could act as the international learning link hypothesized above. Therefore, one would expect less downstream learning opportunities. We define intermediate goods sectors to be the 37 sectors that sold 50 percent or more of their output to other manufacturing sectors in either the 1990 or 1995 IO table (results are robust to alternative definitions).

Second, firm learning may vary with size. In principle, larger firms have greater resources to access and leverage foreign technology. Therefore, one expects to find stronger downstream learning opportunities for larger companies.

Third, the results test for how government ownership might affect performance, trying to inquire whether public ownership might affect the learning mechanism identified before. Because government owned firms may be more likely to be protected from import competition, we expect them to be less aggressive in learning from downstream imports.

4. Results

The results provide strong evidence that Indonesian supplier productivity benefits from downstream imports. Table 3 presents the results of estimating the regression specification shown in Equation 3. Column (1) displays results with only the effect of downstream imports, where it is shown as significant at 1%. Because the production function is log-linear form, the coefficients represent elasticities. Therefore, the 0.12 coefficient on Downstream_Imports suggests that factory output increases approximately 12% as the proportion of downstream of downstream materials imported rises from 0 to 1. Given that the average level of downstream imports is 7%, with a standard deviation of 10%, the effect is meaningful.

Columns (2) to (4) represent the sets of controls discussed in Section 3.3. The effect of downstream imports is robust to the introduction of any or all of the relevant control variables. Consistent with Blalock and Gertler 2003, downstream FDI, included in columns (2) and (4), is positive and significant. Moreover, the inclusion of downstream FDI in the equation lowers the magnitude of downstream imports to roughly half of the value reported in column (1) but the effect remains significant. Columns (3) and (4) also confirm the hypothesis that own-sector imports do not affect the main results and are likely to be non-significant.8

8If the endogeneity of a firm's import decision is significant, the coefficient and standard errors may be biased.
To test for the robustness of the previous results and the associated hypothesis discussed in Section 3.3, Table 4 presents the results with the relevant subsets of firms. As predicted, larger firms are better able to leverage this international learning (column 2). Likewise, the results are much stronger for intermediate goods than for the final goods sectors (columns 3 and 4). Finally, as suspected, government-owned firms benefit far less from downstream imports. All results are robust to the introduction of downstream FDI.

5. Summary and Implications

This study presents evidence that importing is a driver of international technology transfer. Using detailed firm level data from Indonesia, the paper shows strong and significant evidence of learning from downstream imports. Specifically, it shows that firms selling to sectors that rely more on imports have higher productivity than other. These results are robust to a number of different econometric specifications.

The findings also suggest that linkages through vertical supply relationships are the relevant mechanism through which import-driven technology transfer occurs. Ceterus paribus, a local client would prefer a capable local supplier to a distant one in most cases because of lower transportation costs and more reliable delivery. Local clients thus have an incentive to help local suppliers obtain relevant technologies so that the local vendors may eventually displace foreign suppliers. The characterization of the learning process reveals that larger firms, those in intermediate goods sectors, and those with private rather than public ownership, are better able to leverage this international learning.

To our knowledge, these are the first firm-level results showing that imports play a role in technology transfer and the creation of technological capabilities. This is an important contribution towards establishing the existence of international knowledge spillovers, a critical component in the argument that trade promotes growth.

References

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6. Tables
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### Table 1: Descriptive Statistics

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<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
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<tr>
<td>Downstream Imports</td>
<td>6169</td>
<td>0.069</td>
<td>0.110</td>
<td>0</td>
<td>0.903</td>
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<td>Downstream FDI</td>
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<td>0.050</td>
<td>0.106</td>
<td>0</td>
<td>0.987</td>
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<td>Own-sector Imports</td>
<td>6126</td>
<td>0.172</td>
<td>0.277</td>
<td>0</td>
<td>1.000</td>
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### Table 2: Correlation of key variables

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<th>Downstream Imports</th>
<th>Downstream FDI</th>
<th>Own-sector Imports</th>
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<tbody>
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<td>Downstream Imports</td>
<td>1.0000</td>
<td></td>
<td></td>
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<tr>
<td>Downstream FDI</td>
<td>0.6107</td>
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<tr>
<td>Own-sector Imports</td>
<td>0.4342</td>
<td>0.2519</td>
<td>1.0000</td>
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## Table 3: Translog estimation of the effect of import measures on firm productivity

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<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
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<tbody>
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<td><strong>Province Import Share</strong></td>
<td>0.117</td>
<td>0.004</td>
<td>0.115</td>
<td>0.062</td>
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<td></td>
<td>(4.90)</td>
<td>(2.26)</td>
<td>(4.80)</td>
<td>(2.17)</td>
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<tr>
<td><strong>Downstream FDI</strong></td>
<td>0.084</td>
<td>0.084</td>
<td>0.084</td>
<td>0.084</td>
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<tr>
<td></td>
<td>(3.41)</td>
<td>(3.42)</td>
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<tr>
<td><strong>Own-sector Imports</strong></td>
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<tr>
<td>log(labor)</td>
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<td>0.580</td>
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<td></td>
<td>(30.57)</td>
<td>(30.56)</td>
<td>(30.69)</td>
<td>(30.68)</td>
</tr>
<tr>
<td>log(capital)</td>
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<td></td>
<td>(11.00)</td>
<td>(11.03)</td>
<td>(10.88)</td>
<td>(10.90)</td>
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<tr>
<td></td>
<td>(20.58)</td>
<td>(20.63)</td>
<td>(20.57)</td>
<td>(20.62)</td>
</tr>
<tr>
<td>log(energy)</td>
<td>0.110</td>
<td>0.109</td>
<td>0.111</td>
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</tr>
<tr>
<td></td>
<td>(15.54)</td>
<td>(15.46)</td>
<td>(15.75)</td>
<td>(15.67)</td>
</tr>
<tr>
<td>log(K)log(K)</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>(10.34)</td>
<td>(10.34)</td>
<td>(9.96)</td>
<td>(9.95)</td>
</tr>
<tr>
<td>log(L)log(L)</td>
<td>0.010</td>
<td>0.010</td>
<td>0.011</td>
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<tr>
<td></td>
<td>(4.50)</td>
<td>(4.54)</td>
<td>(4.74)</td>
<td>(4.78)</td>
</tr>
<tr>
<td>log(M)log(M)</td>
<td>0.049</td>
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<td>0.048</td>
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<tr>
<td></td>
<td>(84.42)</td>
<td>(84.36)</td>
<td>(83.28)</td>
<td>(83.22)</td>
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<tr>
<td>log(E)log(E)</td>
<td>-0.011</td>
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<td>-0.011</td>
</tr>
<tr>
<td></td>
<td>(25.21)</td>
<td>(25.22)</td>
<td>(25.12)</td>
<td>(25.13)</td>
</tr>
<tr>
<td>log(K)log(L)</td>
<td>0.028</td>
<td>0.028</td>
<td>0.027</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td>(16.58)</td>
<td>(16.53)</td>
<td>(16.15)</td>
<td>(16.11)</td>
</tr>
<tr>
<td>log(K)log(M)</td>
<td>-0.028</td>
<td>-0.028</td>
<td>-0.027</td>
<td>-0.027</td>
</tr>
<tr>
<td></td>
<td>(32.03)</td>
<td>(32.03)</td>
<td>(30.87)</td>
<td>(30.87)</td>
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<tr>
<td>log(K)log(E)</td>
<td>0.007</td>
<td>0.007</td>
<td>0.006</td>
<td>0.006</td>
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<tr>
<td></td>
<td>(9.66)</td>
<td>(9.68)</td>
<td>(9.10)</td>
<td>(9.12)</td>
</tr>
<tr>
<td>log(L)log(M)</td>
<td>-0.079</td>
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<td>-0.079</td>
<td>-0.079</td>
</tr>
<tr>
<td></td>
<td>(44.14)</td>
<td>(44.16)</td>
<td>(44.06)</td>
<td>(44.07)</td>
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<tr>
<td>log(L)log(E)</td>
<td>0.027</td>
<td>0.027</td>
<td>0.027</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td>(18.62)</td>
<td>(18.66)</td>
<td>(18.58)</td>
<td>(18.62)</td>
</tr>
<tr>
<td>log(M)log(E)</td>
<td>-0.005</td>
<td>-0.005</td>
<td>-0.005</td>
<td>-0.004</td>
</tr>
<tr>
<td></td>
<td>(6.38)</td>
<td>(6.33)</td>
<td>(6.05)</td>
<td>(6.00)</td>
</tr>
<tr>
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<td>4.022</td>
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<td></td>
<td>(56.95)</td>
<td>(56.93)</td>
<td>(57.18)</td>
<td>(57.17)</td>
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<td><strong>R-squared</strong></td>
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<td>0.81</td>
<td>0.81</td>
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</tr>
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</table>

Absolute value of t statistics in parentheses.
Table 4: Translog estimation of import measures on firm productivity using (1) all firms, (2) only firms with more than 50 employees, (3) only firms in intermediate goods sectors, and (4) only firms in final goods sectors.