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 increasingly import-intensive sectors have higher productivity growth than other firms. This finding suggests that linkages through 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. Together with the literature linking FDI and exporting to technology spillovers, we provide a third component to the argument that trade and openness promote economic growth.

Keywords: Technology Transfer, Productivity, Imports, Supply Chain, Southeast Asia, Indonesia

JEL classification: F2, O1, O3

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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 is 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 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. We control for the potential endogeneity between imports and productivity by conditioning on static industry- and firm-level attributes and considering only import activity largely exogenous to the focal firm. We find strong evidence that firms selling to sectors that rely more on imports have greater productivity growth than other firms. This finding suggests 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 economic 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 and the importance of the supply chain structure. Section 3 provides some background on the liberalization of Indonesia's trade regime and Section 4 discusses the data sources. Section 5 highlights our econometric identification, Section 6 presents the results, and Section 7 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 lower relative wages, Southern firms can successfully undercut Northern producers' prices if they are able to obtain the relevant technology. Firms in catch-up economies thus have incentives to acquire advanced technologies created elsewhere and the literature often cites cross-border knowledge flows as a channel for this acquistion (see Keller 2001; Saggi 2002 for recent reviews of these issues). However, empirical evidence of international knowledge flows and their impact on technological capabilities in the less developed environment is weak.

The early and perhaps most well known literature exploring international knowledge spillovers used country-level data to correlate economic growth with increased openness to trade. Nevertheless, despite many papers addressing this issue, no consensus exists. For example, Sachs and Warner (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 use industry-level data (Keller 1997, 2000) or that separate general trade from capital-goods trade (Xu and Wang 1999) again show imports to play a role in country productivity growth. A limitation of these studies is that, by using country- or industry-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- and industry-level data motivated efforts to use firm-level data to evaluate the role of trade on growth and international knowledge spillovers.

An early example was 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 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, Roberts and Tybout 1997, Clerides, Lach, and Tybout 1998, Bernard and Jensen 1999, Aw, Chung, and Roberts 2000, Delgado, Fariñas, and Ruano 2002, Van Biesebroeck 2003, and Blalock and Gertler 2004). 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; Kumar 1996; Keller 2001; Moran 2001; Keller 2004 for extensive reviews).

Recent work by Blalock (2002) and Javorcik (2004) examines this contradicting evidence. These papers' 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 or suppliers of the foreign entrant. The work notes 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 research argues 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 does not test whether that such learning impacts firm performance. In the only attempt to measure such a productivity effect, Keller and Yeaple (2003) find that imports influence the productivity of US multinationals, but the result goes away once they control for 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. In the first mechanism, learning occurs through the incorporation of new intermediate products invented abroad in the local production chain. The use of the foreign intermediate product conveys the embodied technological capability and R&D of the foreign producer. For example, an engine producer may decide to import the engine block because the foreign supplier controls the tolerances more tightly than domestic suppliers. Because of the tighter tolerances, the engine assembly process runs more smoothly and productivity rises. An alternative example is a shoe producer that decides to switch to imported leather because its better malleability allows the creation of more intricate shapes, enabling the production of shoes with greater value added.

While this mechanism for productivity growth is intuitive, two reasons might make it rare empirically. First, a change in productivity occurs only if the imported intermediate good can be obtained for less than the full value to the producer of the new technology embodied in it. Since they are of superior quality, one would expect that the foreign engine block and foreign leather cost more than local substitutes. Productivity thus rises only if this increase in cost is less than the benefit it generates for the buyer. Second, even if learning occurs, it is very difficult to measure econometrically because it is potentially confounded with significant endogeneity problems. In fact, it is easy to recognize that a the decision to import is likely to be contemporaneous with unobserved (to the econometrician) positive productivity shocks (Keller and Yeaple 2003). These reasons discourage an examination of the impact of imports on the buyers of foreign products and suggest a focus on an alterative mechanism for learning from imports.

The second mechanism for learning from importing is exposure to foreign technology. 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 typically depends on the local stock of knowledge, learning the new design raises productivity by increasing the local knowledge pool. This mechanism is easy to operationalize and test at the aggregate economy level (see Connolly 2001 and Rivera-Batiz and Romer 1991). But, econometric identification of the phenomenon at the firm level requires careful consideration of how the learning will actually occur.

To better understand this learning mechanism, recall the example of the engine assembler that decides to import engine blocks because of the tighter tolerances. As it starts to work with the foreign supplier, it becomes aware of the technologies that are superior to those of the domestic suppliers. Still, to the extent that this firm is in the business of engine assembly, not engine block manufacturing, the awareness of the new technology is all that will pass to the domestic economy. Because the assembler has no direct use for this new knowledge, no productivity enhancement will be take place (beyond the one described above in the context of the first learning mechanism). But, another group of firms could benefit from this awareness: the domestic engine block manufacturers. Local suppliers of equivalent intermediate products have strong incentives to adopt technologies that enable them to better compete with and eventually displace foreign suppliers. Failure to imitate the foreign import may threaten local supplier profitability, market share, and even survival. In addition, conditional on ability, a domestic client will likely prefer a local supplier to a foreign one because a local transaction poses fewer logistical concerns and less currency exchange risk. Therefore, local clients have an incentive to help local suppliers in finding and acquiring technologies that enable them to compete with foreign suppliers. In fact, the management literature (Womack, Jones, and Roos 1990; Lamming 1993; Nishiguchi 1994) has long acknowledged this role that supply chain relations play in transferring knowledge to and building the capabilities of suppliers. This phenomenon is especially salient in somewhat geographically isolated regions, such as Indonesia, and in complex supply chains such as automotive or machinery manufacturers (Dyer and Ouchi 1993; Cohen, Bessant, Kaplinsky, and Lamming 2002; Tendler and Amorim 1996).

Still, 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 (not) investing in a new technology may be very small. But, if a foreign supplier enters and uses superior technology to steal market share from local suppliers, all three of these reasons would be annulled.

These considerations support the base hypothesis that we will explore in this article: that learning from imports will occur among local suppliers upstream of import-intensive sectors. 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. But it is important to qualify this expectation. In fact, if the learning mechanism we described is associated with exposure to new technologies previously unknown in the domestic economy, one should expect to find a declining marginal effect. Early exposure to downstream imports ought to bring with it the greatest opportunities for learning, as well as competitive pressure to local suppliers. Further import market share gains bring new information at slower rate. After some point, import growth may actually signal the decline of an entire supply sector in the domestic economy. In addition, one should also expect to find the productivity effect to be greater in supply industries with high firm concentration. Firms in these concentrated industries are typically subject to less local competitive pressures and, therefore, exposure to international competition will likely have a greater marginal productivity effect. We will empirically test these two assertions to determine the robustness of our hypothesis.

3 Indonesian Manufacturing and Trade Policy

Indonesia's 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. Third, the country's size and resources support a full supply chain, from raw materials to intermediate and final goods. Fourth, rapid and localized industrialization provides variance in manufacturing activity in both time and geography. Fifth, the country's widespread island archipelago geography and generally poor transportation infrastructure create a number of local markets, each of which can support somewhat independent supply chains. Although regional disaggregation is not necessary for our results, it improves our identification by allowing variation in importing activity between regions but within the same industry. 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 from 1988 to 1996, an increase likely driven by the liberalization of the trade regime.

This sudden openness to imports presents the ideal conditions to test our hypothesis.

4 Data

The analysis is based on data from the Republic of Indonesia's *Budan 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. The SI includes questions about industrial classification (89 input-output table codes), own-

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

ership (public, private, foreign), fixed assets, income, output, exports, materials (and share imported), labor and other related topics. 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.[2] In recent years, BPS has surveyed over 20,000 factories 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 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 Perdangangan Besar* (IHPB), wholesale price indexes (WPI), published by BPS.

5 Identification Strategy and Estimation

We have hypothesized that firms selling to import-intensive sectors experience greater productivity growth than other firms. We test this hypothesis by estimating an establishment-level transcendental logarithmic (translog) production function. The translog production function is second-order logarithmic approximation of the production that places no functional form restrictions on the nature of input substitution or returns to scale. The translog production function controls for input levels and scale effects. The core of our paper is to examine whether the residual in the production function is correlated with importing in downstream sectors.

[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.

We cannot consistently estimate a production function with ordinary least squares if our variable on interest, downstream importing, is correlated with the error term. Such correlation is likely to the extent that downstream importing is endogenous to industry- and firm-level unobservables. We adopt four approaches to correct for this endogeneity. First, we control for static firm-level (and by extension, industry- and region-level) unobservables by introducing firm fixed-effects. Our estimation is thus based only on *changes* in firm productivity associated with changes in downstream imports. Second, we consider only variation in downstream importing that derives from import changes in industries *other* than that of the focal firm. Third, although we believe it to be unlikely, there could be correlation between the error terms associated with a particular firm-year observations and importing in other sectors downstream. We thus use a semi-parametric estimator to condition on idiosyncratic productivity shocks which might simultaneously affect productivity and importing in other sectors. Fourth, we include controls for two time-variant variables, firm ownership and downstream foreign direct investment, which might move contemporaneously with downstream importing activity. We detail our estimation approach below and elaborate on each of these approaches.

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 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). $Purchases_{it}$ is the amount of materials purchased by factory i at time t and $Foreign\_Purchases_{it}$ is the corresponding value 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 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 occurs in those areas is largely related to natural resource extraction 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 region's 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.

$$Own\_Sector\_Imports_{jrt} = \frac{\sum_{i \in jrt} Foreign\_Purchases_{it}}{\sum_{i \in jrt} Purchases_{it}} \tag{1}$$

$$Downstream\_Imports_{jrt} = \sum_{k} \alpha_{jkt} Own\_Sector\_Imports_{krt} \tag{2}$$

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 technology transfer is measured using the $Downstream\_Imports_{jrt}$ 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 its 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, α_{jkt} is the proportion of output of sector j consumed by sector k at time t. The coefficient α_{jkt} is calculated from the national Input-Output (IO) Tables. Values of α_{jkt} before and including 1990 follow from the 1990 IO table, values of α_{jkt} from 1991 through 1994 are linear interpolations of the 1990 and 1995 IO tables, and values of α_{jkt} from 1995 on are from the 1995 IO table. Recall that α_{jkt} does not have a region r subscript because the IO table is generated for the entire national economy.

We note that our measure of downstream imports is based on the share of materials imported by establishments. We do not know *which* materials establishments import. Thus, continuing with our example above, it is possible that the pasta industry imported only packaging material and procured all of its flour domestically. Supposing such an extreme case and assuming no technological relationship between pasta packaging and flour, the measured effect of downstream imports should be zero. In practice, such an extreme situation is unlikely and one can reasonably expect downstream imported to be composed of some materials that are produced domestically and some that our not. Hence, our point estimate of the effect of downstream imports will understate the true effect of downstream imported materials that are also procured locally.

We obtain establishment-level productivity by estimating a translog production function:[3]

$$\begin{aligned}\ln Y_{it} =& \beta_0 Downstream\_Imports_{jrt} + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 \ln M_{it} + \beta 4 \ln E_{it} + \\ & \beta_5 \ln^2 K_{it} + \beta_6 \ln^2 L_{it} + \beta_7 \ln^2 M_{it} + \beta_8 \ln^2 E_{it} + \\ & \beta_9 \ln K_{it} \ln L_{it} + \beta_{10} \ln K_{it} \ln M_{it} + \beta_{10} \ln K_{it} \ln E_{it} + \\ & \beta_{11} \ln L_{it} \ln M_{it} + \beta_{12} \ln L_{it} \ln E_{it} \beta_{13} \ln M_{it} \ln E_{it} + \alpha_i + \gamma_t + \varepsilon_{it}\end{aligned} \tag{3}$$

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, α_i is a fixed effect for factory i, γ_t

[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 permits us to allow a non-unitary elasticity of substitution between inputs and thereby better condition on economies of scale.

is a dummy variable for year t, and ε_{it} is an error term.[4] A positive coefficient on $Downstream\_Imports_{jrt}$ 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. Finally, we note that the error term, ε_{it}, is assumed 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 2003 for a full discussion). We know of no particular economic justification for simultaneity concerns in our data. In fact, to the degree that simultaneity exists, we believe it would place a downward bias on the effect of downstream imports because improvements in domestic supplier productivity would likely lead to less importing in downstream sectors. Nonetheless, we have performed our analysis with the corrections proposed by Olley and Pakes (using investment as a proxy for idiosyncratic shocks. The results (not reported here but available from the authors) are virtually unchanged.

To the extent that heterogeneity across firms and industries is static, our fixed-effect estimation should be consistent. However, industries could be changing over time and we employ two measures to address changes that might be contemporaneous with importing activity. First, because foreign-owned firms are more likely to import than wholly Indonesian-owned firms, it would be easy to confound changes in importing behavior with changes in foreign ownership. To avoid this potential effect, the sample used to calculate own imports is limited to wholly Indonesian-owned firms over the entire panel period.[5] A related concern is that downstream imports are a proxy for downstream foreign direct investment (FDI), a factor known to influence upstream firm productivity (Blomstrom and Kokko 1998; Blalock 2002; Javorcik 2004).[6] 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 own-sector imports, we do not assign causality to this variable. Rather, we use it simply as a control.

As noted in Section 2.2, the argument that exposure to downstream imports should be relevant when imports first enter a firm's downstream market. As the share of im-

[4] A Hausmann test rejects the use of random effect estimation.

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

[6] Downstream 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 k multiplied by the share of sector foreign output.

ports continues to grow, the positive impact on productivity may have a declining marginal rate. To test this idea we will consider a variation of the base model in which a squared term on downstream imports is introduced in the regression. Our expectation is find a negative coefficient on the squared term. A second aspect discussed in section 2.2 was that downstream imports would have a greater effect on less competitive domestic industries. To test this idea, we estimated the regression adding a variable for the interaction of the industry herfindahl concentration and downstream imports.[7] If downstream imports have a more pronounced productivity effect on less competitive (more concentrated) markets, then the coefficient on the interaction term should be positive.

Table 1 shows descriptive statistics for downstream imports, downstream FDI, and own-sector imports. 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. A similarly low value is found for downstream FDI, while the figure is somewhat higher for own-sector imports. The low average value for the downstream imports variable is important because it shows that, during the relevant period of our dataset, firms were mostly seeing the effect of a mild exposure to the entry of foreign players in downstream markets, rather than large movements towards foreign purchases. Yet, there is still a rich variation in the degree of exposure of each sector to downstream imports, helping our estimation process.

Table 2 shows the correlations between the variables of interest. Downstream imports, own-sector imports, and downstream FDI are positively correlated. This finding necessitates our estimation strategy of including all three measures to isolate the only the independent variation in downstream imports.

Another set of interesting issues not immediately considered in the proposed mechanism for productivity improvement, but still of relevance to the discussion, is how firm attributes affect the base hypothesis. We consider two firm attributes: location in the supply chain and size.

First, an immediate corollary from the hypothesis of supply chain learning is the idea that firms in intermediate goods sectors ought to learn more through this 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 fewer 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, which we define as

[7] The industry definition here is the IO table industry code. Alternative industry definitions based on 4-digit ISIC codes yield similar results.

firms with more than 50 employees.[8]

6 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, which is shown as significant at a 99% confidence interval. Because the production function is of log-linear form, the coefficients represent elasticities. Therefore, the 0.12 coefficient on *Downstream_Imports* suggests that factory output increases approximately 0.12% as the proportion of downstream materials imported rises by 1%. Given that the level of downstream imports increased by about 10% from 1988 to 1996 in many industries, the realized gain is about a 1% increase in output in many sectors. When weighted by firm output, the overall level of downstream imports increased by 5%, suggesting about a 0.6% (0.12 times 5%) increase in total manufacturing output from 1988 to 1996.

Columns (2) to (4) represent the sets of controls discussed in Section 5. The effect of downstream imports is robust to the introduction of any or all of the relevant control variables. Consistent with Blalock 2002 and Javorcik 2004, 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), although the effect remains significant. Columns (3) and (4) confirm the hypothesis that own-sector imports do not affect the main results and are likely to be non-significant.[9]

Column (5) tests for the relevance of competition as a critical mechanism for inducing productivity enhancement. The interaction effect between own-sector concentration and downstream imports is positive and significant.[10] Moreover, the explanatory power of the regression improves significantly. These results support our assertion of the critical importance of competition. At the same time, it is important to note that the main coefficient on downstream imports is still significant. This suggests that, even with perfect competition (as the herfindahl index tends to zero), productivity improvement still occurs. The interpretation is that, in addition to any competition effect, downstream imports increase productivity through some kind of knowledge transfer to supply chain customers as explained in Section 2.2. The last

[8] The results are not sensitive to the definition of size. For example, defining large firms as those with more than 200 employees yields nearly identical results

[9] If the endogeneity of a firm's import decision is significant, the coefficient and standard errors may be biased.

[10] Concentration may be simultaneously determined by both productivity and and downstream imports. To remove this possible endogeneity, we estimated an alternative specification in which the concentration index is fixed at the level in 1988, at the start of our panel. Our results are very similar, but significant only at the 90% confidence level.

column (6) in this table includes the squared term on downstream imports. As expected, the coefficient on this term is negative and significant, supporting the idea of a declining marginal impact.

To test for the robustness of the previous results and the associated hypothesis regarding firm size and position in the supply chain discussed in Section 5, Table 4 presents the results for the relevant subsets of firms. As predicted, larger firms are better able to leverage international learning (column 2). Likewise, the results are much stronger for intermediate goods than for final goods sectors (columns 3 and 4). All results are robust to the introduction of downstream FDI.

7 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 growth than other firms. These results are consistent under a number of different econometric approaches that address potential endogeneity between importing activity and firm productivity.

We also find that early exposure to downstream imports brings with it the greatest opportunities for learning, while an increasingly larger presence of imports induces productivity improvements at a declining marginal rate. In addition, results show that productivity improvement is greater in contexts where suppliers are more concentrated, suggesting that competition is a critical vehicle for inducing improvements. Overall, the findings of this research suggest that linkages though vertical supply relationships are the relevant mechanism through which import-driven knowledge transfer occurs.

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

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8 Tables

Variable	Obs	Mean	Std. Dev.	Min	Max
Downstream Imports	6169	0.069	0.110	0	0.903
Downstream FDI	6169	0.050	0.106	0	0.987
Own-sector Imports	6126	0.172	0.277	0	1.000

Table 1: Descriptive Statistics. Unit of observation is an industry-province-year cell.

	Downstream Imports	Downstream FDI	Own-sector Imports
Downstream Imports	1.0000		
Downstream FDI	0.6107	1.0000	
Own-sector Imports	0.4342	0.2519	1.0000

Table 2: Correlation of key variables.

Dep. var: log(output)	(1)	(2)	(3)	(4)	(5)	(6)
Downstream Imports	0.117	0.064	0.115	0.062	0.075	0 .352
	(4.90)	(2.26)	(4.80)	(2.17)	(2.92)	(5.92)
(Downstream Imports)^2						-0.414
						(4.32)
Downstream FDI		0.084		0.084		
		(3.41)		(3.42)		
Own-sector Imports			0.001	0.002		
			(0.05)	(0.15)		
Concentration*Downstream Imports					0.145	
					(4.02)	
log(labor)	0.579	0.579	0.580	0.580	0.579	0.581
	(30.57)	(30.56)	(30.69)	(30.68)	(30.58)	(30.65)
log(capital)	0.098	0.099	0.097	0.097	0.098	0.098
	(11.00)	(11.03)	(10.88)	(10.90)	(11.04)	(10.96)
log(materials)	0.195	0.196	0.195	0.195	0.194	0.195
	(20.58)	(20.63)	(20.57)	(20.62)	(20.52)	(20.61)
log(energy)	0.110	0.109	0.111	0.110	0.109	0.108
	(15.54)	(15.46)	(15.75)	(15.67)	(20.52)	(15.32)
log(K)log(K)	0.005	0.005	0.005	0.005	0.005	0.027
	(10.34)	(10.34)	(9.96)	(9.95)	(10.32)	(10.35)
log(L)log(L)	0.010	0.010	0.011	0.011	0.010	0.010
	(4.50)	(4.54)	(4.74)	(4.78)	(4.51)	(4.43)
log(M)log(M)	0.049	0.049	0.048	0.048	0.049	0.049
	(84.42)	(84.36)	(83.28)	(83.22)	(84.39)	(84.43)
log(E)log(E)	-0.011	-0.011	-0.011	-0.011	-0.011	-0.011
	(25.21)	(25.22)	(25.12)	(25.13)	(25.17)	(25.15)
log(K)log(L)	0.028	0.028	0.027	0.027	0.027	0.027
	(16.58)	(16.53)	(16.15)	(16.11)	(16.58)	(16.60)
log(K)log(M)	-0.028	-0.028	-0.027	-0.027	0.028	-0.028
	(32.03)	(32.03)	(30.87)	(30.87)	(32.03)	(32.04)
log(K)log(E)	0.007	0.007	0.006	0.006	0.006	0.006
	(9.66)	(9.68)	(9.10)	(9.12)	(9.64)	(9.71)
log(L)log(M)	-0.079	-0.079	-0.079	-0.079	-0.079	-0.080
	(44.14)	(44.16)	(44.06)	(44.07)	(44.12)	(44.20))
log(L)log(E)	0.027	0.027	0.027	0.027	0.0266	0.027
	(18.62)	(18.66)	(18.58)	(18.62)	(18.52)	(18.65)
log(M)log(E)	-0.005	-0.005	-0.005	-0.004	-0.004	-0.005
	(6.38)	(6.33)	(6.05)	(6.00)	(6.26)	(6.34)
Constant	4.017	4.016	4.022	4.021	4.020	4.009
	(56.95)	(56.93)	(57.18)	(57.17)	(56.99)	(56.82)
Observations	106302	106302	106263	106263	106302	106302
No. of Establishments	23090	23090	23083	23083	23090	23090
R-squared	0.81	0.81	0.81	0.81	0.94	0.81

Absolute value of t statistics in parentheses

Table 3: Translog estimation of the effect of downstream imports and own-sector imports on plant productivity. Factory fixed effect and year indicators are included but not reported.

Dep. var: log(output)	(1) all factories	(2) more than 50 employees	(3) int. goods sectors	(4) final goods sectors
Downstream Imports	0.064	0.110	0.090	0.037
	(2.26)	(2.90)	(3.00)	(1.18)
Downstream FDI	0.084	0.091	0.063	0.062
	(3.41)	(2.79)	(2.42)	(2.29)
log(labor)	0.579	0.617	0.649	0.682
	(30.56)	(26.25)	(23.91)	(27.37)
log(capital)	0.099	0.100	0.110	0.086
	(11.03)	(7.67)	(8.18)	(8.04)
log(materials)	0.196	0.204	0.244	0.107
	(20.63)	(14.47)	(16.75)	(8.84)
log(energy)	0.109	0.037	0.104	0.053
	(15.46)	(3.52)	(10.41)	(5.83)
log(K)log(K)	0.005	0.005	0.006	0.005
	(10.34)	(7.61)	(8.12)	(9.03)
log(L)log(L)	0.010	0.011	-0.007	0.033
	(4.54)	(4.13)	(2.12)	(10.99)
log(M)log(M)	0.049	0.044	0.049	0.051
	(84.36)	(56.17)	(54.76)	(72.04)
log(E)log(E)	-0.011	-0.012	-0.013	-0.009
	(25.22)	(19.80)	(19.08)	(16.14)
log(K)log(L)	0.028	0.019	0.028	0.026
	(16.53)	(9.49)	(11.55)	(12.31)
log(K)log(M)	-0.028	-0.025	-0.031	-0.027
	(32.03)	(21.42)	(22.71)	(24.95)
log(K)log(E)	0.007	0.008	0.006	0.007
	(9.68)	(8.54)	(6.28)	(8.54)
log(L)log(M)	-0.079	-0.074	-0.078	-0.091
	(44.16)	(32.72)	(29.88)	(39.99)
log(L)log(E)	0.027	0.026	0.031	0.015
	(18.66)	(14.13)	(15.04)	(7.98)
log(M)log(E)	-0.005	0.002	-0.005	0.002
	(6.33)	(1.51)	(4.53)	(1.74)
Constant	4.016	4.225	3.411	4.641
	(56.93)	(39.82)	(31.60)	(52.38)
Observations	106302	57676	40642	74795
Number of Establishments	23090	10759	8493	16343
R-squared	0.81	0.83	0.83	0.81
Absolute value of t statistics in parentheses				

Table 4: Translog estimation of province imports, own-sector imports, and downstream imports on firm productivity using (1 and 5) 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. Factory fixed effects and year indicators are included but not reported.