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Abstract
In this study we analyze the micro-dynamics of catch up in Indonesian paper manufacturing using a two-country plant-level data set for the period 1975-1997. The Indonesian paper industry is selected as a case-study because it experienced spectacular investment and growth. It became one of the world's largest exporters and producers of paper in the world. We apply Data Envelopment Analysis (DEA) to compare the technical efficiency of Indonesian paper mills with that of Finnish mills, which are considered to be the world technological leaders in paper making. We address three questions: What is the distribution of Indonesian plant performance vis-à-vis the technological frontier? What is the role of entry, exit and survival for catch up? What are the characteristics of 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

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1 Introduction

Catch up commonly refers to the process of reducing the technology gap between technologically advanced (rich) and technologically backward (poor) countries. So far most research on this topic has been conducted at the country or industry level. Catch up analysis focuses on the role of variables such as capital intensity, human capital intensity, structural change, R&D investment, initial level of per capital GDP and intersectoral or international technology spillovers. However, due to the high level of aggregation much of growth and catch up remains unexplained. Also, 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 gap relative to international best practice? Or is catch up driven by a few large firms operating closer to the technological frontier, while most 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 making international comparisons of plant-level performance based on micro data. So far only a handful of studies have dealt with this issue. Pack (1987) is one of the first studies looking explicitly at the technology gap between establishments in industrialized and developing countries. It provides measurements of total factor productivity of Kenyan and Philippine textile mills relative to mills in the UK. Probably the most comprehensive study on international comparisons of plant-level performance has been commissioned by the McKinsey Global Institute (Baily and Gersbach, 1995; Baily and Solow, 2001). It covers a relatively large number of countries and industries, even including non-manufacturing sectors such as retailing, telecom and construction. Another research project dealing with international comparisons of productivity at the micro-level is the match-plant study, initiated by the National Productivity Institute (e.g. Mason *et al.*, 1994). A general shortcoming of the existing studies is their limited coverage. Most studies are limited to a few firms and results might therefore not be statistically representative. In addition, often only a single year is covered so that little can be inferred about catch up, a phenomenon that is dynamic per definition.

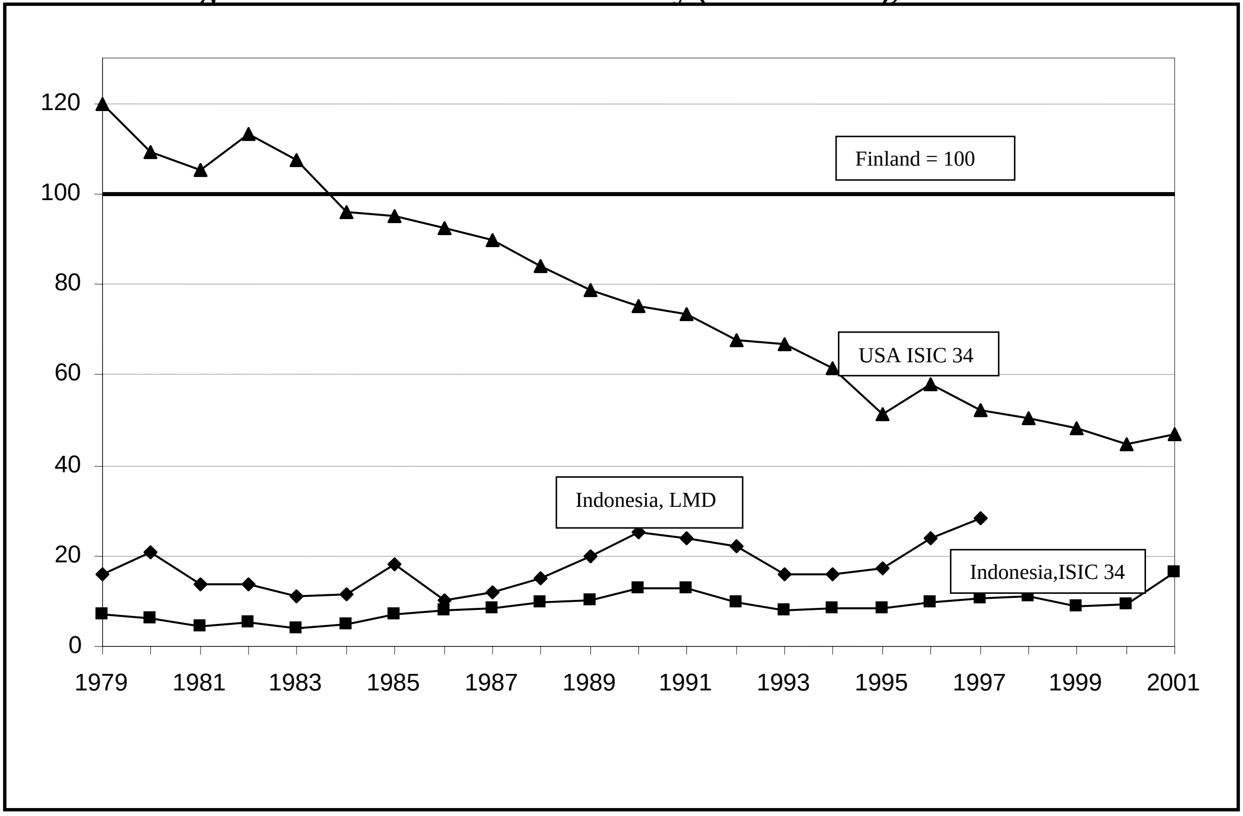
Recently an impressive comprehensive research project has been executed comparing manufacturing census micro-data across 24 industrialized, transition and developing countries (Bartelsman *et al.*, 2004; Bartelsman *et al.*, 2005). This project allows for comparisons of turnover rates, entry rates, exit rates, firm size, firm survival and decompositions of productivity across countries. However, in contrast with our study, even this project does not provide direct international comparisons of performance at the establishment level.

The present paper provides a first attempt to study catch up at the micro level, taking the Indonesian paper industry as case study. We base our analysis on an internationally standardized longitudinal micro-level data set (LMD) based on Indonesian and Finish manufacturing census micro data for the period 1975-1997. In order to measure the technological distance of Indonesian paper mills to the international frontier, we use data envelopment analysis (DEA), a frontier analysis technique. We compare the technical efficiency of Indonesian mills with those of Finnish mills, which are generally considered to represent world best practice in paper manufacturing (Ojainmaa, 1994; Diesen, 2000).

We address the following questions: What is the distribution of Indonesian plant performance vis-à-vis the technological frontier? What is the contribution of entry, exit and survival to aggregate catch up? How do catching-up plants differ from other plants? Answers to these questions are of interest for the formulation of relevant industrial policies and for growth analysis in general.

The Indonesian paper industry provides an interesting case study for catch up. Before the Asian crisis of 1997, Indonesia was perceived to be a second-tier Asian tiger (World Bank, 1993). Growth in GDP per capita averaged 3.6 per cent per year for the period 1960-1998. 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 an important sector in the Indonesian industrialization drive. With output growth of more than 15 per cent per year between 1960 and 2000, it has been among the fastest growing manufacturing sectors in the country. Responding to industrial policy incentives, paper companies invested in the latest equipment and Indonesia emerged as one of the world's largest producers and exporters of paper (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.

Figure 1: Relative Labor Productivity (Finland=100), 1979-2001



Sources: Indonesia/USA (ISIC 34) from Szirmai (1994), updated with back cast data from *Statistik Industri* and US national accounts. USA/Finland (ISIC 34) from O'Mahoney and Van Ark (2003, CD-Rom). Indonesia/Finland (LMD), see section 3.
Note: Indonesia/Finland (ISIC 34) calculated indirectly via the USA.

Figure 1 gives a first indication of the performance of the Indonesian pulp and paper sector (ISIC, rev2: 34) relative to the world productivity leader Finland. In real terms Indonesian labor productivity has increased from 7 to 16 per cent of the Finnish level between 1979 and 2001. The USA was overtaken by Finland in 1984. In 2001 its productivity stood at 47 per cent of the Finnish level. Indonesian catch up, in particular relative to the USA, has been substantial.[1] Note that catch up is achieved in a context where absolute productivity in the USA and Finland is increasing.

The figure also presents a second estimate of relative Indonesian labor productivity in paper manufacturing on the basis of the longitudinal micro-level data set (LMD). In contrast to the more aggregate ISIC based comparison, this comparison excludes a variety of small firms involved in labor intensive activities such as folding boxes and only focuses on paper making proper. As a consequence the overall labor productivity gap becomes smaller and catch up is more pronounced, in particular during the end of the 1990s. This illustrates that international comparisons based on micro-level data may result in different outcomes than the commonly used aggregate industry-level information.

The structure of this paper is as follows. Section 2 summarizes the theoretical framework. In particular it surveys two streams of research that are relevant for our study: analysis of catch up at the macro-level and industrial dynamics in developing countries. In Sections 3, we describe our dataset. Methods are discussed in section 4. In sections 5, 6 and 7 we analyze the catch up of the Indonesian pulp and paper industry. The analysis consists of three steps: (1) technical efficiency estimation, (2) decomposition analysis and (3) investigation of the characteristics of catch-up mills. In the final section we summaries 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. Differences in absorptive capacity in developing countries determine which countries experience catch up, and which tend to fall behind even further. Absorptive capacity itself is determined by the size of the technology gap between leaders and followers. If the size of the gap becomes too large, absorptive capacity will tend to be weaker and a country will not be able to profit from the advantages of backwardness.

[1] The estimates are rough. The US Finland comparison is based on GDP per hour, the Indonesia- US comparison on GDP per person. Also, the UVRs for Indonesia/USA are from 1987, while the USA/Finland UVRs are from 1997.

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

There is a large empirical literature investigating catch up (for overviews see Fagerberg, 1994 and Temple, 1999). With respect to this research two empirical approaches seem to be especially important.

One line 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 (Szirmai and Pilat, 1990; Dollar and Wolff, 1993; Maddison, 2002). 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) is increasingly used to measure international technology gaps between countries (e.g. Färe *et al.*, 1994; Kneller and Stevens, 2002; Los and Timmer, 2005). An advantage of this technique is that the technological frontier is determined on the basis of the combined data of the countries being compared, rather than by comparison with a single country with the highest average productivity.

A second approach to the study of catch up is concerned with identifying factors which hamper or promote catch up. Some elements which are found to contribute to the absorptive capacity of countries are: 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; Aw *et al.*, 2003, van Biesebroeck, 2005; Frazer, 2005; Söderbom et al. 2006). 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 a high number of small traditional firms, producing similar goods side by side (e.g. Nelson, 1968; Blomström and Wolff, 1997; Sleuwaegen and Goedhuys, 2002). 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 underdevelopment of the economy (isolated markets, 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).

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 continues to lag far behind the technology frontier. This limits the extent to which a developing economy 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 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 (2005) finds 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. Tybout notes that the available studies "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. Moreover, 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 histograms and kernel density plots, provide suitable information on the spread of a variable. In this study we try to address a number of these problems.

Thus, the present work on industrial dynamics in developing countries has so far not been able to address the micro-economic issues in catch up, primarily because of the absence of comparative micro datasets. Furthermore, apart from the few studies mentioned above, most empirical research lacks an international perspective. Therefore catch up cannot be assessed.

In this paper we try to combine elements of the existing macro- and micro-research discussed above. In order to make output in paper manufacturing comparable in Finland and Indonesia, we have constructed sector specific conversion factors, which are usually used in more aggregate studies on international comparisons of productivity, and we have made a considerable effort to standardize definitions of input and output. This allows us to pool Indonesian and Finnish micro data in a single comparative dataset. Catch up and the distance to the international technological frontier are measured by means of frontier analysis.

Like national micro-studies, we base our analysis on manufacturing census data of the economies being compared. Besides good coverage, the advantage of using this type of data is that they establish a strong link with more aggregate studies on the comparison of international performance, which are often based on the same manufacturing census data. Finally, we try to identify the determinants of absorptive capacity at the micro-level.

3 Data

The main data source for the Indonesian paper LMD is 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). In this study, we use the digital version of the dataset from 1975 to 1997. Data from the SI was 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 1975-1997. A more detailed description of the dataset is provided in Van Dijk and Szirmai (2006b).

The data for Finnish paper mills derive from the longitudinal data on plants in Finnish manufacturing constructed by Statistics Finland. It is based on annual manufacturing surveys, which have been conducted in Finland since 1974.[3] Next, the data was 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.[4] In this respect, two issues are of particular importance to the analysis here: (1) standardization of definitions and coverage of input and output, and (2) expressing values in a common currency. Both are discussed next.

Before the Indonesian and Finnish data can be compared, they need to be standardized. There are not yet any clear international guidelines for industrial censuses. Therefore, each country has a tendency to use its own definitions, concepts and classifications. Fortunately both the Finnish and Indonesian surveys are based on establishments (as opposed to firms) and can therefore be directly compared. Another possible source of bias is differences in coverage. For example, the Indonesian census excludes establishments with less than 20 employees, whereas after 1995 the Finnish census includes plants with less than 20 persons. However, paper manufacturing is a scale and capital intensive industry. Therefore in this case, none of the plants in our population are below the size threshold.

In total the Indonesian paper LMD contains information about 53 plants, which on average represent 99 per cent of installed capacity. The Finnish LMD contains information about 31 Finnish paper mills, which represent some 76 per cent of total installed paper capacity in Finland.[5]

For international comparisons of productivity, it is important that inputs and outputs are consistently defined across countries. In the statistical analysis below we consider only two inputs, capital and labor, and one output, gross value added. In most plant-level productivity studies, gross value of output is used as output measure rather than value added. Gross value of output is the preferable concept in micro-studies because shifts in the use of intermediates relative to capital and labor over time might create a bias in value added based estimates of productivity (Baily, 1986). Regrettably, due to problems with the survey methodology, reliable data on intermediate inputs are unavailable for Indonesia before 1990 (Jammal,

[3] See Appendix 2 in Maliranta (2003) for a more elaborate description of the longitudinal data on plants in Finnish manufacturing.
[4] See Van Ark (1996) for an overview of measurement issues with respect to international comparisons of productivity.
[5] Secondary data of Indonesian and Finnish paper mills was linked with the LMD through address information. Due to missing or conflicting data the matching was less than 100 per cent.

1993). For this reason, we have chosen to exclude intermediates from the analysis and use value added as the output concept and labor and capital as input concepts.

In their manufacturing surveys both Finland and Indonesia use the national accounts concept of value added, which excludes non-industrial services. Thus, value added across countries can be compared without problems.

The standardization of labor and capital also provided no problem. Both in Finland and in Indonesia, labor input is defined as the number of persons engaged, including self-employed and unpaid family workers. In both countries, capital is approximated by total capacity installed for paper production. Given the lack of internationally comparable information on asset lifetimes, retirement patterns and investment data, this measure based on *core machinery* is favored above 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 establishment level. In order to compare technical efficiency in Finland and Indonesia, we have calculated unit value ratios (UVRs) for the paper industry, using the standard methodology for industry of origin comparisons (Szirmai and Pilat, 1990; Timmer, 2000). To make value added comparable between Indonesia and Finland, it is first expressed in constant 1995 prices using country specific sectoral deflators. Subsequently the Fisher average UVR for 1995 is applied to convert Indonesian values into Markkas (see Annex).

Finally, the data for Indonesia and Finland have been pooled to create a micro-level database suitable for comparative productivity analysis. '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. Measured by capacity, only 1 percent of our Indonesian sample consists of integrated mills in 1997. For the Finnish mills the share is 43 per cent.

A caveat should be mentioned with regard to comparative micro analysis. Due to the lack of plant-specific output prices, quantity and price effects are to a certain degree entangled when we apply aggregate UVRs to individual firm data. (Tybout, 2000; Bartelsman and Doms, 2000; Katayama *et al.*, 2003). This implies that price-cost mark-ups of monopolists might be mistaken for higher firm productivity. Such bias will be more serious in developing countries where markets are more likely to be distorted. A way of circumventing this problem would be to take production in tonnes of paper as output measure. Unfortunately this data was not available for Finland. Furthermore, such an output measure would also require the use of intermediates on the input side, which are not available.[6]

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

[6] This problem does not exist at the level of aggregate UVRs. If monopoly pricing in Indonesia results in higher average prices in rupiahs, the average conversion factor relative to Finland will result in lower markka values.

Table 1: Summary Statistics, 1975 and 1997

Variable		Indonesia	Finland	Pooled
		1975		
Value added (000 95 markka)	Mean	16.93	100.13	81.64
	Std. dev	14.32	63.45	66.16
Labor (persons engaged.)	Mean	426.50	612.21	570.94
	Std. dev	234.30	438.39	406.66
Capacity (000 tonnes)	Mean	20.03	271.17	215.36
	Std. dev	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
	Std. dev	556.76	222.36	456.46
Labor (persons engaged)	Mean	1,262.77	502.81	964.56
	Std. dev	2,214.76	289.65	1,768.45
Capacity (000 tons)	Mean	189.44	452.58	292.70
	Std. dev	348.76	335.85	365.23
Number of observations		31	48	79
		1975-1997		
Value added(000 95 markka)	Mean	76.46	229.94	150.11
	Std. dev	264.95	198.83	247.65
Labor (persons engaged)	Mean	708.10	541.37	628.10
	Std. dev	1166.09	351.93	879.31
Capacity (000 tons)	Mean	72.84	342.51	202.24
	Std. dev	152.25	272.76	256.68
Number of observations		761	702	1463

Sources: Indonesia: Statistik Industri, digital version, 1975-1997 and APKI; Finland: Annual Manufacturing Surveys, Philips International Paper Directory and Philips Paper Trade Directory.

Note: The pooled total of 1,463 observations 1975-1997 refers 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.

4 Data Envelopment Analysis

We use Data Envelopment Analysis (DEA) to measure the performance of Indonesian paper mills relative to international best practice, approximated primarily by Finnish paper factories.[7] In this type of analysis establishments are defined as technically efficient if they achieve the highest output per any given combination of inputs, compared to other establishments.[8] All efficient establishments together make up the best-practice production function or technology frontier, which reflects the outer boundary of all possible 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. 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

[7] See Coelli *et al.* (1998) for an extensive discussion of DEA and efficiency measurement in general.
[8] 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. Under the assumption of constant returns to scale both measures are identical.

plants have an efficiency rating of 100 per cent and establishments below the frontier have an efficiency rating of less than 100 per cent.

We assume that output (value added) is produced with only two inputs (capital and labor) and constant returns to scale. The technical efficiency a plant *i* is computed relative to a meta frontier based on our pooled sample of Finnish and Indonesian plants. Under our assumption that 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:

$$\max_{\lambda,\theta} \quad \theta_i \tag{1}$$

$$\text{subject to:} \quad -\theta_i \cdot y_i + \sum_{n=1}^{N} y_n \cdot \lambda_n \geq 0, \tag{2}$$

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

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

$$\lambda \geq 0. \tag{5}$$

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*). λ is a Nx1 vector of constants. The linear problem has to be solved N times, to obtain a value of θ_i for each establishment in the sample. θ_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.

The advantage of DEA relative to econometric estimation of the frontier, commonly referred to as stochastic frontier analysis, is that apart from the assumption of constant returns to scale DEA does not require any assumptions about the shape of the production function or the distribution of the inefficiencies. It also has the advantage that the efficiency scores are time-variant, something which is still difficult to capture with stochastic frontier models.[9] The assumption of constant returns to scale does not cause any problems for our analysis. Further on in this paper, we regress the efficiency scores on variables such as firm size, in order to take returns to scale into account.

Another advantage of DEA is that second-stage analysis, i.e. regressing efficiency scores upon a set of explanatory variables, is less problematic than in stochastic frontier analysis. Various authors have pointed out a second-stage analysis is only consistent with stochastic frontier analysis when it is undertaken simultaneously with the estimation of technical efficiency scores (see Coelli *et al.*, 1998, p. 207). Since the information on Finnish establishments is much more limited than that for Indonesian plants, such a requirement would severely restrict our investigation of the determinants of catch up.

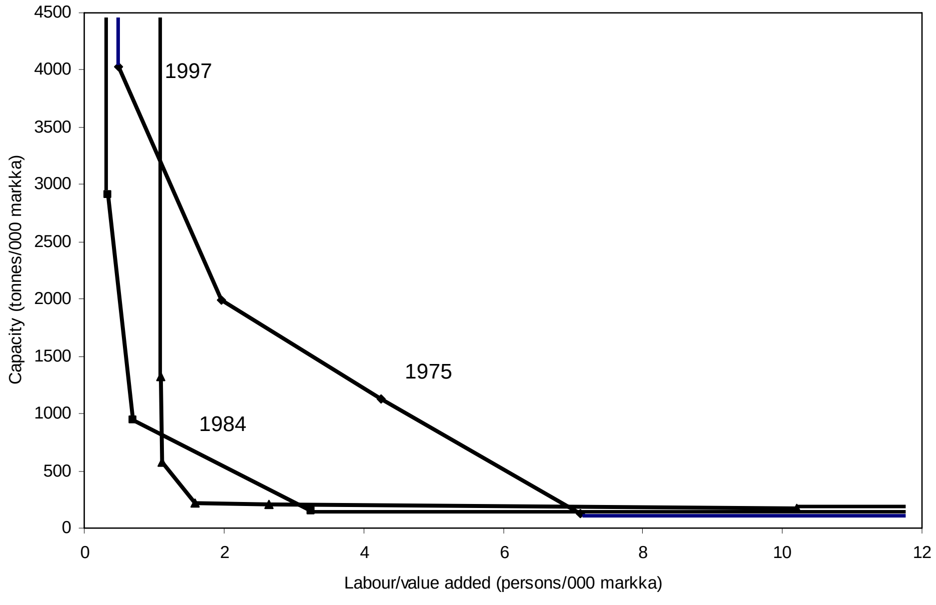
[9] See Greene (2005) for a discussion of this issue.

A disadvantage of DEA 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. Another problem of DEA is that the technical efficiency scores might be biased upwards due to sampling error (Simar and Wilson, 2000a; Simar and Wilson, 2000b). 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 would be available. The sampling bias problem is particularly severe in small samples.

The use of DEA might also have the effect that (a part of) the technical frontier may exhibit inward shifts or "regress" over time. Such a finding is not very credible from a knowledge perspective as it would involve 'forgetting' certain efficient production techniques. A more plausible interpretation is that we simply do not observe all possible production possibilities in a given year. It is likely that older labour intensive techniques are no longer in use at later points in time after 23 years, the time span of our analysis. The reason we find regress at plant level (see figure 2) is that some plants have installed new very capital intensive paper machines alongside the older machinery. Our analysis is at plant level. As such plants have upgraded the average plant performance has improved, even when older vintages of machinery are still in operation.

The problem of regress is illustrated in Figure 2, which depicts the frontier for three selected years. The figure shows that the frontier for 1997 intersects with the 1975 and 1984 frontier.

Figure 2: Best practice in Indonesia and Finland, 1975, 1984 and 1997



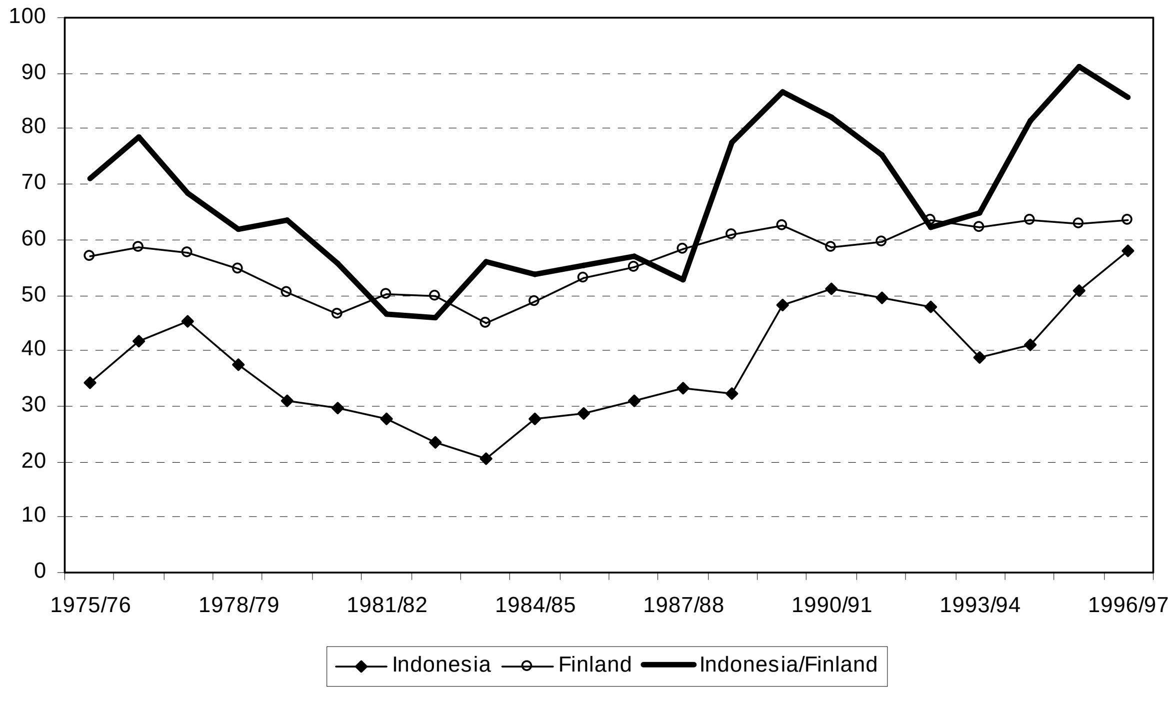
One solution to this problem, proposed by Tulkens and Van den Eeckaut (Tulkens and Vanden Eeckaut, 1995; also see Los and Timmer, 2005), is the use of intertemporal frontiers. In this way the technological frontier in a given year is based on all input-output combinations up to that year making full use of the available historical information. An important disadvantage of this solution is that measurement errors and outliers due to business cycle effects, especially in earlier periods, will continue to distort the location of the frontier in all subsequent years.

In both the temporal and the intertemporal DEA solutions, the effects of outliers will be reduced if we use bootstrapping techniques which allow us to estimate the frontier for the population rather than for the sample. We apply a recently developed methodology for bootstrapping in DEA models proposed by Simar and Wilson (2000a).[10] 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 interpret the bootstrapping estimates as representing the global technology frontier. Given the fact that the two country sample includes a great variety of plants and technologies ranging from traditional labor intensive plants in Indonesia to state-of-the-art plants in both countries, we believe this interpretation is a reasonable one.

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

In our statistical analysis, we have examined four different variants of DEA: are 1. Temporal DEA, 2. Intertemporal DEA, 3. Temporal DEA with bootstrapping and 4. Intertemporal DEA with bootstrapping. The use of intertemporal variants exaggerates the impact of outliers, which is undesirable. The advantage of intertemporal DEA is that it avoids regress of the frontier. In the main text, we only represent the results of temporal DEA with bootstrapping, our preferred variant. The other variants are reproduced in Annex 3.

Figure 3: Aggregate Industry Technical Efficiency by Country, 1975-1997



Note: Figure presents average industry-level technical efficiency of Indonesia and Finland (two-year averages), using value added figures as weights based on the temporal DEA with bootstrapping.

Figure 3 depicts aggregate industry technical efficiency for Indonesia and Finland for the period 1975-1997 (two-year averages). As mentioned, technical efficiency is calculated

[10] 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.

relative to a frontier calculated with temporal DEA and bootstrapping. Plant-level efficiencies are weighted with plant shares in value added to arrive at the average efficiencies depicted in the figure.

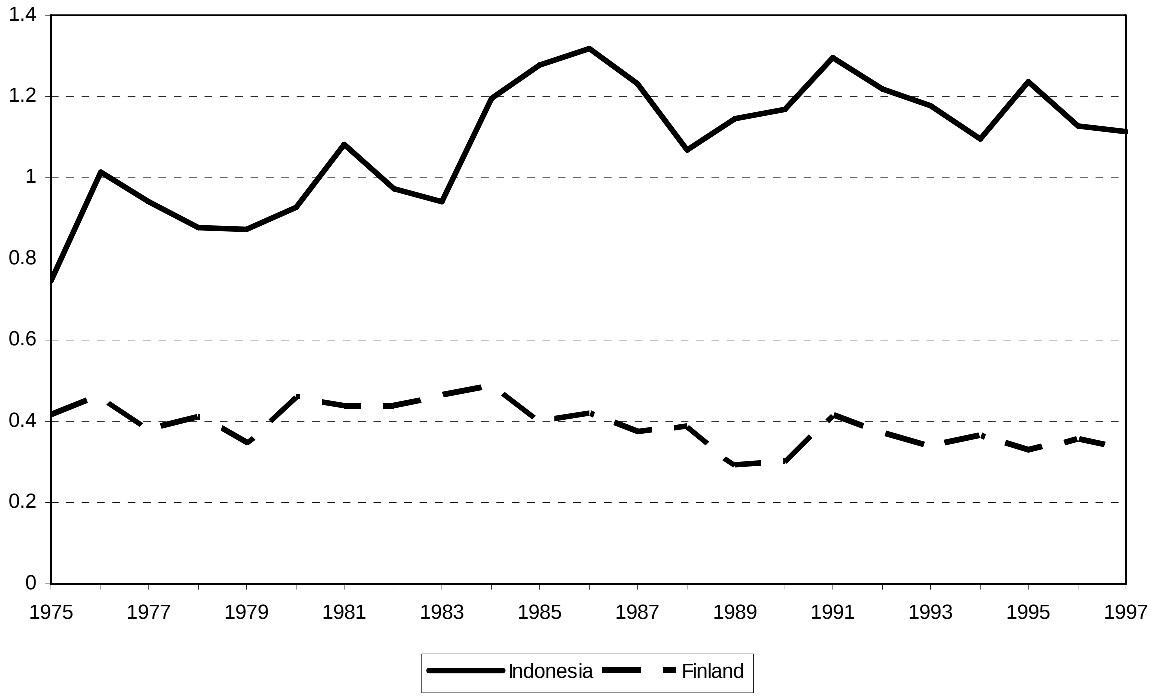
Figure 3 clearly indicates that on average Indonesian paper mills are producing at a greater distance from the frontier than their Finnish competitors. Dividing average efficiency in Indonesia by average efficiency in Finland, results in an estimate of aggregate relative performance. The relative performance corresponds closely to insights derived from qualitative information on the historical development of the Indonesian paper industry (Van Dijk, 2005; Van Dijk and Szirmai, 2006a). During the import substitution phase (1975-1984), TE decreased from about 70 to 50 per cent of Finish performance. The subsequent period of export-oriented industrialization (1984-1997) is characterized by sustained catch up, TE reaching a level of close to 90 per cent of the Finnish level in 1996/1997.

The differences between the temporal variant with bootstrapping and the other three alternatives reproduced in annex 3 turn out to be minor. The pattern of relative performance between the countries and the periodisation of relative stagnation and catch up remains the same in all variants. In the intertemporal variants, both Finland and Indonesia have somewhat lower technical efficiency than in the temporal variants. This is to be expected if one eliminates regression of the frontier. The main difference between the temporal and intertemporal variants is that in the intertemporal variants, the technical efficiency of Finland declines after 1993. As a result of this Indonesian catch up in in the last period is even more pronounced than in the temporal variants.

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 4, 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 whereas efficiency of Finnish plants is more or less fluctuating around a constant trend.

It is worth noting that relative performance in terms of technical efficiency in Figure 3, a measure which takes into account both primary production factors, capital and labor, is much higher than relative labor productivity in Figure 1. This indicates that Indonesia can operate relatively efficiently in spite of using more labor intensive techniques of production.

Figure 4: Coefficient of Variation of Technical Efficiency by Country, 1975-1997



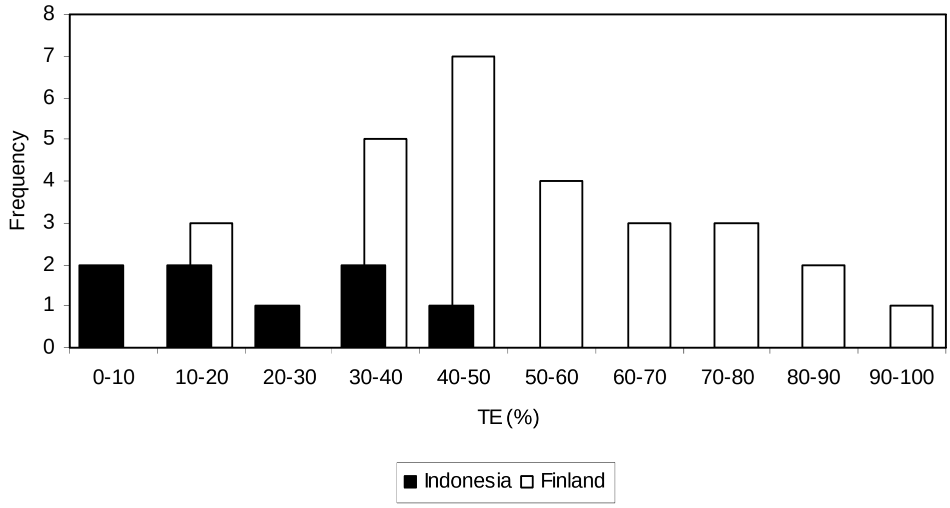
Note: Coefficient of Variation defined as standard deviation/mean. Figure based on temporal DEA with bootstrapping.

The findings in figure 4 are supported by those of figure 5 which depicts histograms of technical efficiency by country for three years: 1975, 1984 and 1997.[11]

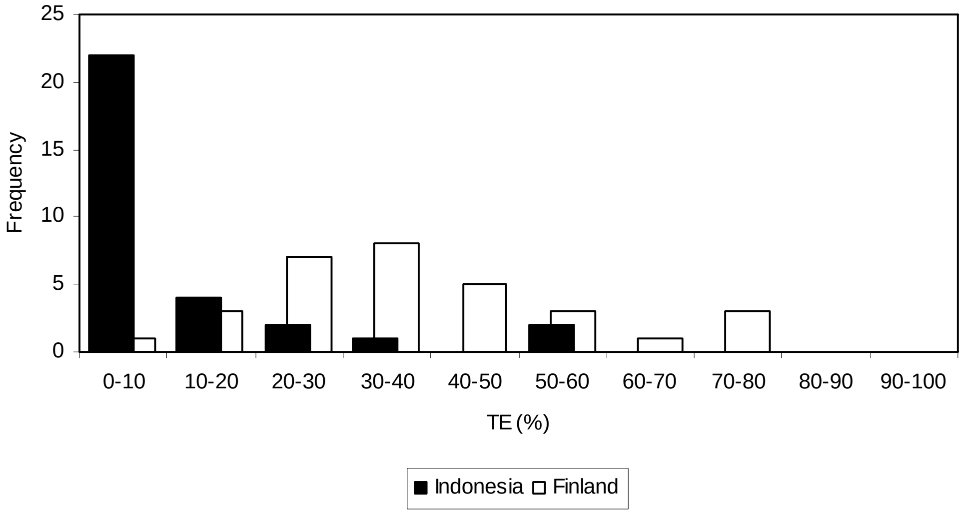
[11] The histograms are based on our preferred variant: temporal DEA with bootstrapping. Histograms for the other three variants are reproduced in Annex 3.

Figure 5: Technical Efficiency Distribution by Country

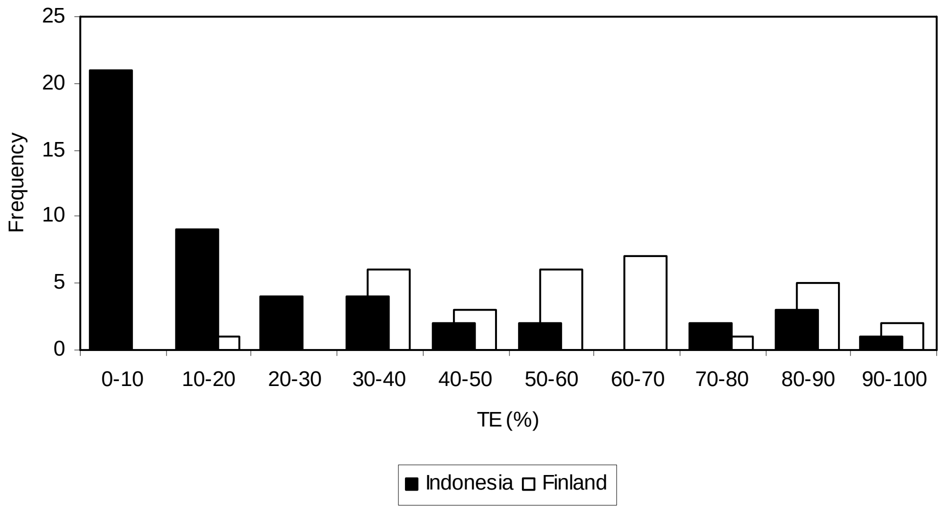
a: 1975



b: 1984



c: 1997



Note: Figure based on temporal 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 as is the case in Figure 4b.

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. In 1975, there are only eight plants, all producing at less than 50 per cent of best practice. In 1984 the distribution has become even more concentrated towards plants with a very low technical efficiency. However, for 1997, we observe a very different pattern. Besides a large group of highly inefficient plants there are a fair number of mills, which 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 (also see section 7 below). They account for a substantial proportion - around 50 per cent - of value added. Therefore, on the aggregate there is real catch up, as evidenced by figure 3.

6 Industrial Dynamics and Catch Up

The previous sections showed that on average Indonesian paper mills have been catching up relative to their Finnish peers, since 1983. What is omitted from the analysis so far is the effect of industrial dynamics on catch up. The closing of the gap relative to best practice measured by an increase of industry-level technical efficiency in figure 3 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 (Baily *et al.*, 1992). 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 3) is defined as:

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

where s_{it} is the value added 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. Then 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 effects (*X*), respectively. The five terms represent: (1) a within-plant component based on plant-level changes, weighted by initial value added shares; (2) a between-plant effect – a change in value added 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 value added share; (4) an 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 3. For the entire period catch up relative to the frontier was limited. Technical efficiency increased by three per cent per year on average. However, given the strong fluctuations in technical efficiency it is useful to look at the two industrial policy periods characterizing the industry.

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*
1975-1997	**3%**	**-81**	**-8**	**79**	**102**	**8**	**100**
1975-1984	**-3.3%**	**-183**	**-37**	**195**	**-75**	**0**	**-100**
1984-1997	**7.5%**	**-12**	**-24**	**118**	**18**	**-0.7**	**100**

Note: Percentages may not add up due to rounding;

* Positive values in this table indicate improvements in technical efficiency, negative values indicate declines. In row 2, where efficiency growth is negative, 100 per cent refers to the 3.3 per cent annual decline in technical efficiency.

Source: See figure 3 and data sources discussed in section 3.

During the import substitution period (1975-84), the paper industry was falling behind at a rate of approximately 3.3 per cent per year. This was caused both by rapidly diminishing performance of existing plants denoted by a within share of -183 per cent, and the entry of plants with below average performance, measured by an entry effect of -75 per cent. There are no exit effects because all plants stayed in business. The between effect contributed -37 per cent to productivity decline. Aggregate efficiency decline would have been much greater if plants of which performance deteriorated had not lost market share to plants with improving technical performance, indicated by the very large positive cross-plant effect of 195. The decomposition results are in line with the characterization of the import substitution phase. 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.

During export-oriented industrialization (1984-97), aggregate technical efficiency grew at a rapid pace of 7.5 per cent on average. The table illustrates that catch up was primarily driven by the expansion of establishments that were improving their efficiency, indicated by a cross-plant share of 118 per cent. Further, the entry share of 18 per cent illustrates that the start-up of new plants also contributed to catch up. It is very interesting to note that the within-plant effect was negative. This implies that if the plant shares had remained unchanged, efficiency would have declined. The between effect is also negative. Value added shifted to plants which had lower than average initial performance. However, ultimately this was compensated for by the fact that the plants that expanded their shares also experienced substantial efficiency growth. Basically, this implies that the new policy environment was conducive to a shift from less dynamic to more dynamic firms.

7 The Determinants of Catch up and 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 plant performance.

The Indonesian paper LMD contains additional information on plant characteristics for the period 1991-1997. 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) and age (AGE), we introduce two dummy variables for ownership: conglomerate (CON) and public plants (PUB). SIZE is measured by gross value of output (in billion rupiahs). 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 and this is also the case for the paper industry (Hill, 2000). 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.

Human capital has been identified as an important determinant of absorptive capacity in the literature on macro-catch up. To capture this we include a variable for the share of foreign labor in total employment (FORLAB). Given the shortage in qualified personnel, management and advanced engineering functions are often performed by foreign personnel or consultants in the Indonesian paper industry, constituting on average one per cent of paper manufacturing employees in the 1990s (Van Dijk and Bell, 2007). Foreign experts bring with them valuable knowledge and expertise and are therefore expected to be an important channel for technology transfer.

Our model also includes a measure for trade exposure by including a dummy variable for export orientation (EXPORT). In the literature trade has been identified as an important conduit for international knowledge spillovers (Pack and Saggi, 1997).

Finally we add a number of dummies to control for integrated plants (INT), product mix (board [BOARD], newspaper [NEWS] tissue [TISS] and special paper [SPEC], the control group is printing and writing paper) and year. As none of the year dummies are significant, they have not been reproduced in Table 3.

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: Regression of Technical Efficiency (1991-1997)

	(1)	(2)	(3)	(4)
Constant	-3.402	-3.124	-3.405	-3.216
	(9.20)**	(8.54)**	(9.00)**	(9.03)**
AGE	0.012	0.017	0.022	0.007
	(1.10)	(1.66)	(2.14)*	(0.69)
SIZE	0.485	0.0.599	0.586	0.484
	(4.19)**	(5.15)**	(5.08)**	(4.16)**
PUB	0.133	-0.024	0.081	0.068
	(0.30)	(0.05)	(0.18)	(0.15)
CON	0.440	0.932	0.687	0.577
	(1.42)	(3.12)**	(2.21)*	(1.91)
FORLAB	18.663	-	27.036	-
	(1.78)		(2.58)*	
EXPORT	0.866	-	-	0.952
	(3.77)**			(4.23)**
INT	-0.546	-0.277	-0.312	-0.546
	(1.95)	(0.99)	(1.12)	(1.94)
BOARD	-0.276	0.032	0.063	-0.330
	(1.06)	(0.13)	(0.25)	(1.28)
NEWS	0.035	0.495	0.110	0.281
	(0.08)	(1.16)	(0.25)	(0.67)
TISS	0.612	0.539	0.510	0.641
	(1.46)	(1.25)	(1.19)	(1.53)
SPEC	2.863	3.195	3.290	2.758
	(7.14)**	(8.07)**	(8.36)**	(6.93)**
Observations	296	296	296	296
R-squared	0.43	0.38	0.40	0.42
Adj. R-squared	0.39	0.35	0.36	0.39

Note: The independent variable is the logistic transformation of technical efficiency; Absolute values of t statistics in parentheses; * significant at 5%; ** significant at 1%; all regressions also include control dummies for year (not depicted).

Table 3 presents our results for alternative specifications of our regression model. Most variables exhibit significant and stable coefficients and all the signs are according to what would be expected. 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; van Biesebroeck, 2005). We do not find any significant correlation between AGE and technical efficiency.

Both the CON and FORLAB are positively and significantly correlated with plant performance, but only when EXPORT is excluded from the regression. This is due to the fact that in particular conglomerate plants tend to sell their products abroad and employ a relatively large share of foreign managers and engineers (see the correlation matrix in Annex Table A.2). 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.

EXPORT is positively and significantly related with technical efficiency, corroborating the idea that trade is an important channel for technology transfer improvements in performance. However, this result should be interpreted with care because we cannot infer causality from our analysis. Indeed, other studies have found that the positive association between exporting and efficiency is explained by the self-selection of the more efficient firms into the export market (Clerides *et al.*, 1998). It requires time-series data to investigate these issues more closely which are not available for our study.

Finally, of the control dummies only SPEC is significant and positive. This is probably caused by the fact that the price of specialty papers is much higher than that of other types of paper. The higher efficiency of specialty mills is therefore likely to be caused by a price instead of an output effect.

8 Conclusions

The aim of this paper has been to investigate the micro-dynamics of catch up. 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 LMD for the period 1975-1997 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. The paper extends the scope of micro-data analysis, which so far lacks a clear international comparative perspective.

During the period of import-substituting industrialization (1975-1984), we found that the Indonesian paper industry was falling behind the frontier in aggregate terms. The export oriented industrialization phase (1984-1997) was characterized by catch up. 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 this dispersion has increased over time. Decomposition analysis pointed out that aggregate catch up was primarily driven by the expansion of the incumbent mills which were improving their performance over time. The entry of new firms also contributed positively to catch up, but to a lesser extent.

Overall catch up of the Indonesian paper industry relative to the global frontier can be described as a highly localized process in which only a few establishments have achieved near best-practice performance. Most other plants, accounting for around half of value added in the late nineties, have stayed behind. We found that the Indonesian plants operating closer to the frontier are the subsidiaries of large business groups, plants with a relative high share of foreign labor and plants which are export oriented.

An important insight deriving from this research is that establishment performance in developing countries is erratic and more dispersed than in advanced economies. Aggregate analysis of performance 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. The micro analysis indicates that a large part of the sector is falling behind, while weak performance does not result in plant exit. The diffusion of technology from best practice plants to stagnant plants is limited. Among others, policy could focus on improving the absorptive capacity of the plants which are presently falling behind.

This being said, this paper should be regarded only as a first step in increasing our understanding of catch up at the micro-level. The study could be improved by collecting additional data on prices, intermediate inputs and vital information on plant characteristics such as the education of the workforce. In addition, the comparative micro approach should be extended to other industries and countries.

Annex 1. Unit Value Ratios

Table A.1 presents Finnish-Indonesian UVRs for the paper industry for the benchmark year 1995. Figures are for 1995 because it was the only recent year for which data on both countries was available. This year can be considered representative for the production structure as the Indonesian paper industry was already well established in this period and paper was both being produced and exported. For Indonesia, commodity data on quantities and output values are taken from the manufacturing census (*Statistik Industri*, SI). Gross value of industry output in the benchmark year 1995 is directly obtained from the paper LMD. The source for the Finnish commodity quantity and value data is *Europroms*, which, in turn, takes its data from national manufacturing censes. Output data is obtained from the longitudinal data set on plants in Finnish manufacturing.

In total four product groups could be matched, including pulp. For the present comparison we omitted pulp and limited ourselves to three important product groups for paper. The coverage ratio for Indonesian paper is 34 per cent, for Finland 18 per cent. Such discrepancies in coverage, which also have been found in other international comparisons between rich and poor countries, have to do with differences in production structure (Timmer, 2000). Poor countries tend to specialize in homogeneous low-quality and low value added products while rich countries produce relatively more products in the higher valued added segment, which cannot be matched. For example, Indonesia manufactures mainly wood free paper and boards, while Finland is now increasingly moving to specialty papers in which it still has a comparative advantage.[12] Consequently, product UVRs are probably biased downwards and therefore the productivity measures have to be considered as upper bounds. The final UVR (Fisher average) is 290 Rupiah/Markka. The relative price level in Indonesia, defined as the ratio between UVR and exchange rate, is 0.56. This indicates that paper produced in Indonesia is relatively much cheaper than in Finland.

Table A. 1: Indonesia/Finland Paper Product Matchings, 1995

	Unit value (local currency)		*Matched output as % of total gross value of output*		*UVR [a] (rupiah/markka)*	*Relative price level (Indonesia/Finland)[b]*
	Finland (Markka/ton)	*Indonesia (000 Rupiah/ton)*	*Finland*	*Indonesia*		
Newsprint	2,925	1,152	5	2	394	76
Sack kraft	3,615	1,118	1	2	309	60
Woodfree[c]	4,480	1,198	12	30	267	52
Total	3,843	1,190	18	34	290	56

Note:
[a] Fischer index, defined as the geometric average of Laspeyres (Finnish weights) and Paasche (Indonesian weights) indices
[b] Relative price level is defined as the UVR divided by the exchange rate (514.94 Rupiah/Markka) times 100.
[c] Includes coated and uncoated wood free paper.

Source: Own computations based on: Finnish product listings from Eurostat, *European production and market statistics (Europroms)*, 2001; Finnish paper output data (ISIC 3411) from Statistics Finland, *Longitudinal Data on Plants in Finnish Manufacturing*, 2003; Indonesian product listings from BPS, *Statistik Industri*, Bagian IIIB, 1995; Indonesian output data from paper industry LMD; exchange rates from Heston *et al.*, *Penn World Table Version 6.1*, 2001.

[12] Another potential problem, which also causes a downward bias in the UVRs are quality differences between Finnish and Indonesian paper. However, as both goods are very simple and homogeneous products, this distortion is probably not serious.

Annex 2. Correlation Matrix

Table A. 2: Correlation Matrix

	TE	SIZE	PUB	CON	FORLAB	EXPORT
TE	1					
SIZE	0.4139*	1				
PUB	0.0820*	-0.0155	1			
CON	0.2693*	0.4867*	-0.1616*	1		
FORLAB	0.2473*	0.2416*	-0.1564*	0.4537*	1	
EXPORT	0.2157*	0.4292*	-0.023	0.3159*	0.2214*	1

* significant at the 5% level

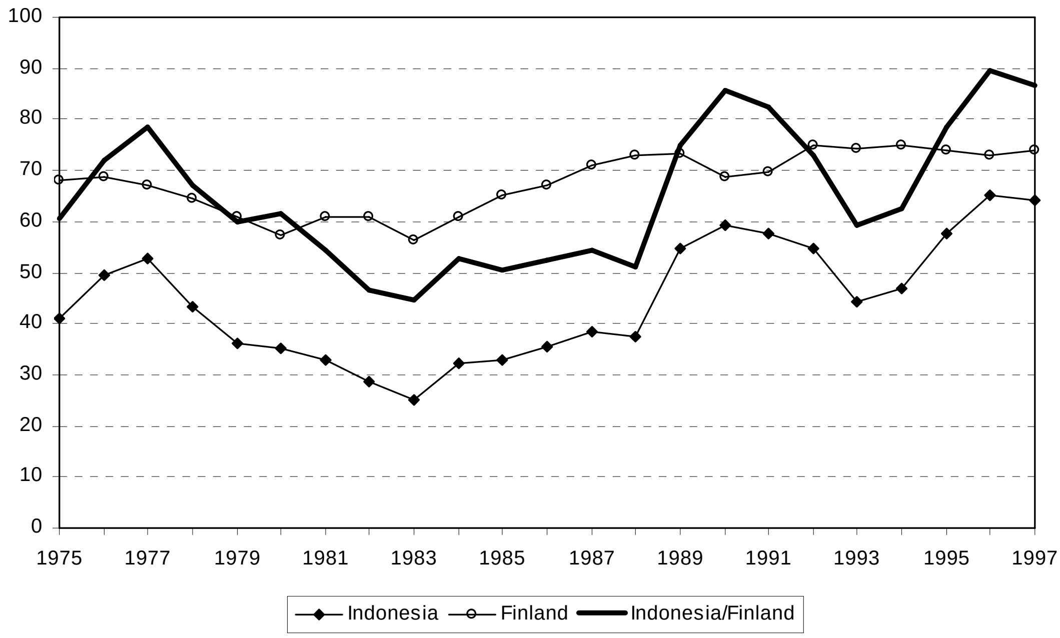
Annex 3: Alternative DEA Solutions

In the main text, we presented our preferred solution: Temporal DEA with bootstrapping. Here we present three alternatives: 1. Temporal DEA without bootstrapping; 2 Intertemporal DEA without bootstrapping and 3. Intertemporal DEA with bootstrapping.

1. Temporal DEA without Bootstrapping

Figure A-1 represents the results of the temporal DEA variant without bootstrapping. Both countries are somewhat closer to the frontier, which is to be expected as bootstrapping diminishes the effects of outliers.

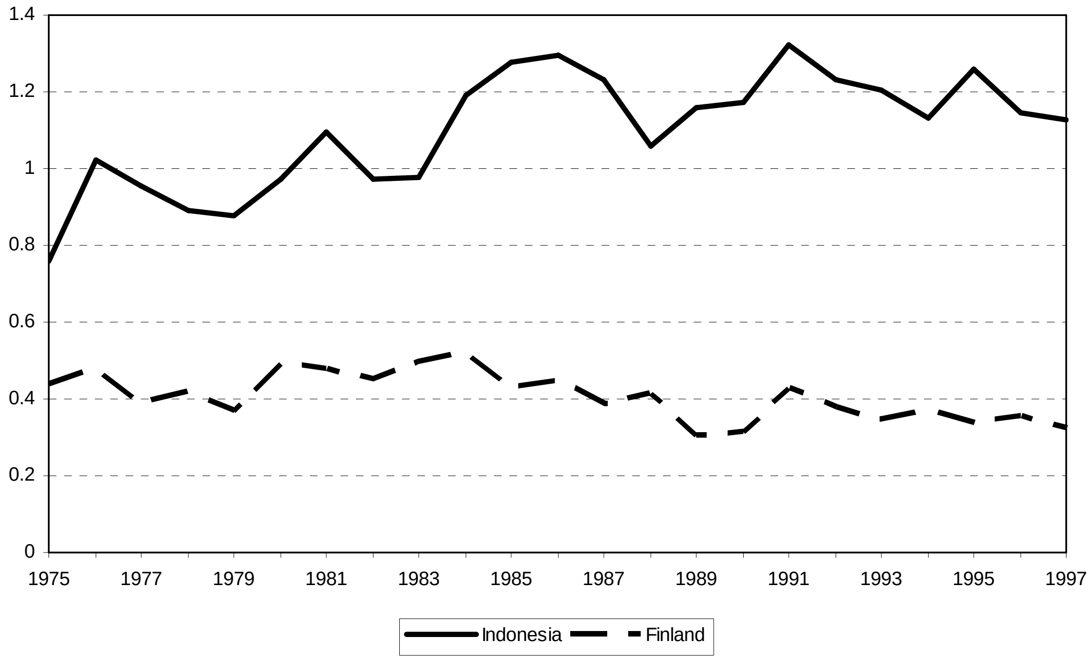
Figure A-1: Aggregate Industry Technical Efficiency by Country, 1976-1997 (temporal variant)



Note: Figure presents average industry-level technical efficiency of Indonesia and Finland (two-year averages), using output as weights based on temporal DEA.

Figure A-2:

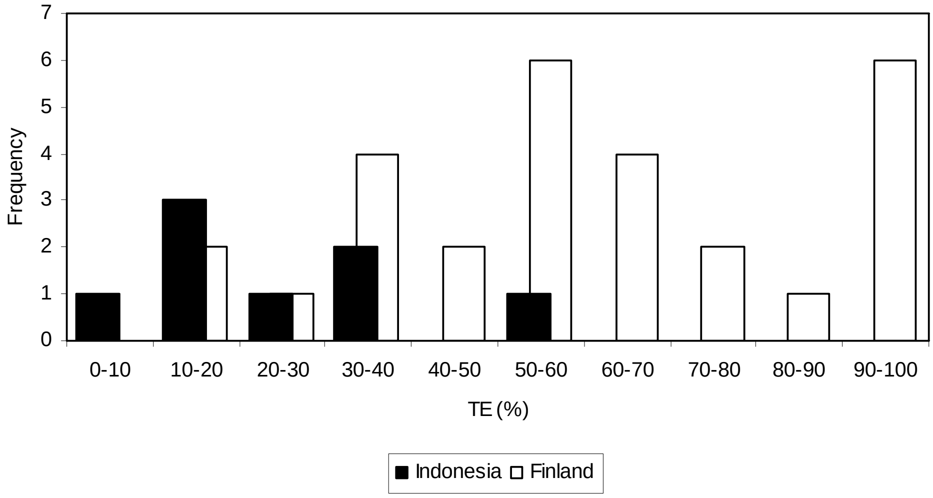
Coefficient of Variation of Technical Efficiency by Country, 1975-1997



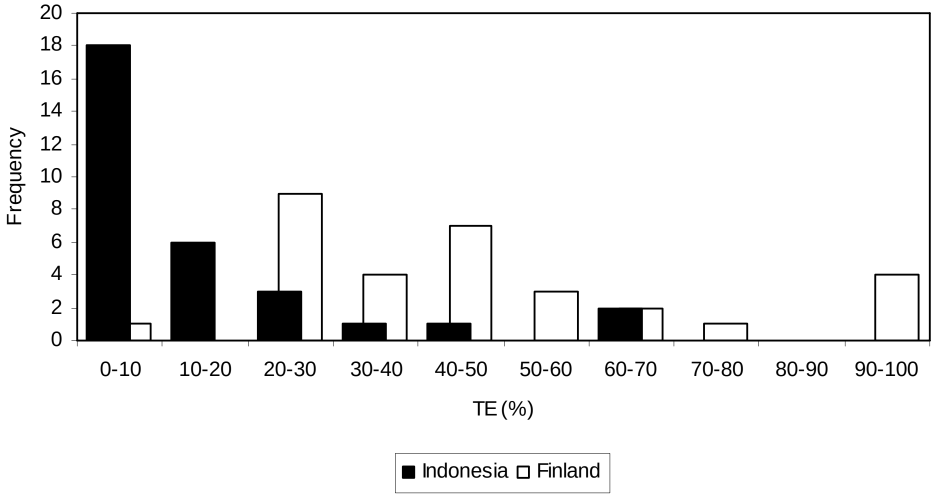
Note: Coefficient of Variation defined as standard deviation/mean

Figure A.3 : Technical Efficiency Distribution by Country (temporal variant)

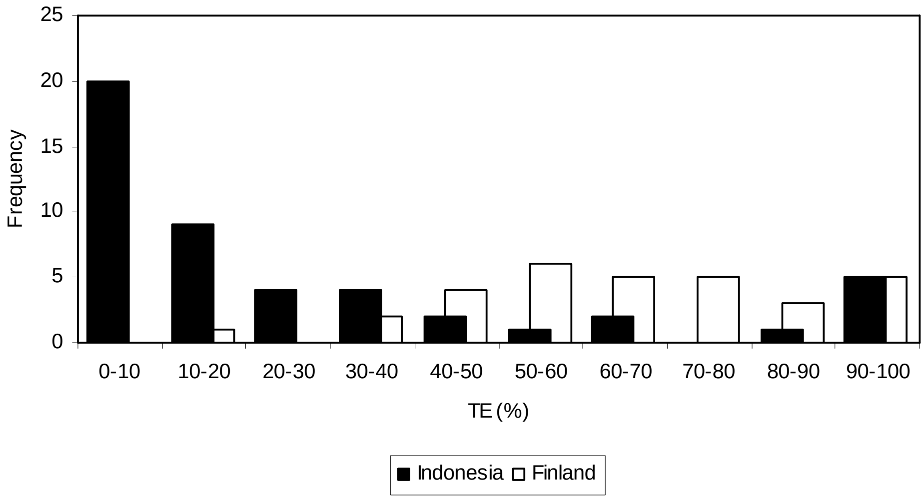
a: 1975



b: 1984



c: 1997

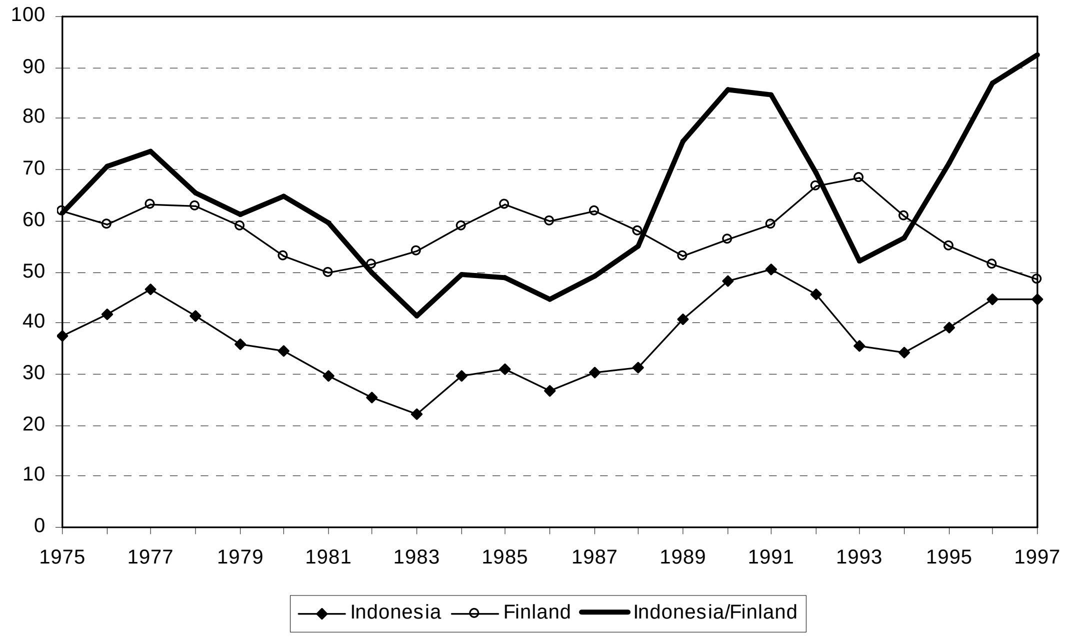


I

2. Intertemporal DEA without Bootstrapping

Figure A-4 depicts aggregate industry technical efficiency for Indonesia and Finland for the period 1976-1997 relative to the intertemporal frontier based on best practice of establishments for all years. There are some interesting differences with the standard DEA of figure 3. While the pattern for Indonesia remains largely unchanged, aggregate efficiency in Finland declines quite substantially after 1993, while it increases modestly in the standard estimates. As a result, Indonesia shows more dramatic catch up after 1993, and relative performance becomes more unstable. The explanation for this lies in the fact that state of the art Indonesian plants start producing in the second half of the nineties influencing the location of the intertemporal frontier. The periodisation of catch up and relative stagnation remains unchanged. For both countries aggregate efficiency is somewhat lower, than in the temporal variants. This is to be as expected if one eliminates regression of the frontier.

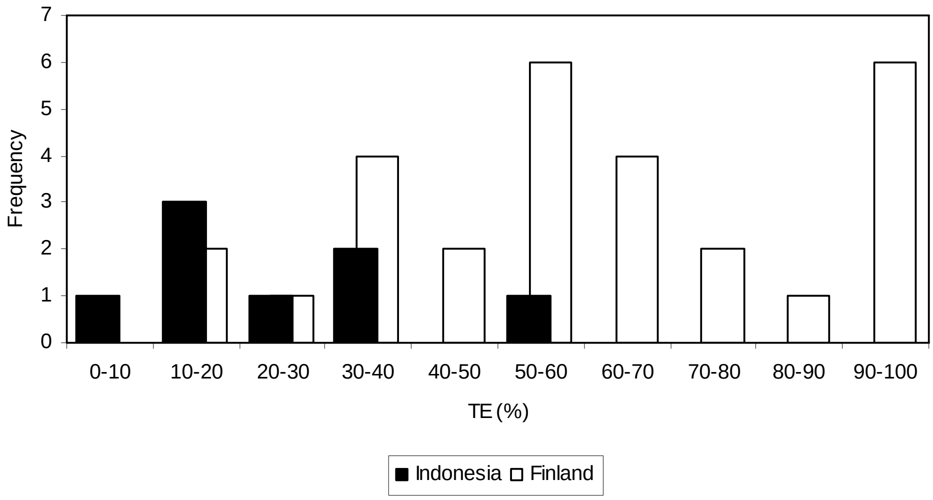
Figure A-4: Aggregate Industry Technical Efficiency by Country, 1976-1997 (intertemporal variant)



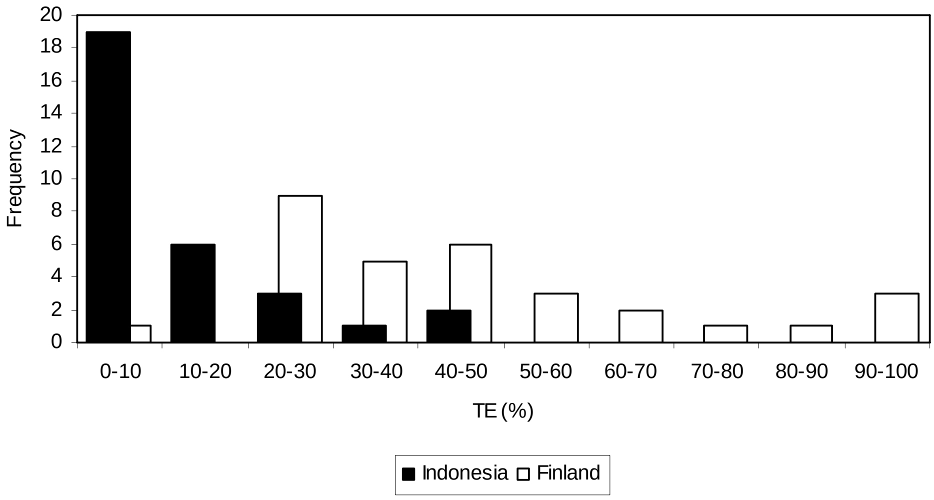
Note: Figure presents average industry-level technical efficiency of Indonesia and Finland (two-year averages), using output as weights based on intertemporal DEA.

Figure A-5: Technical Efficiency Distribution by Country (intertemporal variant)

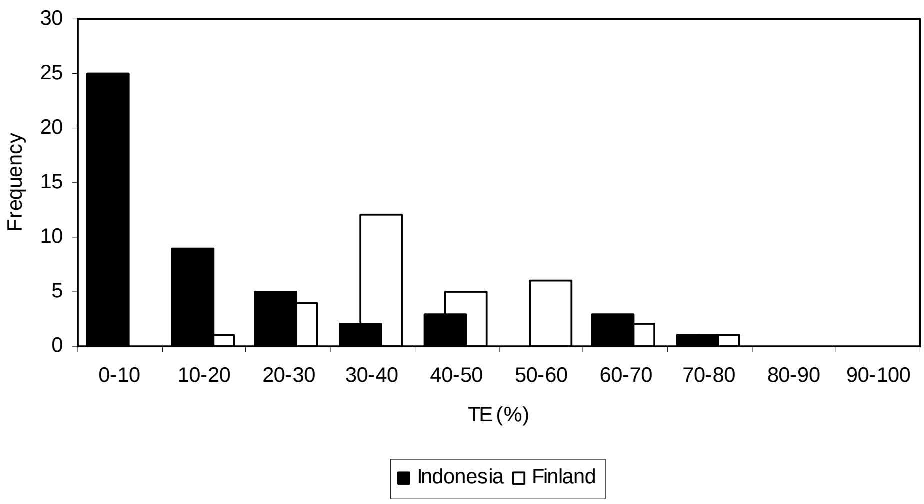
a: 1975



a: 1984



a: 1997



3. Intertemporal DEA with Bootstrapping

Figures A-6 and A-7 present the results for the intertemporal variant with bootstrapping. The effect of bootstrapping is that the technical inefficiency increases in both countries. In relative terms there is hardly any difference with the intertemporal variant without bootstrapping. However, the effects of bootstrapping are clearly visible in the histogrammes, where there are less firms close to the frontier in 1997.

Figure A-6: Aggregate Industry Technical Efficiency by Country, 1976-1997 (intertemporal bootstrapping variant with bootstrapping)

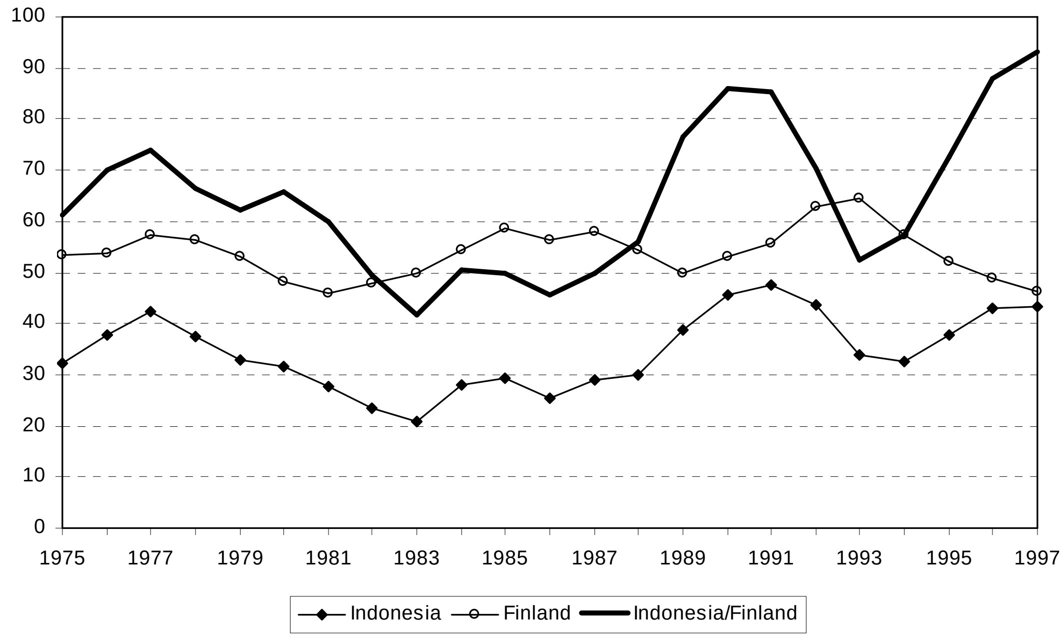
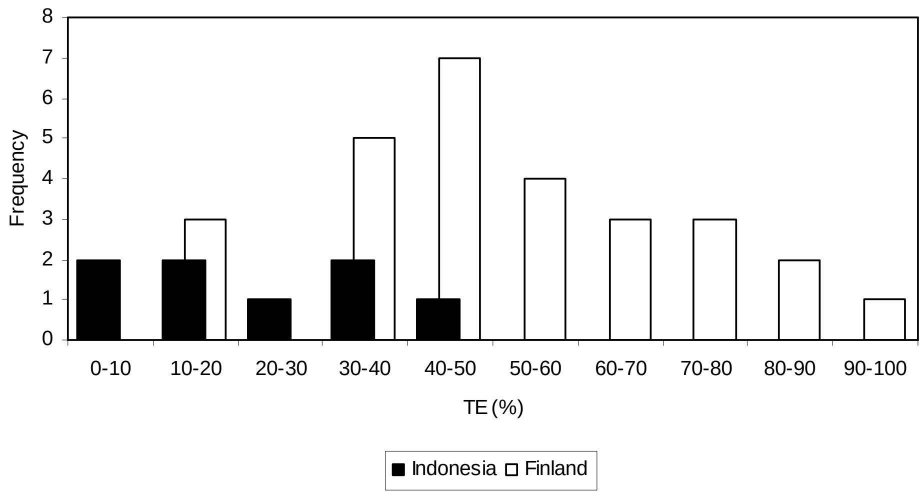
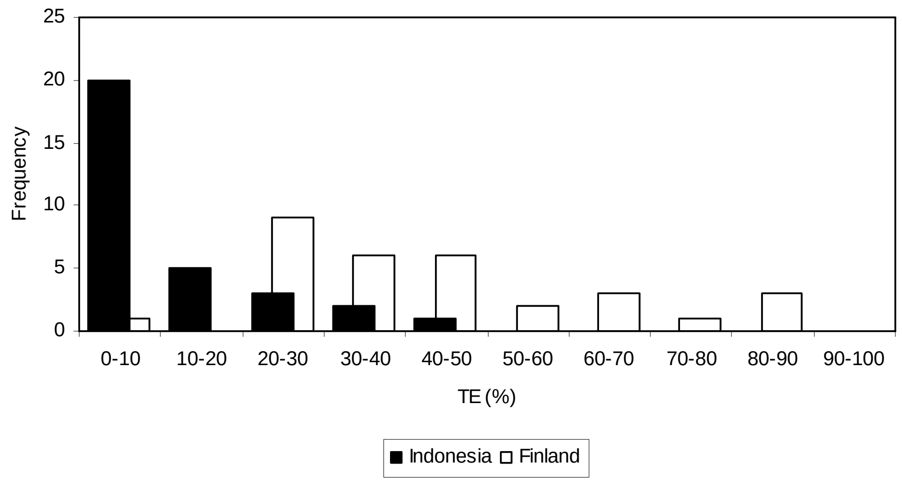


Figure A-7: Technical Efficiency by Country (Intertemporal Bootstrapping)

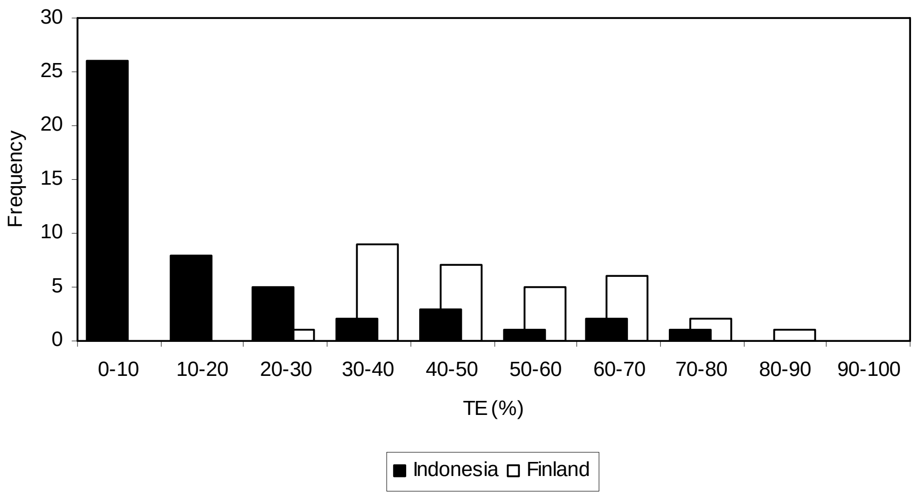
a: 1975



a: 1984



a: 1997



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