Catch Up at the Micro-Level: Evidence from an Industry Case Study Using Manufacturing Census Data

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Abstract

In this paper we provide a first attempt to analyse catch up at the micro level, not possible in conventional macro-studies. The Indonesian pulp and paper industry has been selected as case-study because it experienced spectacular investment and growth, becoming one of the world's largest exporters and producers of paper in the world. We apply stochastic frontier analysis to compare technical efficiency of Indonesian paper mills with Finnish plants, which can be considered as the world technological leaders in the industry. The analysis is performed on a pooled dataset based on manufacturing census data for the period 1975-1997.

In the paper we address the following questions: What is the distribution of Indonesian plant performance vis-à-vis the technological frontier? What is the role of entry, exit and survival on catch up? And, what are the characteristics of catching-up plants. Although we find that on average the Indonesian paper industry has closed the gap with the technology frontier during the 1990s, catch up has been a highly localised 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 commonly refers to the process of reducing the technology gap between technologically leading (i.e. rich) and technologically backward (i.e. poor) countries. So far most research on this topic has been conducted at the country or industry level. Due to the high level of aggregation these studies are not able to reveal the micro-dynamics underlying the catch up process. Are all plants producing relatively close to the technological frontier or have only some succeeded in closing the technology gap while others have stayed behind? Is industry-level catch up the result of entry of modern plants, improvements in efficiency of surviving plants or exit of inefficient establishments? These questions can only be answered by making international comparisons of plant-level performance. So far only a handful of studies have dealt with this issue.[1] A major shortcoming of the existing work is their limited coverage. Most studies are confined to only a few firms and results might therefore not be statistically representative. Also often only one year is covered and therefore little can be inferred on the process of catch up, which is per definition a dynamic phenomenon.

This paper provides a first attempt to study catch up at the micro level by taking the Indonesian paper industry as case study. To overcome the limitations of existing literature we base our analysis on an internationally standardised longitudinal micro-level data set (LMD) based on manufacturing census data for the period 1975-1997. In order to measure the technology gap of Indonesian paper mills with the frontier we use stochastic frontier analysis to compare technical efficiency with those of Finnish plants, which are generally considered as the world's technological leaders in paper manufacturing (Ojainmaa, 1994; Diesen, 2000). We will address the following questions: What is the distribution of Indonesian plant performance vis-à-vis the technological frontier? What is the role of entry, exit and survival on catch up? And, what are the characteristics of catching-up plants. Answers to these questions provide interesting input for industrial policy formulation and growth research in general.

For a number of reasons the Indonesian paper industry provides an attractive case study of catch up. Before the Asian crisis of 1997, Indonesia was considered as a second-tier Asian tiger (World Bank, 1993). Growth in GDP per capita averaged 3.6 percent per year for the period 1960-1998. The evidence suggests that the country was on a progressive path of industrialisation and development, crudely disrupted by the crisis (Hill, 1996). The paper sector was an important sector in Indonesian industrialisation. With an annual average growth in output of more than 15 percent between 1960 and 2000, it has been among the fastest growing manufacturing sectors in the country. As a consequence of industrial policy, paper companies invested in the latest equipment and Indonesia became one of the world's largest

[1] Probably the most comprehensive study 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 other than manufacturing sectors such as retailing, telecom and construction. Another research project dealing with international comparisons of productivity at the micro-level are the match-plant studies, initiated by the National Productivity institute (e.g. Mason *et al.*, 1994). Lastly, Pack (1987), who studies total factor productivity of Kenyan and Philippine textile mills relative to the UK, is one of the few studies looking explicitly at the technology gap between establishments in industrialised and developing countries.

exporters and producers of paper in the world (Van Dijk, 2005). Finally, the availability of high quality historical data at plant level, a rarity for developing countries, also contributed to the choice of the country and industry studied.

The structure of this paper is as follows. Section 2 summarises 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 Section 3, we describe our dataset and in section 4 we analyse 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 summarise the major findings and conclusions.

2 Theoretical Framework

2.1 Technology Diffusion, Catch Up and Absorptive Capacity

There is increasing belief 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 commercialisation of technology new to the world, the main source of growth for advanced capitalist economies, while diffusion implies the international spillover of existing technology to following countries. Consequently, it has been argued that poor countries enjoy so called "advantages of backwardness" (Gerschenkron, 1962). They have the 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, which is a country's capability to assimilate existing technology and adapt it to a new environment (Abramovitz, 1986; Cohen and Levinthal, 1989; Verspagen, 1993).[2]

There exist a large volume of empirical studies investigating catch up (for overviews see Fagerberg (1994), Fagerberg and Godinho (2005), and Temple (1999)). With respect to this research two empirical approaches seem to be especially important. On line of studies puts 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 the level (as opposed to growth rates) of labour 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 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; Kumar

[2] Abramovitz uses the term social capability (also see Koo and Perkins, 1995) instead of absorptive capability. We prefer the latter as this is more often used nowadays in the literature.

and Russell, 2002; Kneller and Stevens, 2002). The advantage of this technique above the standard approach is that the technological frontier is determined by the data instead of by one single country with the highest productivity.

A second approach to study catch up is concerned with identifying factors which hamper or promote catch up. Some elements which are found the contribute to the absorptive capacity of countries are: education (Benhabib and Spiegel, 1994); R&D (Fagerberg, 1988) and international trade (Coe *et al.*, 1997).

2.2 Market Structure and Industrial Dynamics in Developing Countries

Following practices in industrialised countries (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; Sjöholm, 1998; Aw *et al.*, 2003). 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 (e.g. Nelson, 1968; Blomström and Wolff, 1997; Sleuwaegen and Goedhuys, 2002).[3] Markets are commonly characterised by a few large-scale modern companies and a high number of small traditional firms, producing similar goods side by side (Blomström and Wolff, 1997; Sleuwaegen and Goedhuys, 2002; Cimoli and Katz, 2003). 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. Empirical research indicates that plant size correlates negatively with income per capita both across countries and within countries through time. The literature offers a range of possible explanations for dualistic market structures in developing countries. Some reflect the general underdevelopment of the economy (isolated markets, high share of low-tech industries, macro instability, abundance of low-skilled labour) while others relate to distorting government policies (protectionist trade policy, excessive regulation and preferential treatment of influential companies) (Fafchamps, 1994).

The fact that manufacturing sectors in developing countries are characterised 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 restrained growth. If the industrial sector in developing countries is indeed characterised by poorly functioning markets and a high number of 'sick' firms one would expect that the dispersion of performance in those countries is relatively higher in comparison to rich economies, where it can be assumed that markets are competitive. However, somewhat surprisingly, the available evidence does not seem support this hypothesis. Tybout (2000) finds that average technical for developing countries is not typically lower than found in similar studies for high-income countries. A

[3] The concept of dualism goes back to the roots of development studies (Boeke, 1966). In most textbooks on economic development the term refers to the simultaneous existence of a traditional (i.e. small-scale agriculture) and a modern sector (i.e. industry and plantation agriculture). In this study, however, we are only interested in intra-industry dualism.

corresponding result is 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.

However, as Tybout notes himself, the results of the available studies "are not very informative" (Tybout, 2000, p. 25). 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 uses average technical efficiency to draw conclusions on differences in the distribution of performance across countries, which is highly misleading. Only measures like standard deviation and coefficient of variation or graphical tools like histogram and kernel density plots, provide suitable information on the spread of a variable. In this study we try to accommodate most of these problems.

2.3 Discussion

Macro-level research on catch up has provided important insights on the broad sources of catch up. However, due to its high level of aggregation it cannot say much about this process at the micro-level. Research on industrial dynamics in developing countries has pointed out that due to a combination of factors industries are frequently characterised by dualistic market structures, composed of large-scale capital intensive firms and small backward companies. This suggests that the distribution of plant performance is much more dispersed in developing countries than in rich countries. Hence what is referred to as 'catching up' in macro-orientated studies, might in reality just be caused by the emergence of a small number of modern firms, while the majority of plants are in fact lagging far behind the technology frontier. Presently, the work on industrial dynamics has not addressed these issues. Apart from a handful of studies, already mentioned above, most empirical research lacks an international perspective and 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 comparable across countries, we construct sector specific conversion factors, which are usually used in more aggregate studies on international comparisons of productivity and put considerable effort to standardise input and output definitions. Catch up and the distance to the international technological frontier are measured by means of stochastic frontier analysis. Similar to the micro-studies, we base our analysis on manufacturing census data. Besides almost perfect 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 manufacturing census data as well. Finally, we try to identify the determinants of absorptive capacity at the micro-level.

3 Data Construction

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) expressing values in a common currency, (2) standardisation of input and output definitions. Both are discussed next.

3.1 Currency Conversion

Level comparisons of international output and productivity require a conversion factor to express values in the same currency. Exchange rates are not suited because they are often influenced by other factors than trade, such as political reasons, capital movements and speculation. Furthermore, they reflect the relative price levels of all tradable goods and are thus less appropriate for industry-specific conversions. A better alternative is the industry-of-origin approach. In this approach, sectoral specific unit value ratios (UVRs) are derived using producer output data (Szirmai and Pilat, 1990; Timmer, 2000; Van Dijk, 2003). Ideally, one would like to compare producer prices across countries but, unfortunately, these are mostly not available. As an alternative, one can use unit values (uv) based on quantity and value data of product or product groups instead. A product group is made up of goods with roughly similar characteristics, like carpets and rugs, car tyres, wines or sport shoes. The unit value can be regarded as the average ex-factory price of a product or product group in a given year. It is defined as:

$$uv_i = \frac{o_i}{q_i} \tag{1}$$

where o is output value and q the quantity of goods produced. To derive industry specific UVRs of matched products between two countries (i.e. similar products or product groups, produced in both countries), in this case Indonesia (I) and Finland (F), is computed:

$$UVR_i^{I/F} = \frac{uv_i^I}{uv_i^F} \tag{2}$$

Finally, using output values as weights, UVRs are aggregated to provide industry specific conversion factors.

Table 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 in this period the Indonesian paper industry was already well established and both paper were produced and exported. For Indonesia, product data is taken from the manufacturing census (*Statistik Industri*, SI) and total industry output is directly obtained from the paper LMD, discussed below. The source for the Finnish quantity and value data is

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

Europroms, which, in turn, takes its data from national manufacturing censes. Output data is obtained from the longitudinal data on plants in Finnish manufacturing, discussed below.

Although only four product groups could be matched, coverage for Indonesian paper is 45 percent and the coverage ratio for Finland is 38 percent. 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 specialise 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.[5] Consequently, product UVRs are probably biased downwards and therefore the productivity measures have to be considered as upper bounds. The final UVR is 264 Rupiah/Markka. With a relative price level, defined as the ratio between UVR and exchange rate, of 51 percent, paper produced in Indonesia is relatively much cheaper than in Finland.

Table 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*		
Pulp	3,125	715	20	12	229	44
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	3,435	1,017	38	45	264	51

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.

3.2 Sources and standardisation of 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

[5] 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.

study, we use the electronic version of the dataset from 1975 to 1997. Data from the SI data was subsequently merged with information on capacity, production, product mix, age 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, 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 presented in Van Dijk and Szirmai (2005).

The data for Finnish paper mills was distilled 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.[6] 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.

Before the Indonesian and Finnish data can be compared, they need to be standardised. There are not yet any clear international guidelines for industrial censes and, therefore, each country has a tendency to use its own definitions, concepts and classifications. A possible problem is the unit of analysis in the manufacturing census. Fortunately both the Finnish and Indonesian surveys are based on plants (as opposed to firms) and can therefore be directly compared. Another possible source of bias is coverage. For example, the Indonesian census excludes establishments with less than 20 employees, whereas the Finnish census encompassed all plants owned by firms that employ no less than 20 persons till 1995 and all plants owned by firms that employ no less then 20 persons thereafter. However, paper manufacturing is a scale and capital intensive industry and therefore none of the plants in our sample falls below the size threshold. In total the Indonesian paper LMD contains information on 53 plants, which on average reflect 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.[7]

For international comparisons of productivity, it is also important that inputs and outputs are consistently defined across countries. In the statistical analysis below we consider only two inputs, capital and labour, and one output, gross value added. In most firm-level productivity studies, gross output is used as output measure instead of value added. This is the preferable concept in micro-studies because shifts in the use of intermediates relative to capital and labour 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 intermediates are unavailable for Indonesia before 1990 (Jammal, 1993). Moreover, international comparison of energy and raw materials requires the construction of a large number of additional UVRs, which has not been attempted here. For these reasons, I

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

[7] Secondary data on capacity of Finnish paper mills was linked with the longitudinal data on plants in Finnish manufacturing through address information. Due to missing or conflicting data the matching was less than 100 percent.

have chosen to exclude intermediates from the analysis and use value added as the output concept. Nevertheless productivity estimation on the basis of all inputs is recommended in theory and would be a desirable target for future research.

It was relatively easy to harmonise the measures for value added, capital and labour. Both Finland and Indonesia use the national accounts concept of value added, which exclude non-industrial services, in their surveys (Ark, 1993). To make value added comparable between Indonesia and Finland, it has first expressed in constant 1995 prices using country specific industry deflators after which the industry UVR is applied to convert Indonesian values in Markka's. Here an important caveat should be mentioned. Due to the lack of firm-specific prices, quantity and price effects are to a certain degree entangled (Tybout, 2000; Bartelsman and Doms, 2000; Katayama *et al.*, 2003). This implies that price-cost mark-ups of monopolists might be mistaken for higher productivity. Such bias might be more serious in developing countries where competition is 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, as said, also not available.

The standardisation of labour and capital also provided no problem. For both Finland and Indonesia, labour is defined as total people employed, including self-employed and unpaid family workers for both countries. Capital in both countries is approximated by total paper capacity installed. Given the lack of international comparable information on asset lifetimes, retirement patterns and investment data, this measure is favoured above book value of capital or perpetual inventory method (PIM) based on capital stock estimates, which are more common in productivity studies.

Finally, the data for Indonesia and Finland have been pooled to create a database suited for comparative productivity analysis. I decided to exclude 'pure' pulp mills from the sample because they cannot directly be compared with paper mills. Integrated mills (i.e. plants having both paper processing facilities), however, are still included. Table 2 presents summary statistics for the main variables by country. On average paper mils in Indonesia are smaller in terms of output, value added and capacity but not in terms of labour than their Finnish competitors. However, high standard deviations indicate that plant heterogeneity in Indonesia is much higher than in Finland, corresponding with the findings of dualism discussed above. Market structure in terms of the types of paper produces is very similar across countries although the share of newsprint companies is somewhat higher in Finland, while the share of board plants is lower. Finally, Finland also has a higher number of vertically integrated plants than Indonesia.

Table 2: Summary statistics

Variable	*Definition*	*Indonesia*		*Finland*		*Pooled*	
		Mean	*Std. dev.*	*Mean*	*Std. dev.*	*Mean*	*Std. dev.*
VA	Value added (mill. 95 markka)	83.28	286.57	229.95	198.83	153.66	258.88
DINT	Integrated mill (0 or 1)	0.26	0.44	0.54	0.50	0.40	0.49
DBOARD	Board mill (0 or 1)	0.51	0.50	0.42	0.49	0.47	0.50
DNEWS	Newsprint mill (0 or1)	0.04	0.19	0.13	0.34	0.08	0.28
DSPEC	Tissue mill (0 or 1)	0.06	0.23	0.06	0.25	0.06	0.24
DTISS	Specialty mill (0 or 1)	0.06	0.23	0.06	0.24	0.06	0.24
K	Paper cap. (000 tons)	72.84	152.25	342.51	272.76	202.24	256.68
L	Labour input (pers. eng.)	708.10	1166.09	541.37	351.93	628.10	879.31
AGE	Age of establishment (years)	13.11	13.02	32.71	24.31	22.51	21.62
SIZE	Output (mill. 1995 markka)	268.39	681.02	724.25	548.42	487.13	661.22
N	Number of observations	761		702		1463	

4 Analysis

4.1 Frontier Analysis

In this study we use stochastic frontier analysis to investigate the performance of Indonesian paper mills relative to international best practice. In this type of analysis, a frontier production function, which defines the outer boundary of input-output combinations for any set of observations, is constructed. Firms are defined as technically efficient if they are producing at the technological frontier (Coelli *et al.*, 1998). All plants operating below the frontier are considered technically inefficient because their output falls short of what could have been produced, given the inputs used. We apply the econometric model proposed by Battese and Coelli (1995), which has been frequently applied in other studies (Audibert, 1997; Lusigi and Thirtle, 1997; Lundvall and Battese, 2000). This model allows for a separate investigation of both shifts in best practice production and analysis of technical efficiency of production, i.e. the distance to the frontier. In this study, we estimate a translog production function of the following form:

$$\begin{aligned} \ln Y_{it} &= \beta_0 + \beta_{01} DINT_{it} + \beta_{02} DBOARD_{it} + \beta_{03} DNEWS_{it} + \beta_{04} DTISS_{it} \\ &+ \beta_{05} DSPEC_{it} + \sum_{j=1}^{3} \beta_j x_{jit} + \sum_{j\leq}^{3} \sum_{k=1}^{3} \beta_{jk} x_{jit} x_{kit} + v_{it} - u_{it} \end{aligned} \quad (3)$$

where the subscripts i and t represent the i-th plant (i=1,2,...N, where N is the number of plants in the sample) and the t-th year of observation (t=1,2, M, corresponding with 1975 to 1997), respectively;

ln Y represents the natural logarithm of gross value added at constant prices;

DINT is a dummy for integrated paper mills, which has a value of one if the mill produces both paper, and zero when only paper is produced;

DBOARD, DNEWS, DTISS and DSPEC are dummy variables for board, newsprint, tissue and specialty mills, respectively, to control for the possible effect of output mix differences in production technology across paper plants. Printing and writing mills form the control group.

x_1 represents the natural logarithm of capital stock (*K*), approximated by total paper capacity installed;

x_2 represents the natural logarithm of labour input (*L*), measured as number of persons engaged;

x_3 represents a time variable (*T)*, which is related to the shift of the frontier;

v_{it} is assumed to be independent and identically distributed as normal random variable with mean zero and variance σ_v^2, independent of u_i;

u_{it} is assumed to be the non-negative truncation of a normal distribution. It is restricted to be non-negative to ensure that plants' production point lies beneath the frontier.

The first part of the equation defines the production frontier, while deviations from it are measured by the two error terms. v_{it} catches the effects of random shocks and statistical noise, and u_i is associated with the technical *in*efficiency. Technical efficiency of the i-th establishment in the t-th year is measured as the ratio of the observed output to the stochastic frontier output and computed as $te_{it}=exp(-u_{it})$.

To detect underlying causes of differences in estimated technical inefficiency between plants, Battese and Coelli express technical inefficiency as a function of possible explanatory variables and a random error term. For this study, the technical inefficiency model becomes:[8]

$$u_{it} = \delta_0 + \delta_1 AGE_{it} + \delta_2 SIZE_{it} + \delta_3 YEAR_t + \delta_4 DINDO_i + w_{it} \qquad (4)$$

where, w_{it} is defined as the truncation of the normal distribution with zero mean and variance σ_u^2 such that w_{it} is non-negative. *AGE* and *YEAR* are control variables standard included in production analyses using panel data. *SIZE,* measured by annual output in million markka, is added to capture the influence of plant scale on efficiency. *DINDO* is a dummy for mills located in Indonesia. Equation (3) and (4) are estimated simultaneously by maximum likelihood estimation, using FRONTIER 4.1, a program for stochastic frontier analysis developed by Coelli (1996).

[8] u_{it} is a measure of the degree of inefficiency. The higher u_{it}, the lower the degree of technical efficiency te_{it}

Table 3: Model Estimation

Variable	*Parameters*		
Frontier model			
CONSTANT	β_0	-1.62	(-4.57)***
DINT	β_{01}	-0.23	(-4.61)***
DBOARD	β_{02}	-0.23	(-4.72)***
DNEWS	β_{03}	-0.08	(-1.54)
DTISS	β_{04}	-0.21	(-2.89)***
DSPEC	β_{05}	0.16	(1.96)**
L	β_1	0.76	(5.86)***
K	β_2	0.81	(10.88)***
T	β_3	0.01	(0.27)
L*L	β_{11}	0.03	(2.47)**
K*K	β_{22}	0.07	(6.68)***
T*T	β_{33}	-0.001	(-3.25)***
L*K	β_{12}	-0.17	(-10.72)***
L*T	β_{13}	0.02	(4.93)***
K*T	β_{23}	-0.004	(-2.07)**
Inefficiency model			
CONSTANT	δ_0	-2.90	(-6.25)***
AGE	δ_1	0.003	(0.76)
SIZE	δ_2	-0.002	(-27.80)***
YEAR	δ_3	0.06	(4.65)***
DINDO	δ_4	4.47	(11.26)***
$\sigma_s^2 = \sigma_v^2+\sigma_u^2$		1.73	(13.01)***
$\gamma = \sigma_u^2/(\sigma_v^2+\sigma_u^2)$		0.96	(165.55)***
Returns to scale [a]		0.80	(-1.38)
Technical change [b]		0.05	(2.16)**
Loglikelihood		-1576.54	
N		1463	

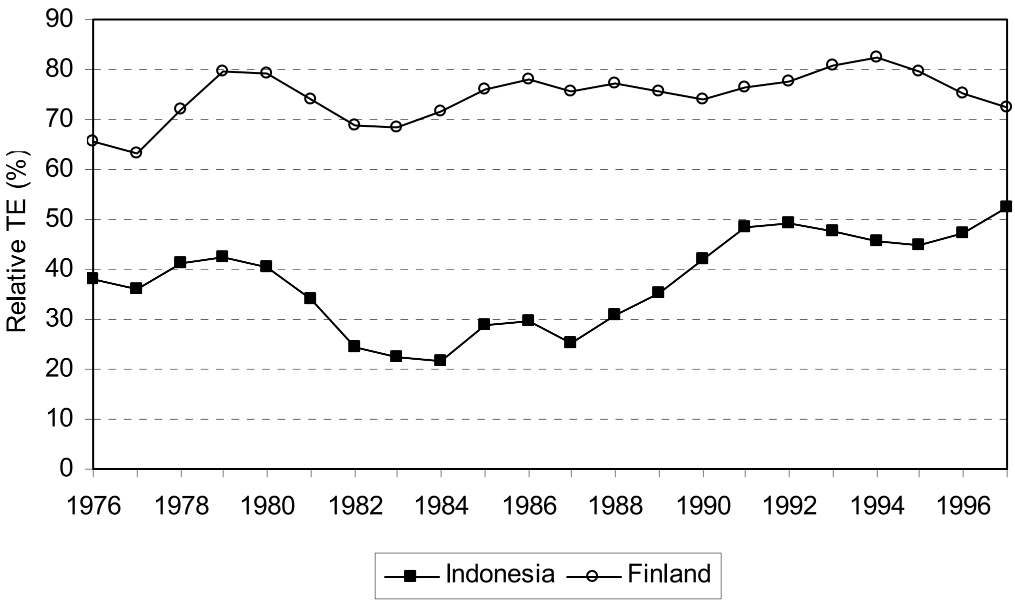
Note: t-values between parentheses; *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level;

[a] Returns-to-scale=$[\beta_1+(2\beta_{11}lnK)+(\beta_{12}lnL)]+[\beta_2+(2\beta_{22}lnL)+(\beta_{12}lnK)]$ using mean values for *lnK* and *lnL*. t-values are for hypotheses tests of returns to scale unequal to one (=constant returns to scale);

[b] Technical change=$\beta_3+2\beta_{33}t+\beta_{13}lnK+\beta_{23}lnL$, using mean values for *t*, *lnK* and *lnL* for mills of which *te* is higher than 80 percent. Technical change measures the movement of the frontier and it is therefore only based on a sample of best performing mills. A threshold of 20 percent seems to be a reasonable choice.

Table 3 shows the results for the frontier and inefficiency model. Except for *DNEWS* all control variables are significant at the 10 percent level or less, pointing at different production functions per paper grade and type of mill. Except for the time trend, all β-parameters are significant. Table 3 also presents estimates for returns-to-scale and technical change. Hypotheses tests point out that the technology is characterised by constant returns to scale and technical change (i.e. a shift of the frontier) of about 5 percent per year on average. The latter is computed using a sample of mills for which *te* is higher than 80 percent. As technological advance measures the movement of the frontier, it should be based only on mills which are located at the frontier. Though arbitrary, a threshold of 20 percent seems to be an acceptable choice.[9]

Figure 1: Aggregate Industry Technical Efficiency by Country, 1976-1997



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

Source: Technical efficiency scores from Table 3.

Figure 1 depicts aggregate industry technical efficiency for Indonesia and Finland for the period 1976-1997 (two-year averages). Following common practice in firm level studies on total factor productivity, I use output as the weighting variable (Baily *et al.*, 1992; Foster *et al.*, 1998). The figure corresponds closely with qualitative information on the historical development of the Indonesian paper industry (Van Dijk, 2005). During the import substitution phase (1975-1984) technical efficiency is decreasing from about 40 to 20 percent, while the subsequent period of export oriented industrialisation (1984-1997) is characterised by catching up till a level of over 50 percent. Figure 1 also shows that on

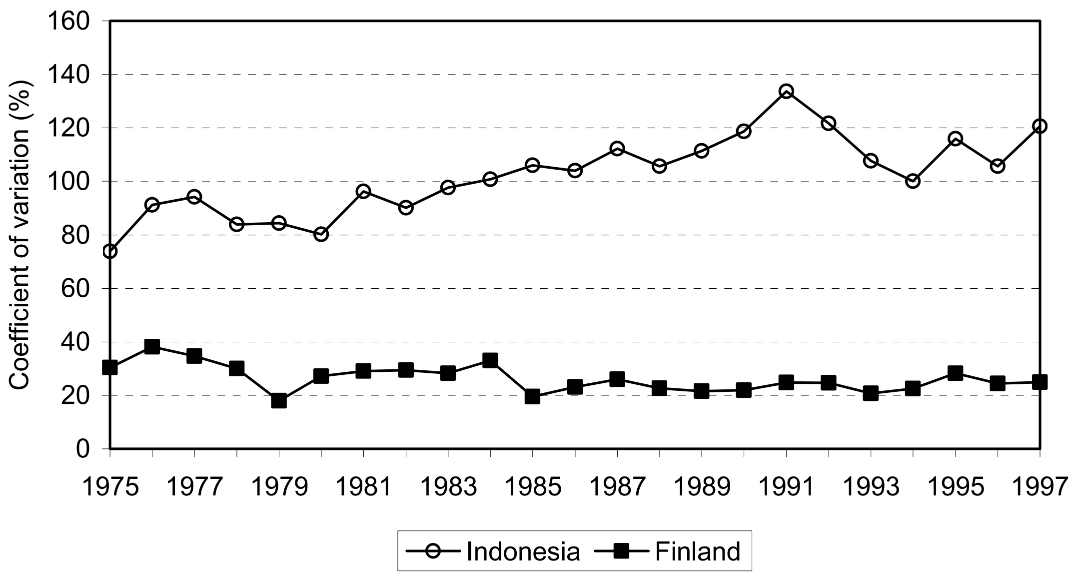
[9] I would like to thank Jaap Bos for this suggestion.

average Indonesia paper mills are producing at a larger distance from the frontier than their Finnish competitors.

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 picture. Plant performance in Indonesia is not only much more dispersed than in Finland, indicated by a higher absolute coefficient of variation, but also slightly growing over time whereas efficiency of Finnish plants is more or less fluctuating around a constant trend.

These patterns are mirrored by Figure 3, which depicts histograms of technical efficiency by country for 1975, 1984 and 1997. Because of data uncertainties one should not put much weight on small differences in plant performance but changes in distribution over time are nonetheless revealing. The figures show that on average Finnish paper mills exhibit a fairly constant technical efficiency around 70-80 percent throughout the whole period. Conversely, there is much more fluctuation in technical efficiency of the Indonesian paper mills, both in time and space. In 1975, there are only eight plants, mostly producing at less than 50 percent of best practice and in 1984 the distribution has become even more concentrated towards plants with a very low efficiency. However, we observe a somewhat different pattern in 1997. Besides a large group of highly inefficient plants there are a fair amount of mills, which produce at the high end of the distribution, comparable to, or even better than, the performance of Finnish plants. All and all there seems to be an increasing divergence over time in the performance of Indonesian plants, indicating that catch up in the export oriented industrialisation phase has been a highly localised process in which only a few plants have closed the technology gap with the frontier.

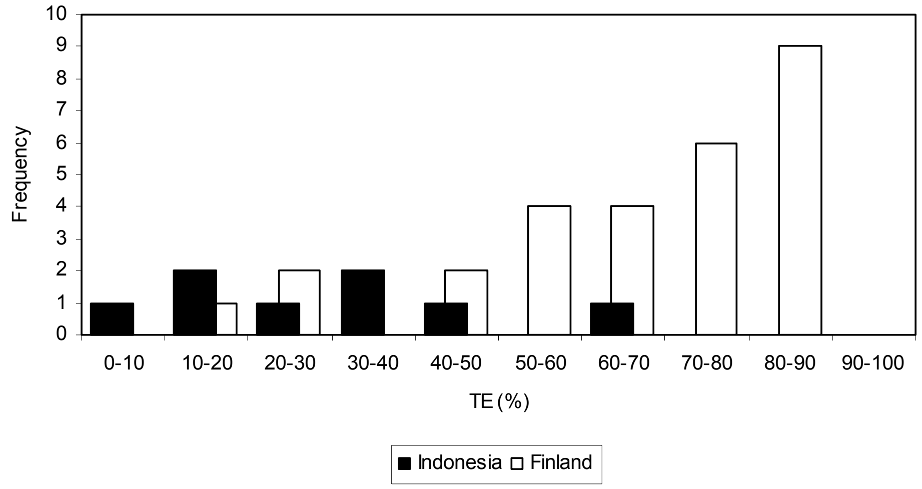
Figure 2: Technical Efficiency Coefficient of Variation by Country, 1975-1997



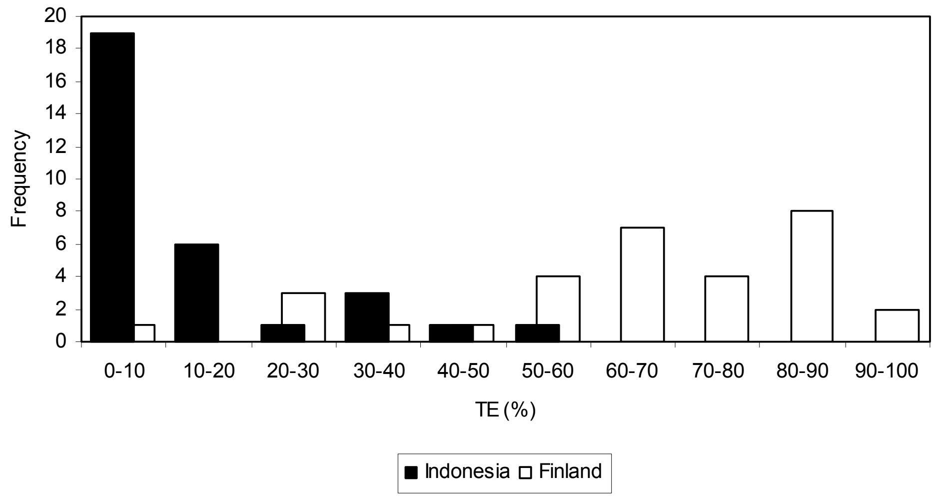
Note: Coefficient of Variation defined as standard deviation/mean

Figure 3: Technical Efficiency Distribution by Country

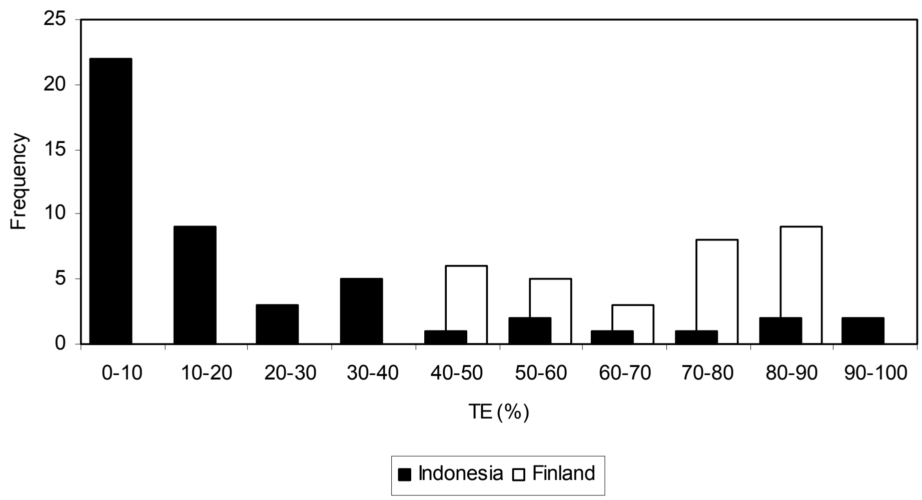
a: 1975



b: 1984



c: 1997



4.1.1 Industrial Dynamics and Catch Up

The previous sections showed that on average Indonesian paper mills were catching up relative to their Finnish peers. What is omitted from the analysis so far is the effect of industrial dynamics on catch up. The closing of the gap measured by an increase of industry-level technical efficiency in Figure 1 may be caused by two factors: (1) improvements in performance of individual establishments at a given size, and (2) reallocation effects caused by the expansion or contraction of surviving plants as well as entry and exit effects (Baily *et al.*, 1992). Haltiwanger *et al.* (1998) present and overview of 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:

$$TE_t = \sum_i s_{it} te_{it} \tag{5}$$

where s_{it} is the 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 period. Then the difference in aggregate technical efficiency levels at time t and $t-1$ can be written as:

$$\begin{aligned} TE_t - TE_{t-1} = &\sum\nolimits_{i\in C} s_{it-1}\Delta te_{it} + \sum\nolimits_{i\in C} (te_{it-1} - TE_{t-1})\Delta s_{it} + \sum\nolimits_{i\in C} \Delta te_{it}\Delta s_{it} \\ &+ \sum\nolimits_{i\in N} s_{it}(te_{it} - TE_{t-1}) - \sum\nolimits_{i\in X} s_{it-1}(te_{it-1} - TE_{t-1}) \end{aligned} \tag{6}$$

The first three components of equation (6) 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 output shares; (2) a between-plant effect – a change in 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 output share; (4) an entry effect, composed of 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 (6) by TE_0 gives the contribution of the five components to aggregate industry technical efficiency growth.

Table 4 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 correspond with the figures on average catch up at industry level (Figure 1). During import substitution industrialisation the paper industry was falling behind at a rate of approximately seven percent per year. This was caused both by rapidly diminishing performance of existing firms denoted by a within share of 81 percent, and the entry of firms with below average performance, measured by an entry effect of 85 percent. There are no exit effects because all plants stayed in business. Aggregate efficiency growth would have been even lower if mills of which performance deteriorated had not lost market share, indicated by the negative cross-plant effect. The low figure for the between effect points out that static effects of shifting market shares were almost insignificant. The decomposition results are in line with the characterisation of the import substitution phase. High tariffs and limited domestic competition provided neither incentive for efficient production, nor the entry of modern plants using best-practice technology.

During EOI, aggregate industry technical efficiency grew at rapid pace with on average 6 percent. The table illustrates that catch up was primarily driven by the expansion of establishments with also improved efficiency, indicated by a cross-plant share of 127 percent. Further, the entry share of 59 percent illustrates that the start-up of new plants also contributed substantially to catch up. Finally, the negative exit share (-20 percent) suggests that several high performing plants were forced out of the market, negatively affecting average industry efficiency.

Table 4: Decomposition of TE by Subperiod and Ownership

	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	0.9	-340	-34	327	175	-28	100
1975-1984	-7.2	81	5	-71	85	0	100
1984-1997	6.0	-29	-37	127	59	-20	100

Note: Percentages may not add up due to rounding.

Source: See Figure 1.

4.1.2 Catch up and plant characteristics

The analyses in the previous section 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 characteristics of best-performing mills.

A first indication is given by the inefficiency model at the bottom of Table 3 in which inefficiency scores are correlated with a number of explanatory variables. Due to lack of comparable data, we are only able to relate a few variables with plant performance. The model points out that size is negatively and significantly related to technical *in*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 industrialised and developing countries (Caves, 1992;

Lundvall and Battese, 2000). Finally, the analysis shows that after controlling for size, age and time, there is still a large gap in performance between Indonesian and Finnish mills, indicated by the positive and highly significant coefficient for *DINDO* in both models. This suggests that national factors are an important determinant of international differences in performance. It should however be noted that *DINDO* also captures the average effect of firm specific characteristics for which no sufficient data are available.

Fortunately, the Indonesian paper LMD contains additional information on plant characteristics for the period 1991-1997. We are therefore able to regress the efficiency scores for Indonesian mills on a number of additional variables to examine the traits of catching up plants for the period 1992-1997. We include the following variables. As *TE* is a fractional variable bounded between zero and one, directly using it 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 *TE* continuous (Ramanathan, 1989). Besides age and size we include variables for ownership, human capital, sophistication of machinery and international exposure.

We introduce dummy variables for conglomerate and public plants. Many manufacturing sectors in Indonesia are dominated by a number of very large internationally operating business groups and this is also the case for the paper industry (Hill, 1996). 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, 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 non production workers, which can be considered as a proxy for skilled labour. In addition we investigate the influence of the share of foreign labour on technical efficiency. 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 percent of paper manufacturing employees in the 1990s (Van Dijk, 2005). 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. In the literature trade has been identified as an important conduit for international knowledge spillovers (Pack and Saggi, 1997). Finally we add control dummies for year (not depicted).

Table 5 shows alternative specifications of our regression model. Most variables exhibit significant and stable coefficients and all the signs are according to what would be expected. Like before, we find that larger firms have a higher technical efficiency. Age is negatively correlated with inefficiency, indicating that younger plants which are likely to operate the last vintage of process technology exhibit higher performance. Ownership also has a strong influence on plant performance.

In line with expectations, paper mills that are part of a large business group enjoy certain advantages not available to independently operating establishments resulting in higher efficiency. Maybe in contrasts to the literature on state-owned companies in developing countries (World Bank, 1995), we find that public mills are more efficient than independent plants when not controlled for human capital and trade exposure. Secondary information on two of the three government mills still operating in 1997, underpin our results. PT Kertas Leces is considered a reasonably modern mill (AUSNEWZ, 1999), while PT Kertas Padalarang, although using almost 80 year old equipment, is manufacturing and exporting higher quality paper products (Minderhoud, 2002).

Table 5: Regression of Technical Efficiency (1991-1997)

	(1)	*(2)*	*(3)*
Size	0.001	0.001	0.001
	(7.08)**	(8.30)**	(6.14)**
Age	-0.016	-0.016	-0.020
	(2.09)*	(2.66)**	(2.66)**
Public	0.724	-	0.583
	(2.12)*		(1.71)
Conglomerate	1.106	-	0.771
	(5.09)**		(3.40)**
Foreign labour	-	20.742	12.263
		(2.90)**	(1.64)
Non production workers	-	0.502	0.157
		(1.16)	(0.35)
Export	-	0.878	0.779
		(5.31)**	(4.74)**
Constant	-2.253	-2.834	-2.728
	(9.81)**	(10.76)**	(10.38)**
Observations	294	294	294
R-squared	0.38	0.40	0.43
adj. R-squared	0.35	0.38	0.40

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

Regarding the indicators for human capital, the regression results indicate a positive and statistically significant relationship between foreign labour and technical efficiency in estimation 2. When we add dummies for ownership the coefficient for foreign labour becomes insignificant. This is not surprisingly as in particular large conglomerate companies are the ones to attract expensive foreign consultants and engineers. The coefficient for non production workers is positive but not significant in all models. This is probably to the broad type of indicator used for skilled employees. It would have been more appropriate to use a more direct measure such as years or type of education but this information was not available for our sample.

Finally, also 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 also not available for our study.

5 Conclusions

The aim of this paper has been to investigate catch up at the micro level. For this purpose we have analysed the performance of the Indonesian paper industry vis-à-vis that of Finland, which can be considered as world's technological leader. We have used a combined Indonesian-Finnish LMD for the period 1975-1997 to estimate plant level technical efficiency, analyse the industrial dynamics underlying the catching-up process and investigate what characterises the firms which have managed to catch up. Considerable effort has been made to ensure inputs and outputs are comparable across countries.

We found that during the period of import substituting industrialisation (1975-1984) the Indonesian paper industry was falling behind the frontier, while the export oriented industrialisation (1984-1997) phase was characterised by catch up. Closer investigation of the underlying plant-level data discloses that the averages only tell half of the story. Establishment performance in Indonesia is relatively much more dispersed than in Finland and this dispersion has become increasingly larger over time. Decomposition analysis pointed out that catch was mainly driven by the expansion of plants that also improved performance. Overall catch up of the Indonesian paper industry relative to the global frontier can therefore be described as a highly localised process in which only a few firms have achieved near best-practice performance, while most other plants have stayed behind. Finally, we found that Indonesian plants which are subsidiaries of large business groups, have a relative high share of foreign labour and are engaged in international trade are operating closer to the technological frontier than other mills.

This case study entails some important implications for aggregate research on economic growth and catch up. In contrasts to the existing micro-evidence which lack a clear international comparative perspective (Tybout, 2000), this research shows that in developing countries performance at the establishment-level is likely to be an erratic and much more dispersed phenomenon than in industrialised countries. Consequently, aggregate indicators of performance, such as output, labour or total factor productivity for developing countries can be misleading, resulting in wrong policy conclusions. On the basis of the aggregate figures for technical efficiency (Figure 1), one is likely to conclude that the development of the Indonesian paper industry can be regarded as a successful case of technical change and catch up. However, the analysis of distribution proves otherwise.

Having said this, this paper should be regarded only as a first step in increasing our understanding of catch up at the micro-level. This study could be improved by collecting additional data on prices, intermediate input and information on plant characteristics such as education of workforce. Problems with data availability were also the reason that our research was restricted to the investigation of only one single manufacturing sector. Future research should be directed at making more elaborate international comparisons of performance, possibly including additional industries and countries.

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