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# THE MICRO-DYNAMICS OF CATCH-UP IN INDONESIAN PAPER MANUFACTURING

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In this study we analyze the micro-dynamics of catch-up in Indonesian paper manufacturing, using a two-country plant-level dataset for the period 1975–97. We apply data envelopment analysis (DEA) to measure to what extent Indonesian paper mills are catching up with Finnish mills in terms of technical efficiency. Three questions are addressed: What is the distribution of Indonesian plant technical efficiency vis-à-vis the technological frontier? What is the role of entry, exit, and survival in Indonesia for catch-up in the paper industry as a whole? In what ways do catching-up plants in Indonesia differ from non-catching-up plants? We find that on average the Indonesian paper industry moved closer to the technological frontier during the 1990s. However, catch-up has been a highly localized process in which only a few large establishments have achieved near best-practice performance, while most other plants have stayed behind.

## 1. Introduction

Catch-up refers to the process of reducing the technology and productivity gaps between technologically advanced (rich) and technologically backward (poor) countries. So far, most comparative research on this topic has been conducted at the country or industry level. However, due to the high level of aggregation these studies are not able to reveal the micro-dynamics of the catch-up process. Is catch-up an industry-wide process where all developing country firms are reducing the gaps relative to international best practice? Or is catch-up driven by a few large firms operating closer to the technological frontier, while many of the other firms are falling behind? Is industry-level catch-up associated with the entry of newly established modern plants, improvements in the efficiency of incumbent plants, or the exit of inefficient establishments?

These questions can only be answered by supplementing international comparisons of economic performance at the macro-level with international comparisons of plant-level performance based on micro-data. A better understanding of

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these questions will increase our understanding of the process of catching up or falling behind. Better insights in the micro-dynamics of catch-up will also contribute to the formulation of effective industrial and technology policies.

So far only a few studies have dealt with this issue in a quantitative fashion.[1] A common shortcoming of the existing studies is their limited coverage. Most studies only cover a few firms per country and results might therefore not be statistically representative. In addition, international comparisons of performance are often only presented for one single year so that little can be inferred about catch-up, a phenomenon that is dynamic per definition. Finally, the lumping together of firms from a variety of industries may obscure important sectoral characteristics.

This paper provides a first attempt to study catch-up at the micro-level, focusing on a detailed analysis of a single industry, the Indonesian paper industry, in such a way that the methodological issues outlined above can be addressed. We use an internationally standardized longitudinal micro-level dataset (LMD) based on Indonesian and Finnish manufacturing census micro-data for the period 1975–97. We apply data envelopment analysis (DEA) to measure the technical efficiency of Indonesian paper mills vis-à-vis Finnish mills, which are generally considered to represent world best practice in paper manufacturing (Ojainmaa, 1994; Diesen, 2000). Catch-up is defined as closing the technical efficiency gap with the frontier.

We address the following questions: (1) What is the distribution of Indonesian plant performance vis-à-vis the technological frontier and how does this change over time? Our expectation is that in a developing country there will be a greater dispersion of firm performance than in advanced economies. Also, we expect that the dispersion of plant performance will increase over time, as technological improvements do not easily flow from plant to plant in a developing country context. (2) What is the role of entry, exit, and survival in Indonesia for catch-up in the Indonesian paper industry as a whole? (3) In what ways do catching-up plants in Indonesia differ from non-catching-up plants? What are the characteristics of the plants that contribute to catch-up?

The Indonesian paper industry provides an interesting case for the study of catch-up. Before the Asian crisis of 1997, Indonesia was generally perceived to be a second-tier Asian tiger (World Bank, 1993; Hill, 2000). Growth in GDP per capita averaged 3.6 percent per year for the period 1960–98. Indonesian growth was driven to an important extent by the manufacturing sector, which experienced rapid growth of output, exports, and productivity. Between 1988 and 1997, productivity per hour worked increased from 6.2 to 11.1 percent of the U.S. level (Stuivenwold and Timmer, 2003). The evidence suggests that the country was on a progressive path of industrialization and development, rudely disrupted by the financial crisis (Hill, 2000).

The paper sector was one of the dynamic sectors contributing to the Indonesian industrialization drive. With output growth of more than 15 percent per year between 1960 and 2000, it has been among the fastest growing manufacturing

[1]Pack (1987) is one of the first studies looking explicitly at the technology gap between establishments in industrialized and developing countries. Other relevant studies are Mason *et al.* (1994), Baily and Solow (2001), and Bartelsman *et al.* (2005).

sectors in the country. Responding to explicit industrial policy incentives, paper companies invested in the latest equipment and Indonesia emerged as one of the world's major producers and exporters of paper products (Van Dijk, 2005). Finally, the availability of high quality historical data at plant level, a rarity for developing countries, also influenced the choice of country and sector.

The structure of this paper is as follows. Section 2 summarizes the theoretical framework. In Section 3, we describe our dataset. DEA is discussed in Section 4. In Sections 5, 6, and 7 we analyze the micro-dynamics of catch-up in the Indonesian pulp and paper industry. In the final section we summarize the major findings and conclusions.

## 2. Theoretical Framework

### 2.1. *Catch-Up, Technology Diffusion, and Absorptive Capacity*

There is an increasing emphasis in the literature that technical change is the key factor in explaining differences in income per capita between countries (Romer, 1990; Aghion and Howitt, 1998; Fagerberg and Verspagen, 2002). In this view global economic growth is shaped by the interplay of innovation and diffusion. Innovation refers to the creation and commercialization of technology new to the world. This is the main source of growth for the advanced capitalist economies. Diffusion involves international spillovers of existing technology from lead countries to follower countries. Consequently, it has been argued from a variety of perspectives that poor countries enjoy so called "advantages of backwardness" (Gerschenkron, 1962). They have an opportunity to catch up by exploiting foreign technology without going through the costly and painstaking process of creating new products and processes themselves. However, this is neither an easy nor an automatic process. Catch-up depends heavily on absorptive capacity, a country's capability to assimilate existing technology and adapt it to a new environment (Abramovitz, 1986; Verspagen, 1993).[2] The balance between innovation and diffusion determines the extent to which divergence or convergence predominate on a global scale.

There is a large empirical literature investigating catch-up (for overviews, see Fagerberg, 1994; Temple, 1999). One set of studies focuses in particular on quantifying the technology gap across countries, putting special emphasis on the collection of historical data and the construction of appropriate currency converters to ensure international comparability of inputs and outputs. Typically, catch-up is examined by looking at long-run trends in comparative levels (as opposed to growth rates) of labor and total factor productivity vis-à-vis the technological frontier at the industry or country level (e.g. Szirmai and Pilat, 1990; Dollar and Wolff, 1993; Timmer, 2000). Such an analysis provides information on the size of the international technology gap and the sources of and scope for catching up. Recently, frontier analysis (parametric and non-parametric) has been increasingly used to measure international technology gaps between countries (e.g. Färe *et al.*, 1994; Kneller and Stevens, 2006; Los and Timmer, 2005).

[2]Abramovitz uses the term social capability instead of absorptive capacity. Here we use the latter term as this is more often used in the current literature (e.g. Cohen and Levinthal, 1989).

A second set of studies is concerned with identifying the factors which hamper or promote catch-up. Factors which are found to contribute to the absorptive capacity of countries include: education (Benhabib and Spiegel, 1994), R&D (Fagerberg, 1988), international trade (Coe *et al.*, 1997), firm level technological capabilities (Lall, 1992), and technology and industrial policies (Kim, 1997).

### 2.2. *Industrial Dynamics and Dualistic Market Structures in Developing Countries*

Following research trends in the advanced economies (Bartelsman and Doms, 2000), the increasing availability of manufacturing census data has spurred the research on industrial dynamics in developing countries (e.g. Roberts and Tybout, 1996; Van Biesebroeck, 2005a). Tybout (2000) presents an excellent summary of the state of the art in this field. Probably the most distinctive feature of manufacturing sectors in developing countries is the existence of dualistic market structures. Developing country markets are commonly characterized by a few large-scale modern companies and large numbers of small traditional firms, producing similar goods side by side (e.g. Nelson, 1968; Blomström and Wolff, 1997; Sleuwaegen and Goedhuys, 2002; Shiferaw, 2007). In many sectors—though not in paper manufacturing—small firms tend to operate in the informal sector. Poor countries exhibit a "missing middle," indicated by the very small share of firms with 10 to 50 workers relative to the shares of firms in smaller or larger size classes.

The literature offers a range of possible explanations for dualistic market structures in developing countries. Some explanations focus on the general under-development of the economy exemplified by barriers to entry, limited diffusion of technology, fragmented markets, survival of inefficient incumbents, high shares of low-tech industries, macro-economic instability, and abundance of low-skilled labor. Others relate to distorting government policies such as protectionist trade policies, excessive regulation, and preferential treatment of influential companies (Fafchamps, 1994).[3]

That manufacturing sectors in developing countries are characterized by dualism does not have to be a problem per se. What matters is if and to what extent this phenomenon reflects obstacles to technology diffusion and a lack of competition, resulting in inefficiencies, limited technical change, and constrained growth. If the industrial sector in developing countries is indeed characterized by poorly functioning markets and high numbers of backward firms, one would expect a greater dispersion of performance in those countries relative to the advanced economies, where markets are more competitive. Hence what is referred to as "catching up" in macro-oriented studies, might in reality just be caused by the emergence of a few modern firms, while the majority of plants continue to lag far behind the technology frontier. This limits the extent to which a developing economy as a whole can profit from international diffusion of technology.

Somewhat surprisingly, the empirical evidence available so far does not always seem to support the dispersion hypothesis. Tybout (2000) finds that average

[3]See also Jovanovic (1982) and Hopenhayn (1992) who present dynamic models of industry evolution showing that under certain conditions efficient and inefficient firms coexist even when markets work properly.

technical inefficiency within developing countries is not typically lower than found in similar studies for high-income countries. Comparable results are obtained by Blomström and Wolff (1997), who find that there is not much variation in total factor productivity levels across plant sizes for the Mexican manufacturing sector. Van Biesebroeck (2005a) does find divergence of productivity performance in Africa, with large manufacturing firms growing more rapidly than small ones. But he makes no direct comparisons with advanced economies. Shiferaw (2007) finds a high degree of heterogeneity of firm level productivity in Ethiopia, with large efficient firms staying at the top of the productivity distribution. However, in the long run, the growth of those small entrants that survive makes a positive contribution to aggregate productivity growth. This counteracts the declining productivity trends for incumbents.

Tybout notes that the available studies on industrial dynamics "are not very informative" (Tybout, 2000, p. 25; see also Katayama *et al.*, 2003). The results of most studies are difficult to compare because of variations in methodology, industry classification, and variable definition. The analysis is often performed on broad samples, lumping together firms producing different goods or using various technologies that might not be comparable. Further, as mentioned above, there are only a handful of studies that provide a direct comparison of international performance at the plant level, most of which are characterized by limited coverage. Finally, Tybout himself uses average technical efficiency to draw conclusions about differences in the distribution of performance between countries, which can be misleading. Only measures of dispersion like the standard deviation, the coefficient of variation, or graphical tools like kernel density plots, provide suitable information on the spread of a variable.

In this paper we address a number of these issues in a longitudinal two-country comparison for a single industry. The central focus is the dispersion of plant level performance and the comparison of such dispersion between an advanced and a developing economy. In order to make the value of output in paper manufacturing comparable in Finland and Indonesia, we have constructed a sector specific unit value ratio, and we use standardized definitions of input and output. This allows us to pool Indonesian and Finnish micro-data in a single comparative dataset expressed in a common currency. We use DEA to estimate technical efficiency of Indonesian paper plants vis-à-vis the technological frontier composed of Finnish mills and catch-up as closing the distance with best-practice.[4] Finally, we try to identify the determinants of technical efficiency at the micro-level.

## 3. Data

Like most national micro-studies, we base our comparative analysis on establishment-level manufacturing census data of the two economies being com-

[4]Our definition of catch-up is in line with Färe *et al.* (1994) who decompose total factor productivity into technical change (movement of the frontier) and technical efficiency change (catching up). In this paper we are interested in the investigating the micro-dynamics (entry, exit, and growth effects) of catch-up and therefore only focus on (changes in) technical efficiency relative to the technological frontier from the perspective of a latecomer (Indonesia) country. We do not analyze shifts in the frontier (innovation) itself.

pared. Besides good coverage, the advantage of using this type of data is that they are consistent with more aggregate studies on the comparison of international performance, which are usually based on the same manufacturing census data.

The main data source for the Indonesian paper LMD is the backcast version of the annual survey of large and medium scale manufacturing establishments (*Statistik Industri Besar dan Sedang*, SI), compiled by Indonesia's Central Bureau of Statistics (*Badan Pusat Statistik*, BPS). Data on value added and employment from the SI were subsequently merged with information on capacity, production, product mix, age, export orientation, use of foreign labor, and technology data from a number of other sources, mainly the Indonesian Paper Association (*Asosiasi Pulp & Kertas Indonesia*, APKI). To the best of our knowledge, the Indonesian paper LMD represents the history of virtually all paper mills that have ever been in operation in Indonesia for the period 1975–97. A more detailed description of the dataset is provided in Van Dijk and Szirmai (2007).

The data for Finnish paper mills derive from the longitudinal data on plants in the Finnish manufacturing constructed by Statistics Finland. It is based on annual manufacturing surveys, which have been conducted in Finland since 1974.[5] Next, the data were linked with information on capacity from annual issues of the *Philips International Paper Directory* and *Philips Paper Trade Directory* to construct a Finnish paper LMD, comparable to the Indonesian dataset.

International comparisons of productivity require that inputs and outputs are comparable across countries.[6] Two issues are of particular importance to the analysis here: (1) standardization of definitions and coverage of input and output; and (2) the use of appropriate currency converters.

With regard to standardization, both the Finnish and Indonesian surveys are based on establishments (as opposed to firms) and can therefore be directly compared.[7]

In most plant-level productivity studies, gross value of output is used as output measure rather than value added (Baily, 1986). Regrettably, no breakdown of intermediate inputs into energy, materials, and semi-fabricated products is available for Indonesia in the years before 1990. Also one cannot simply deduct value added from output to get reliable series on intermediate inputs due to the peculiarities of the Indonesian backcasting procedures (Jammal, 1993). For this reason, we have excluded intermediates from the analysis. We use value added as the output concept and labor and capital as the inputs. In their manufacturing surveys, both Finland and Indonesia use the national accounts concept of value added, which excludes non-industrial services. Thus, value added can be compared without problems.

[5]See appendix 2 in Maliranta (2003) for a more elaborate description of the longitudinal data on plants in Finnish manufacturing.

[6]See Van Ark (1996) for an overview of measurement issues with respect to international comparisons of productivity.

[7]The Indonesian census excludes establishments with less than 20 employees, while the Finnish census includes such plants since 1995. However, paper manufacturing is a scale and capital intensive industry. None of the plants in the Indonesian population falls below the size threshold, so there are no differences in coverage. In the backcast version of the dataset corrections are made for the fact that new entrants take many years to appear in the dataset (Jammal, 1993).

The standardization of the labor and capital inputs also provided no problems. For both Finland and Indonesia, labor input is defined as the number of persons engaged, including the self-employed and unpaid family workers. For both countries, we approximate the capital stock by total current capacity installed for paper production (available for all years). Given the lack of internationally comparable information on asset lifetimes, retirement patterns, and investment data, this measure based on *core machinery* is preferred over cumulated investment according to the perpetual inventory method. For a discussion of the core machinery approach, see Szirmai *et al.* (2002).

Just as in macro-comparisons, micro-comparisons require adequate currency converters to compare real output and productivity at the establishment level. It is well known that exchange rates do not provide a realistic basis for comparisons of real output (e.g. Van Ark, 1996). They tend to underestimate developing country real output. In order to make plant-level comparisons of output between Finland and Indonesia, we have calculated an industry-of-origin average unit value ratio (UVR) for the paper industry, using the standard methodology of the International Comparisons of Output and Productivity Project (ICOP) (e.g. Szirmai and Pilat, 1990; Szirmai, 1994; Van Ark, 1996; Timmer, 2000).

The (Fisher) UVR for the benchmark year 1995 is 290 Rupiah per Finnish Markka. The value added series in both countries are deflated using country specific deflators calculated using the prices of wood-free paper. The series are expressed in constant 1995 prices. Subsequently the UVR for 1995 is applied to convert Indonesian time series values into constant 1995 Markkas (for details, see Van Dijk and Szirmai, 2007).

A caveat is in order regarding the application of sectoral UVRs to individual firm data. Due to the lack of plant-specific output prices, quantity and price effects may be entangled at the micro-level (Bartelsman and Doms, 2000; Tybout, 2000; Katayama *et al.*, 2003). Thus, a price-cost mark-up by a monopolist might be mistaken for higher plant productivity. On internationally competitive markets, there are few opportunities for monopolistic pricing. As the largest Indonesian plants export a substantial part of their output, we do not expect monopoly pricing to cause serious bias in this study.

Finally, the data for Indonesia and Finland have been pooled to create a micro-level database suitable for comparative productivity analysis. In total the Indonesian paper LMD contains information on 53 plants, which on average represent 99 percent of installed capacity. The Finnish LMD contains information on about 31 Finnish paper mills, which represent about 76 percent of total paper capacity installed in Finland.[8] "Pure" pulp mills are excluded from the sample because they cannot directly be compared with paper mills. Integrated mills (i.e. plants having both pulp and paper processing facilities), however, are still included. Twenty percent of our Indonesian sample consists of integrated mills in 1997. For the Finnish mills the share is 60 percent.

Table 1 presents summary statistics for the main variables by country. On average paper mills in Indonesia are smaller than their Finnish competitors in

[8]Secondary data of Indonesian and Finnish paper mills were linked with the LMD through address information. Due to missing or conflicting data the matching was less than 100 percent.

TABLE 1
Summary Statistics, 1975 and 1997

| Variable | | Indonesia | Finland | Pooled |
|---|---|---|---|---|
| **1975** | | | | |
| Value added (000 95 Markka) | Mean | 16.93 | 100.13 | 81.64 |
| | S.D. | 14.32 | 63.45 | 66.16 |
| Labor (persons engaged) | Mean | 426.50 | 612.21 | 570.94 |
| | S.D. | 234.30 | 438.39 | 406.66 |
| Capacity (000 tonnes) | Mean | 20.03 | 271.17 | 215.36 |
| | S.D. | 15.48 | 222.10 | 222.07 |
| Number of observations | | 8 | 28 | 36 |
| **1997** | | | | |
| Value added (000 95 Markka) | Mean | 196.82 | 299.68 | 237.18 |
| | S.D. | 556.76 | 222.36 | 456.46 |
| Labor (persons engaged) | Mean | 1262.77 | 502.81 | 964.56 |
| | S.D. | 2214.76 | 289.65 | 1768.45 |
| Capacity (000 tons) | Mean | 189.44 | 452.58 | 292.70 |
| | S.D. | 348.76 | 335.85 | 365.23 |
| Number of observations | | 31 | 48 | 79 |
| **1975–97** | | | | |
| Value added (000 95 Markka) | Mean | 76.46 | 229.94 | 150.11 |
| | S.D. | 264.95 | 198.83 | 247.65 |
| Labor (persons engaged) | Mean | 708.10 | 541.37 | 628.10 |
| | S.D. | 1166.09 | 351.93 | 879.31 |
| Capacity (000 tons) | Mean | 72.84 | 342.51 | 202.24 |
| | S.D. | 152.25 | 272.76 | 256.68 |
| Number of observations | | 761 | 702 | 1463 |

*Notes*: The pooled total of 1463 observations 1975–97 refers to an unbalanced panel covering in total 53 Indonesian and 31 Finnish plants. The summary statistics for 1975 and 1997 refer to the plants in existence in the specified year. The 1995 UVR used to convert Rupiah into Markka is 290 Rupiah per Markka (see van Dijk and Szirmai, 2007, annex table 2).

*Source*: Indonesia: Statistik Industri, digital version, 1975–97 and APKI. Finland: Annual Manufacturing Surveys, Philips International Paper Directory and Philips Paper Trade Directory.

terms of value added and capacity. In terms of average employment they are much larger. The standard deviations for 1997 indicate that plant heterogeneity in Indonesia has become much higher than that in Finland, in line with the discussion of dualism discussed above. Plant heterogeneity in Indonesia has increased over time since 1975.

## 4. Data Envelopment Analysis

We use DEA to measure the performance of Indonesian paper mills relative to international best practice, approximated primarily by Finnish paper factories.[9] In DEA, establishments are defined as technically efficient if they achieve the highest output per any given combination of inputs, compared to other establishments.[10] All efficient establishments together make up the best-practice production function or technology frontier, which reflects the outer boundary of all possible

[9]See Coelli *et al.* (1998) for an extensive discussion of DEA and efficiency measurement in general.

[10]Here we employ the output-oriented measure of technical efficiency. One can also use an input-oriented measure, which investigates how much inputs can be reduced without reducing outputs while remaining within the feasible production set.

input–output combinations for the dataset under consideration. All establishments operating below the frontier are considered technically inefficient because their output falls short of what could have been produced, given the inputs used. Technical efficiency is measured relative to best practice in a given year. Thus, we are only focusing on relative efficiency, not on technical change (shifts of the frontier). DEA uses linear programming techniques to compare the efficiency of each plant with that of the others in order to construct a convex piece-wise hull (i.e. the technology frontier) that envelops the data. Technically efficient plants have an efficiency rating of 100 percent and establishments below the frontier have an efficiency rating of less than 100 percent.

We assume that output (value added) is produced with only two inputs (capital and labor) and variable returns to scale (VRS). The technical efficiency a plant $i$ is computed relative to a meta-frontier based on our pooled sample of Finnish and Indonesian plants. We assume that the available technology is identical for Indonesian and Finnish plants.[11] As Finnish paper mills (or at least some of them) are the technologically most advanced producers in the world, our measure of technical efficiency can be interpreted as the gap with the global technological frontier. But some of the most advanced Indonesian plants could also be operating at the global frontier. In temporal perspective, increasing technical efficiency can be regarded as bridging the technology gap and catching up with best practice, while decreasing technical efficiency reflects falling behind.

Technical efficiency is calculated by solving the following linear programming problem:

(1) $$\max_{,\theta} \quad \theta_i$$

subject to:

(2) $$-\theta_i \cdot y_i + \sum_{n=1}^{N} y_n \cdot \lambda_n \geq 0,$$

(3) $$k_i - \sum_{n=1}^{N} k_n \cdot \lambda_n \geq 0,$$

(4) $$l_i - \sum_{n=1}^{N} l_n \cdot \lambda_n \geq 0,$$

(5) $$\lambda \geq 0.$$

The column vectors $k_i$, $l_i$, and $y_i$ represent respectively capital, labor, and value added for the $i$-th establishment (out of N). $\lambda$ is an $N \times 1$ vector of constants. The

[11]For paper manufacturing this is a reasonable assumption. Paper is produced with similar types of machinery and associated technological knowledge. Worldwide paper machinery is supplied by 3–5 firms. All countries employ the same technology and the technology used for different types of paper does not differ in any important ways.

linear problem has to be solved N times, to obtain a value of $\theta_i$ for each establishment in the sample. $\theta_i$ reflects the proportional increase in output that could be achieved by the *i*-th plant with input quantities held constant. Finally, technical efficiency is computed as $1/\theta_i$, which varies between zero and one.

An advantage of DEA relative to econometric estimation of the frontier, commonly referred to as stochastic frontier analysis (SFA), is that DEA does not require any assumptions about the shape of the production function or the distribution of the inefficiencies. For our purposes, another advantage of DEA is that the second-stage analysis, i.e. regressing efficiency scores upon a set of explanatory variables, is simpler than in SFA. Various authors have pointed out that second-stage analysis is only consistent with SFA when it is undertaken simultaneously with the estimation of technical efficiency scores (see Coelli *et al.*, 1998, p. 207). Since Indonesian data are only available since 1990 and the information on Finnish establishments is much more limited than that for Indonesian plants, such a requirement would require the extensive use of dummy variables. In addition, SFA with simultaneous second-stage analysis is not (yet) flexible enough to incorporate sophisticated regression techniques like generalized method of moments (see Section 7).

An important disadvantage of DEA compared to SFA is that it makes no allowance for shocks and statistical errors. This implies that outliers may have a strong impact on the location and shape of the frontier.[12] Another problem of DEA is that the technical efficiency scores might be biased upwards due to sampling error (Simar and Wilson, 2000, 2006). The bias occurs because the computed frontier is based on a finite sample. It may lie below the "true" frontier, which would be found if information on the complete population were available.

The effects of outliers will be reduced if we use bootstrapping techniques which allow us to estimate the frontier for the hypothetical population rather than for the sample. We apply a recently developed methodology for bootstrapping in DEA models proposed by Simar and Wilson (2000).[13] Kneip *et al.* (2008) distinguish between two types of bootstrapping—smoothing and subsampling. We follow their recommendations to use the smoothing approach.

As Indonesian plants represent almost all of the Indonesian population and Finnish plants represent a very substantial proportion of Finnish plants, the function of bootstrapping is not so much to reproduce the frontier for the full population of plants in the two countries. Rather, we have two countries with plants representing extremes of global production process, ranging from traditional labor intensive plants in Indonesia to state of the art plants in both countries. We therefore interpret the bootstrapping estimates as providing a better approximation of the global technology frontier in paper making.

[12]In earlier work we used SFA rather than DEA (Van Dijk, 2005). The TE scores of the SFA are very similar to those of the DEA, indicated by a correlation coefficient of 0.85. This implies that possible outliers do not distort the overall result of the DEA analysis.

[13]In contrast to standard bootstrapping, this approach uses kernel density estimation to take into account the bounded nature of the efficiency scores. We use the software package FEAR 1.0, developed by Wilson (2005), to compute the DEA scores after bootstrapping.

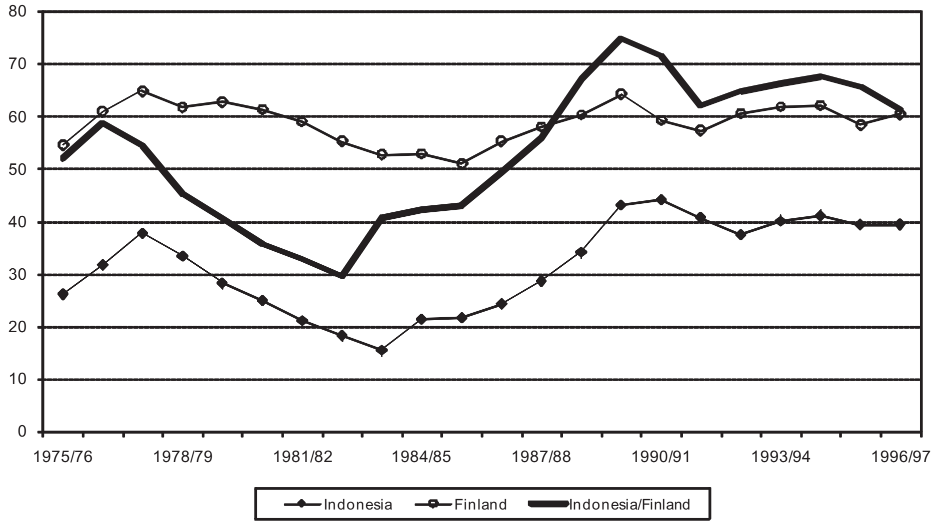


Figure 1. Aggregate Industry Technical Efficiency by Country, 1975–97

*Note*: Figure presents average industry-level technical efficiency of Indonesia and Finland (two-year averages), using gross output figures as weight, based on output-oriented VRS DEA with bootstrapping.

## 5. Aggregate Catch-Up and the Dispersion of Plant-Level Performance

This section looks at the distribution of Indonesian plant performance in comparison with that of Finnish plants (the technological frontier). Figure 1 depicts aggregate industry technical efficiency for Indonesia and Finland for the period 1975–97 (two-year averages). Technical efficiency is calculated on the basis of output-oriented DEA with variable returns to scale and bootstrapping.[14] Plant-level efficiencies are weighted with plant shares in gross output added to arrive at the average efficiencies depicted in the figure.[15]

Figure 1 clearly indicates that on average Indonesian paper mills are producing at a greater distance from the frontier than their Finnish competitors. Dividing average efficiency in Indonesia by average efficiency in Finland, results in an estimate of aggregate relative performance. The relative performance corresponds closely to insights derived from qualitative information on the historical development of the Indonesian paper industry (Van Dijk, 2005; Van Dijk and Szirmai, 2006). During the import substitution phase (1975–84), TE decreased from about 52 to 41 percent of Finnish efficiency. The subsequent period of export-oriented industrialization (1984–97) is characterized by sustained catch-up, TE reaching a level of 75 percent of the Finnish level in 1989/1990, and fluctuating around 63 percent from 1990 until 1997.

[14]In our sample more than 80 percent (1212 out of 1463) of the technical efficiency estimates pass the test for the use of bias corrected estimates (see Simar and Wilson, 2000, p. 790).

[15]For a similar use of output weights, see Timmer and Szirmai (2000). The use of gross output weights is preferable to the use of value added weights. If value added weights are used, integrated mills producing both pulp and paper receive too high weights.

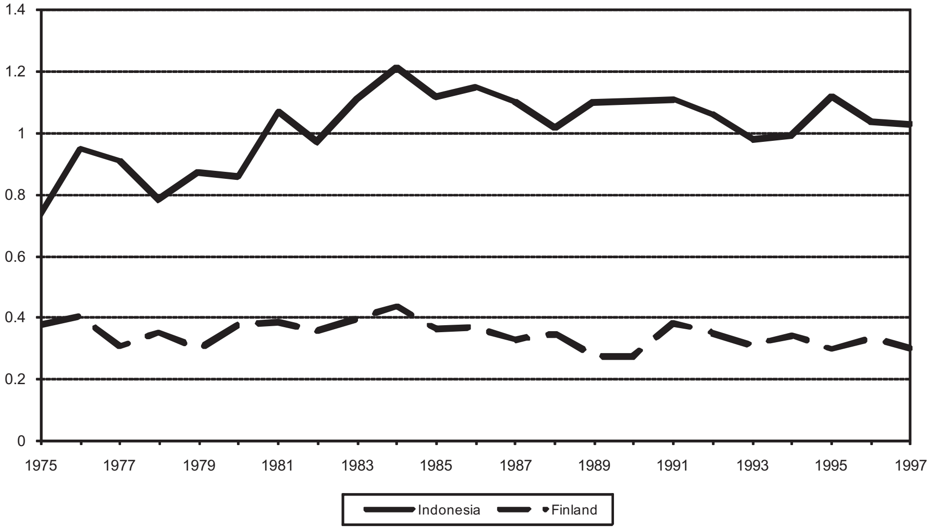


Figure 2. Coefficient of Variation of Technical Efficiency by Country, 1975–97

*Note*: Coefficient of variation defined as standard deviation/mean. Figure based on output-oriented VRS DEA with bootstrapping.

In order to investigate the micro-dynamics of catch-up, it is necessary to investigate the distribution of plant performance across the two countries and how it changes over time. A first indication is given by Figure 2, which depicts the coefficient of variation for technical efficiency by year and country. Two results are immediately evident from the figure. First, plant performance in Indonesia is much more dispersed than in Finland, as indicated by a higher absolute coefficient of variation. Next, dispersion of performance in Indonesia is increasing over time from 1975 until the mid-1980s and remains at this high level thereafter, whereas efficiency of Finnish plants is more or less fluctuating around a constant trend.

The findings in Figure 2 are supported by those of Figure 3 which depicts kernel distributions of technical efficiency by country for three years: 1975, 1984, and 1997. The changes in the distribution of performance over time are revealing. The figures show that the technical performance of Finnish paper mills is fairly evenly distributed around a modus with relatively high levels of technical efficiency. There is much more fluctuation in the technical efficiency of the Indonesian paper mills, both in time and space. For each of the three years the Kolmogorov–Smirnov test points out that the distribution of technical efficiency for Finnish plans is not equal to that for Indonesian plants.

In 1975, there are only eight Indonesian paper plants, all producing at less than 50 percent of best practice. In 1984 the distribution has become even more concentrated towards plants with a very low technical efficiency. Nonetheless, there are four plants that produce at around 60 percent of best practice. For 1997, the spread in performance has increased substantially. Besides a large group of highly inefficient plants, there are a fair number of Indonesian mills, which

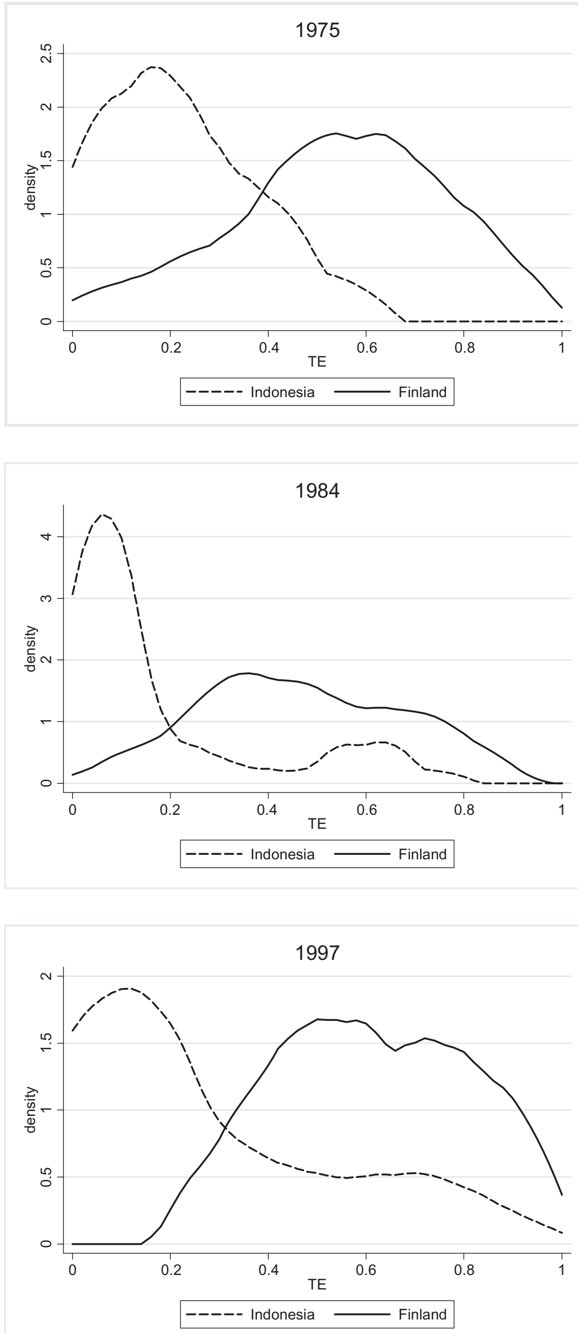


Figure 3. Technical Efficiency Kernel Density Plots by Country, 1975, 1984, 1997

*Notes*: Figure based on output-oriented VRS DEA with bootstrapping. As a consequence of the bootstrapping technique it is possible that none of the plants in the sample are operating at the frontier. The p-values for the Kolmogorov–Smirnov test for equality of distribution between Finland and Indonesia are: 0.001 (1975); 0.000 (1984); and 0.000 (1997).

produce at the high end of the distribution. Their performance is comparable to the performance of the best Finnish plants.

All in all there is an increasing divergence over time in the performance of Indonesian plants, indicating that catch-up in the export-oriented industrialization phase has been a highly localized process in which a few plants have closed the technology gap with the frontier. However, the more efficient plants are very large ones (see also Section 7). They account for a substantial proportion—around 35 percent—of gross output. Therefore, on the aggregate there is real catch-up, as evidenced by Figure 1. The emergence of a longer right-hand tail of the distribution is consistent with the increase in the coefficient of variation in Figure 2. It points to the emergence of a small number of plants which are approaching the technological frontier.

## 6. Industrial Dynamics and Catch-Up

The previous sections showed that on average Indonesian paper mills have been catching up relative to their Finnish counterparts, since 1983. What is omitted from the analysis so far is the effect of industrial dynamics on aggregate catch-up. What is the role of entry, exit, and survival for catch-up in the Indonesian paper industry as a whole? The closing of the gap relative to international best practice measured by an increase of industry-level technical efficiency in Figure 1 may be caused by two factors: (1) improvements in performance of individual mills holding mill size constant; and (2) reallocation effects caused by the expansion or contraction of surviving establishments as well as entry and exit effects (Van Biesebroeck, 2005a; Shiferaw, 2007). Foster *et al.* (2001) present and review the various approaches to decompose aggregate industry performance into within-plant and reallocation effects. We use their preferred decomposition.

Aggregate technical efficiency of the Indonesian paper industry (depicted in Figure 1) is defined as:

$$TE_t = \sum_i s_{it} te_{it}, \tag{6}$$

where $s_{it}$ is the gross output share of firm $i$ in total industry output at time $t$ and $te_{it}$ is plant-level technical efficiency for the same firm and time. The difference in aggregate technical efficiency levels at time $t$ and $t$–1 can be written as:

$$\begin{aligned} TE_t - TE_{t-1} = & \sum\nolimits_{i\in C} s_{it-1}\Delta te_{it} + \sum\nolimits_{i\in C}(te_{it-1} - TE_{t-1})\Delta s_{it} + \sum\nolimits_{i\in C}\Delta te_{it}\Delta s_{it} \\ & + \sum\nolimits_{i\in N} s_{it}(te_{it} - TE_{t-1}) - \sum\nolimits_{i\in X} s_{it-1}(te_{it-1} - TE_{t-1}) \end{aligned}. \tag{7}$$

The first three components of equation (7) make up the contribution of continuing plants ($C$), and the other two represent entry ($N$) and exit ($X$) effects, respectively. The five terms represent: (1) a within-plant component based on plant-level efficiency changes, weighted by initial gross output shares; (2) a between-plant effect—a change in gross output shares weighted by the deviation of initial plant efficiency from the initial industry average; (3) a cross (or covariance) term—a sum of plant efficiency growth times change in gross output share; (4) an

TABLE 2

Decomposition of Technical Efficiency by Subperiod

| | Technical Efficiency Growth (annual) | Percentage of Technical Efficiency Growth Explained by:* | | | | | |
|---|---|---|---|---|---|---|---|
| | | Within-Plant Effect | Between-Plant Effect | Cross-Plant Effect | Entry Effect | Exit Effect | Total Effect |
| 1975–97 | 2% | –93 | 18 | 89 | 70 | 17 | 100 |
| 1975–84 | –3.6% | –25 | 43 | 29 | –147 | 0 | 100 |
| 1984–97 | 5.8% | 20 | –8 | 61 | 26 | 1.7 | 100 |

*Notes*: Percentages may not add up due to rounding; number of plants is 8 (1975), 31 (1984), and 48 (1997).

*Positive values in this table indicate improvements in technical efficiency; negative values indicate deterioration in technical efficiency. In row 2, where efficiency growth is negative, 100 percent refers to the 3.6% annual decline in technical efficiency.

*Source*: See Figure 1 and data sources discussed in Section 3.

entry effect, composed off end-of-year plant-share weighted by the difference in technical efficiency of the entering plant and initial industry efficiency; and (5) an exit effect—an initial-share-weighted sum of the deviation of initial technical efficiency of exiting plants from initial industry efficiency. The between-plant effect and the terms for entry and exit involve deviations of plant-level technical efficiency from industry-level performance in the initial period. This means that a continuing plant with increasing output share makes a positive contribution to aggregate technical efficiency only if it has a higher initial technical efficiency than the industry average. Similarly, entering (exiting) plants contribute positively only if they have a higher (lower) technical efficiency than the initial industry average. Dividing both sides of equation (7) by $TE_0$ gives the contribution of the five components to aggregate industry technical efficiency growth.

Table 2 presents the decomposition results for various periods. The first column gives the annual average growth, followed by the contribution of within-plant, between-plant, cross-plant, entry, and exit effects. The results provide a breakdown of the average changes in technical efficiency of Indonesian plants relative to the frontier depicted in Figure 1. For the entire period technical efficiency increased by 2 percent per year on average, indicating a modest degree of catch-up. However, given the strong fluctuations in technical efficiency, it is useful to look at the two industrial policy periods characterizing the industry, the import-substitution period and the export-orientation period.

The results per sub-period differ dramatically. During the import substitution period (1975–84), the highly protected paper industry was falling behind at a rate of 3.6 percent per year. This was caused both by deteriorating performance of existing plants, denoted by a within plant effect of –25 percent, and the entry of plants with below average performance, measured by an entry effect of no less than –147 percent. There are no exit effects because all plants stayed in business. Aggregate efficiency decline would have been much greater if inefficient plants had not lost market share to plants with higher and improving technical performance, indicated by a positive between-plant effect of 43 percent and a positive cross-plant effect of 29 percent. The decomposition results are in line with the characterization of the import substitution phase (Hill, 2000). High tariffs and limited domestic competition provided no incentives for efficient production, or for the entry of more efficient modern plants using best-practice technology.[16] New plants are highly inefficient.

During export-oriented industrialization (1984–97), aggregate technical efficiency grew at a rapid pace of 5.8 percent on average. The table illustrates that catch-up was driven by three factors. Existing plants were improving their efficiency (a within effect of 20 percent), new, more efficient plants were entering the market (an entry effect of 26 percent), and plants with increasing productivity were gaining output shares at the expense of plants with decreasing productivity (a cross-plant effect of 61 percent). The dynamic cross-plant effect contributed most to catch-up. The between effect is negative (–8 percent). Output shifted to plants which had lower than average initial efficiency. This implies that some of the negative incentives of the import substitution period were still in place in the export-oriented period. However, ultimately this was compensated for by the fact that the plants that expanded their shares experienced substantial efficiency growth. In sum, this implies that the new export-oriented policy environment was conducive to a shift from less dynamic to more dynamic firms, to the entry of new more efficient firms, and to the improvement of the performance of incumbent firms. Exit hardly ever occurred in Indonesian papermaking, and therefore exit effects were negligible.

## 7. The Determinants of Technical Efficiency

The analyses in the previous sections showed that plant performance in the Indonesian industry is highly dispersed. Only a small group of plants have matched Finnish technical efficiency levels, while a large number of mills have stayed behind. What has not been addressed so far is why some plants have achieved (near) best-practice performance and others have not. In this section we try to answer this question by exploring the influence of plant characteristics on technical efficiency.

The Indonesian paper LMD contains some additional information on plant characteristics for the period 1989–97. As similar information is not available for Finnish establishments, we only regress the efficiency scores for Indonesian mills on a number of additional variables to examine the traits of catching up plants.

Besides the commonly used standard variables for size (SIZE)—measured by gross value of output (in billon rupiahs)—and age (AGE), we introduce two dummy variables for ownership: conglomerates (CON) and state-owned plants (PUB). The control group is formed by the independently operating establishments. Many manufacturing sectors in Indonesia are dominated by a number of very large internationally operating business conglomerates (Hill, 2000) and this is also the case for the paper industry (Van Dijk and Bell, 2007). Subsidiaries of these companies are expected to operate close to the frontier because of their high absorptive capacity caused by access to R&D facilities, finance, superior production technology, and advanced engineering and management know-how.

[16]An alternative interpretation of this period would be that technological changes require learning and that returns on investment only turn up with some delay. We find the interpretation based on lack of incentives more in line with the literature on Indonesian industrialization.

Our model also includes a measure for trade exposure by including a dummy variable for export orientation. In the literature trade has been identified as an important conduit for international knowledge spillovers and technological learning (Pack and Saggi, 1997). This suggests a positive correlation between export orientation and firm performance.

The literature that investigates the relationship between firm performance and export orientation has found mixed evidence for the learning-by-exporting hypothesis. Overall, exporters are more productive than non-exporters, even after controlling for observed plant heterogeneity. However, the empirical evidence points out that this positive relationship is explained by the fact that more productive firms self-select into export markets (Wagner, 2007). Nonetheless, some studies do confirm that learning-by-exporting takes place (e.g. Van Biesebroeck, 2005b), but the evidence is less conclusive: exporting does not necessarily lead to higher productivity.

In our analysis we only investigate the learning-by-exporting hypothesis. In line with other studies we include a lagged dummy for exporting plants ($EXP_{t-1}$) because we expect that learning is not instantaneous.

Finally, we add a number of dummies to control for integrated mills (INT), product mix (board (BOARD), newspaper (NEWS), tissue (TISS) and special paper (SPEC); the control group is printing and writing paper) and time (not reproduced in Table 3 to save space).

The dependent variable Technical Efficiency (TE) is a fractional variable bounded between zero and one. Therefore using it directly in ordinary least squares estimation would introduce a bias. To solve for the boundary problem we apply the logistic transformation ($\ln(TE/(1-TE))$) to make technical efficiency continuous (Ramanathan, 1989).

Table 3 presents three different regression models: a standard ordinary least squares (OLS) model, a random (RAN) effects model, and a generalized method of moments (GMM) model.

The OLS model is included for reference only as it does not take into account the panel nature of our sample and the endogeneity of the export variable. Nonetheless, it gives a first impression of the relationship between the independent variable and the regressors. The model points out that SIZE is positively and significantly related to technical efficiency, which either indicates that returns to size are significant or that efficient firms have grown more than inefficient ones. The positive relationship between size and efficiency is a common result, which has been found for both industrialized and developing countries (Caves, 1992; Lundvall and Battese, 2000). The model also shows that conglomerate firms are more efficient. This finding is in line with our expectations that paper mills which are part of a large business group enjoy certain advantages not available to independently operating establishments, resulting in higher efficiency. On average, public plants are not more or less efficient than independently operating establishments. We also find the common result that exporting is associated with better performance. We do not find any significant correlation for AGE and PUB.

The random effects model explicitly takes into account the panel nature of our data. Similar to other studies, we add the lagged dependent variable ($TE_{t-1}$) to model dynamics and reduce potential serial correlation of the residual. The

TABLE 3

Regression of Technical Efficiency (1989–97)

| | OLS | RAN | GMM |
|---|---|---|---|
| Constant | –2.640*** | –0.990*** | –1.854*** |
| | (0.291) | (0.311) | (0.655) |
| $TE_{t-1}$ | – | 0.623*** | 0.336** |
| | | (0.055) | (0.150) |
| AGE | 0.003 | 0.001 | –0.015 |
| | (0.008) | (0.007) | (0.014) |
| SIZE | 0.000*** | 0.000*** | 0.000 |
| | (0.000) | (0.000) | (0.000) |
| $EXP_{t-1}$ | 0.910*** | 0.375** | 2.489*** |
| | (0.174) | (0.159) | (0.872) |
| PUB | 0.558 | 0.436 | 0.687 |
| | (0.348) | (0.306) | (0.452) |
| CON | 0.783*** | 0.236 | 0.021 |
| | (0.275) | (0.216) | (0.526) |
| INT | –0.351* | –0.356** | –0.919** |
| | (0.195) | (0.151) | (0.394) |
| BOARD | –0.204 | –0.101 | –0.660 |
| | (0.198) | (0.179) | (0.441) |
| NEWS | –0.186 | –0.369 | –0.674 |
| | (0.390) | (0.422) | (0.420) |
| TISS | 2.180*** | 0.795** | 2.070** |
| | (0.398) | (0.318) | (0.903) |
| SPEC | 2.458*** | 1.061*** | 1.134* |
| | (0.273) | (0.295) | (0.611) |
| N | 341 | 341 | 341 |
| $R^2$ | 0.437 | 0.671 | – |
| F (OLS)/Wald (RAN and GMM) | 0.000*** | 0.000*** | 0.000*** |
| A–B test for AR(2) in first differences | – | – | 0.293 |
| Sargan | – | – | 0.128 |
| Hansen | – | – | 0.095* |

*Notes*: The dependent variable (TE) is the logistic transformation of technical efficiency based on output-oriented VRS DEA with bootstrapping; robust standard errors in parentheses for OLS and RAN; Windmeijer finite sample corrected standard errors for GMM; *significant at 10% level; **significant at 5% level; ***significant at 1% level; all regressions include control dummies for year (not depicted); p-values presented for all tests.

For GMM, the instrument set for the levels equation consists of a constant, AGE, PUB, CON, dummy variables for integrated plants, product mix and time, and first differences for $TE_{t-1}$, $EXP_{t-1}$ and $SIZE_{t-1}$. The instrument set for the differenced equation consists of $TE_{t-2}$, $EXP_{t-2}$, $SIZE_{t-2}$.

findings are very similar to the OLS but we no longer find a significant positive effect for conglomerate ownership.

Finally, we use the System GMM (GMM-SYS) estimator developed by Blundell and Bond (1998) that controls for endogeneity in a panel data setting. More specifically, for endogenous variables it uses twice lagged levels of the variable as instruments for contemporaneous differences and lagged differences as instruments for contemporaneous levels. The model also allows the inclusion of exogenous variables in a standard instrumental variable estimation. All equations are estimated jointly as a system.[17] Our model resembles that of Bigsten *et al.* (2004)

[17]The GMM model is estimated by using xtabond2 in Stata, applying the “collapse” option to limit the number of instruments.

and Van Biesebroeck (2005b), by assuming that TE, EXP, and SIZE are endogenous, while AGE, PUB, CON, and the control dummies for integrated mills, product mix, and time are treated as exogenous (see notes to Table 3).

Again, we find that $EXP_{t-1}$ is significantly and positively related to technical efficiency, corroborating the learning-by-exporting hypothesis. Since the dependent variable in our model has been transformed, the estimated coefficients are difficult to interpret without modification. Using Greene (2008), we find that the marginal effect of $EXP_{t-1}$ on TE is 0.27, which means that, on average, exporting has a considerable effect on technical efficiency.[18] The main difference is that SIZE is no longer significant. This effect might be absorbed by the export variable as the large plants tend to produce for the foreign market. The instrument set passes the Arellano–Bond (A–B) test for AR(2) in first differences, the Sargan test, and the Hansen test, all at the 5 percent level.

Overall, our findings strongly suggest that that learning-by-exporting results in higher technical efficiency in line with the literature on learning by exporting (e.g. Pack and Saggi, 1997; An and Iyigun, 2004). In addition we find that catch-up plants are characterized by large size and conglomerate ownership, although these results are less conclusive.

## 8. Conclusions

The aim of this paper has been to investigate the micro-dynamics of catch-up. It forms a bridge between catch-up analysis, which traditionally has been conducted at the industry or national level, and micro-data analysis, for which long-run international comparison of performance is a newly emerging field of research. For this purpose we have analyzed the performance of the Indonesian paper manufacturing plants in a comparison with plants in Finland, the world technological leader in paper manufacturing. We used a combined Indonesian–Finnish longitudinal micro-dataset for the period 1975–97 to estimate plant-level technical efficiency, to analyze the industrial dynamics underlying the catching-up process, and to investigate the typical characteristics of firms which have managed to catch up. Considerable effort has been made to ensure inputs and outputs are comparable across countries.

In this paper we have looked at the micro-dynamics of catch-up, focusing on changes in *relative* performance vis-à-vis the technological frontier from the perspective of a developing country. We have not investigated the movement of the frontier itself or differences in total factor productivity growth between Finland and Indonesia. An interesting avenue for future research would be to follow Färe *et al*. (1994) and Los and Timmer (2005), who decompose productivity growth in technical change and technical efficiency change components.

During the period of import-substituting industrialization (1975–84), we found that the Indonesian paper industry was falling behind the frontier in aggregate terms. The export oriented industrialization phase (1984–97) was character-

[18]To compute the marginal effect we used Greene (2008, pp. 667–77), taking into account that EXP is a binary variable. Corresponding marginal effects for OLS and RAN are 0.11 and 0.04, respectively. Individual marginal effects are computed for each observation and then averaged.

ized by aggregate catch-up in terms of technical efficiency. Closer investigation of the underlying plant-level data discloses that these aggregate figures only tell part of the story. Establishment performance in Indonesia is much more dispersed than in Finland and the degree of dispersion has increased over time. This points to pervasive market imperfections. Most inefficient firms stay in the market and there is little diffusion of best practice.

Decomposition analysis pointed out that aggregate catch-up after 1984 was primarily driven by the expansion of the incumbent mills which were improving their performance over time. The entry of new modern plants and efficiency improvements of incumbent plants also contributed positively to catch-up, but to a lesser extent.

Finally, we found that firms that are producing close to the technological frontier are characterized by learning-by-exporting, and, to a lesser extent, large size and conglomerate ownership.

An important insight deriving from this research is that establishment performance in developing countries is erratic and much more dispersed than in advanced economies. This is in line with the literature on dualistic market structures in developing countries (e.g. Fafchamps, 1994; Tybout, 2000). This means that aggregate analysis of performance (e.g. Timmer (2000) on catch-up of Asian countries) could result in wrong policy conclusions. On the basis of the aggregate figures for technical efficiency one might conclude that the Indonesian paper industry represents a successful case of technical change and catch-up. However, in reality catch-up of the Indonesian paper industry relative to the global frontier has been a highly localized process in which only a few establishments have achieved near best-practice performance. Most of the other plants stayed in business while operating far from the technological frontier.

One of the challenges to industrial policy is how to contribute to broader-based industry-wide upgrading. Our results indicate that exporting has been an important channel for technological learning, resulting in near frontier performance and catch-up. This is in line with detailed industry-level case studies for Korea and Taiwan (Wade, 1990; Kim, 1997) which concluded that access to foreign markets resulted in profound technological upgrading and capacity building. However, in contrast to the Indonesian paper industry, catch-up in Korea and Taiwan was industry-wide, not localized. The main reason for this was a combination of trade and industrial policies, including limited import protection, fixed export targets and export assistance, reverse engineering, technology licensing, and R&D support. For Indonesia there are lessons to be learned in the field of technology-related industrial policies.

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