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SUMMARY
In this paper, we analyse the diffusion and adoption of paper making machinery in the Indonesian pulp and paper industry, from 1923 till 2000. The two main questions in this paper are: (1) What patterns of technology diffusion can be discerned in the Indonesian paper manufacturing sector? (2) What role have industrial policies played in the diffusion of technology and the expansion of the paper industry? To address these questions, we develop a machine index (*mach*), which measures the technological distance of each paper machine to the world technological frontier through time. The documented trends in an aggregate version of the technology index reveal a pattern of rapid catch up. The paper argues that industrial policy has played an important role in the speed and nature of diffusion of paper making machinery in Indonesia. A more disaggregated analysis indicates that conglomerate owned mills adopted advanced paper machines close to the technological frontier, while independent and publicly owned mills installed more outdated equipment. Embodied technological catch up in paper making has thus been a highly polarised phenomenon, limited to only a few firms, which had the financial resources and the capabilities to install large-scale modern machinery.

Keywords
Asia, Indonesia, Pulp and paper industry, Technology diffusion, Technology adoption, Industrial policy

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1 Introduction

The diffusion of new vintages of capital goods is an important source of economic growth and has attracted much research. In this paper we analyse the diffusion and adoption of paper making machinery in the Indonesian pulp and paper industry, since the installation of the first paper machine (PM) in 1923. We pay special attention to the impact of industrial policies on the diffusion of technology in this important industry.

There is a considerable body of literature investigating technology diffusion and adoption. Diffusion is defined as the process by which new technologies spread across the economy over time, while adoption refers to the installation of new technology by individual firms (Lissoni and Metcalfe, 1994; Stoneman, 2002). Technology diffusion is therefore a much more aggregate phenomenon than technology adoption which involves the decisionmaking process of individual firms. Both are important to understand the causes of embodied technical change.

So far most empirical and theoretical studies on these topics have primarily focused on industrialised countries.[1] Technology diffusion and adoption in a developing country context has attracted less attention and is less well understood.[2] In this paper we try to fill this gap by explicitly focusing on the analysis of diffusion of technology in a developing country context.

Conditions in developing countries differ considerably from those in industrialised countries, in terms of macro-economic stability, competitiveness of markets, rationality of economic policy and transparency of governance (Tybout, 2000). This affects the diffusion of capital goods through the economy. For instance, frequent mention has been made of the dual economy characteristics of industries in developing economies, in which large-scale modern firms operate next to small traditional companies, using outdated technology (Nelson, 1968; Blomström and Wolff, 1997).

Industrial policies in developing countries may facilitate technology diffusion and promote catch up. The classical reference is Gerschenkron (1962) who pointed out that investment banks and the state played a major role in accelerated industrial development in Germany and Russia in the late nineteenth century. In the post-war period, we see similar patterns in South Korea where industrial policies and *chaebol* formation have facilitated rapid capital accumulation, diffusion of technology and industrialisation (Amsden, 1989; Kim, 1997).

Two main questions are posed in this paper. First, what patterns of diffusion can be discerned in the Indonesian paper manufacturing sector? Second, what role have industrial policies played in the diffusion and adoption of paper machine technology in Indonesia?

The Indonesian paper manufacturing sector provides an interesting case study of industrial development and technical change. Before the Asian crisis of 1997, Indonesia was seen as a second-tier Asian tiger (World Bank, 1993). Growth in GDP per capita averaged 3.6 per cent per year between 1960 and 1998 (Fane, 1999). The evidence suggested that the country was on a progressive path of industrialisation and development, crudely disrupted by the financial crisis of 1997 (Hill, 2000). Paper manufacturing has been an important sector in Indonesian industrialisation. With an annual average growth in output of more than 15 per cent between 1960 and 2000, it was one the fastest growing industries of the New Order of the Suharto regime. Since the mid-eighties, the industry experienced spectacular investment and modernisation, turning Indonesia into one of world's largest producers and exporters of paper

products. Companies installed the latest vintages of machinery, matching those operated in Finland, the world technological leader in paper manufacturing.

During its approximately 80 years of existence, Indonesian paper making has gone through a number of stages. These include colonial, state-led, import-substituting and export-oriented industrialisation, finally ending in a period of deep recession and hesitant recovery. The long time span and the frequent changes in industrial policy offer ample opportunity to investigate technology diffusion and adoption in a developing country context. The analysis is based on a rich database consisting of virtually all PMs installed over the life cycle of the industry since 1923.

The structure of this paper is as follows. Section 2 of this paper focuses on the evolution of industrial policy. In section 3, we describe the dataset. We present and discuss a machine index, which is used to analyse the diffusion of technology in the industry. The empirical analysis is presented in section 4. It focuses on three issues: (a) the influence of policy regime on technological catch up, (b) machine-level variations in technological level and the emergence of a dual technological structure, and (c) the influence of ownership and policy on adoption decisions. Conclusions are drawn in section 5.

2 The Evolution of Industrial Policy[3]

Since 1923, one can distinguish five industrial policy regimes in the Indonesian pulp and paper industry. They closely mirror the development of Indonesian manufacturing as a whole.[4]

2.1 Colonial Industrialisation: 1923-1958

In 1923, the first mill, N.V. Papier Fabriek Padalarang, was established on Java by the Dutch paper producer, N.V. Gelderland, as part of a programme by the colonial government to promote industrialisation in Indonesia,. In 1939, the same company established a second mill in Letjes, East Java with a capacity of 3,000 tonnes per year (tpy). Both mills were built to produce printing and writing paper from rice straw to provide for the needs of the Dutch colonial government. The combined capacity of the two mills amounted to about 6,500 tpy, produced by three PMs (in 1933 Padalarang installed a second machine). Although fairly small-scale, the machinery can be considered of reasonable quality. It was supplied by the Swiss/German company Escher Wyss, one of the leading equipment manufacturers at the time. Like total manufacturing, the development of the industry came to a standstill during the war years and the post-independence-period.

2.2 State-led Industrialisation: 1958-1974

After independence the Indonesian government adopted a policy of state-led industrialisation to build up a strong national industry. This also applied to the pulp and paper industry. In 1958, like many other formerly Dutch owned companies, the two paper mills were nationalised. Their main function was meeting the demand of the Ministry of Culture and Education for writing books and paper. Between the late 1950s and early 1970s, the domestic supply of paper was expanded through the construction of five more public mills. Installed capacity amounted to a total of 44,500 tpy, but because of various problems such as the lack of spare parts and shortages of raw material, actual production was only 18,000 tons, corresponding with an utilisation rate of about 41 per cent (Koehler, 1972). Overall, the Indonesian pulp and paper industry was uncompetitive in the early 1970s. By international standards all firms were small and export potential was limited.

2.3 Import Substituting Industrialisation (ISI): 1974-1984

The Indonesian government aimed to stimulate growth through import substituting industrialisation during the late 1970s and early 1980s (Fane, 1999). In this policy context the pulp and paper industry went through a phase of rapid development between 1974 and 1984. The number of firms increased from 7 to 31, and installed paper capacity expanded almost tenfold from 61,873 to 606,000 tpy (Figure 1). The industry also diversified as the first board and tissue paper producers entered the market. All new mills were privately owned. The predominant factor behind the rapid expansion was the introduction of high tariff protection, stimulating the investment in new, mainly non-integrated, mills. Nominal tariffs of up to 60 per cent were levied on all grades of paper whereas no tariffs were levied on pulp inputs. The World Bank (1981) estimated that the rate of effective protection was 90 per cent on average, ranging from very high rates of protection for smaller mills, to 60 per cent for the larger ones. Subsidised energy prices also contributed to high effective protection rates (FAO, 1984). About 50 per cent of the plants, were only profitable because of tariff protection, and international competitiveness remained limited (Jaakko Pöyry, 1984).

2.4 Export Oriented Industrialisation (EOI): 1984-1997

Around 1984, the Indonesian government adopted a more liberal approach to industrialisation (Hill, 2000). As in other manufacturing sectors, tariffs on pulp and paper were phased out to increase international competition. However, unlike most other manufacturing sectors, government intervention did not stop there. The pulp and paper industry was regarded by the Indonesian government and, in particular the Ministry of Industry and Trade, as an important opportunity to replace the declining oil industry as a source of foreign exchange (WALHI/ YLBHI, 1992; Stafford, 2000). At the end of the 1980s, therefore, the Ministry announced its plan to rank Indonesia among the top ten pulp and paper producers of the world by the year 2000. A related reason for promoting the pulp and paper industry was the continuing importance of views about resource-based industrialisation that had been prominent in Indonesia since the start of the New Order (Auty, 1987). These views were largely focused on the county's abundant tropical forest resources. The expansion of a pulp and paper industry was seen as the logical next step in the downstream integration of wood based manufacturing.

One of the key elements in the industrial policy to promote a large export-oriented national pulp and paper industry has been the provision of large tracts of mixed tropical hardwood (MTH) against very low concession costs for the establishment of industrial tree plantations (*Hutan Tanaman Industri*, or HTI). HTI licence-holders are allowed to clear-cut their concession areas and use the obtained wood as a temporary 'bridging supply' till the pulpwood plantations are fully online (Manurung and Kusumaningtyas, 1999). One consequence was that Indonesian companies' raw material costs were at times only 20-30 per cent of those faced by American and European producers.[5] Other subsidies provided by the Indonesian government to promote the pulp and paper industry included: plantation subsidies, discounted loans from state owned banks and tax deductions (Barr, 2001b).

As a consequence of the industrial policy the pulp and paper sector started to grow rapidly, elevating Indonesia to one of the world's leading pulp and paper producers and exporters. Pulp and paper capacity was boosted by the expansion of existing plants and the construction of new mills. In contrast to previously installed processing facilities, companies purchased large state-of-the-art PMs – some of which were among the largest in the world (Rudd, 1999) – to take full advantage of scale economies and guarantee profitability during downward

cycles. Between 1984 and 1997, production capacity of paper increased from 606,000 to 7,168,000 tpy, an average increase of 15 per cent per year (Figure 1).

2.5 Crisis and Emerging Reform: The period since 1997

In 1997, the East Asian financial crisis had a disastrous impact on the Indonesian economy, which in turn put an end to the expansion of the pulp and paper industry. Many large pulp and paper companies were already heavily indebted before the onset of the Asian crisis, because of the financing of the gigantic capacity expansion they had pursued. Consequently, when the Rupiah depreciated, dollar-denominated debts started to put considerable financial pressure on the companies and forced many pulp and paper companies to delay or cancel their plans for future expansion (Ibnusantosa, 2002). Finally, the move to a more democratic political system, triggered by the economic crisis, allowed more open and critical assessment of Indonesia's environmental performance (World Bank, 2001). With respect to the pulp and paper industry it became clear that its development had been unsustainable (Barr, 2001a). As a result, the government introduced new regulations limiting the use of mixed tropical hardwood and reducing the size of plantations to a maximum of 200,000 ha (except for Irian Jaya). Plantations have to be fully operational before new plants are allowed to come on-line (Sutopo, 2000).

Figure 1: Capacity, Net Export, Production and Consumption of Paper (000 tpy), 1960-2000
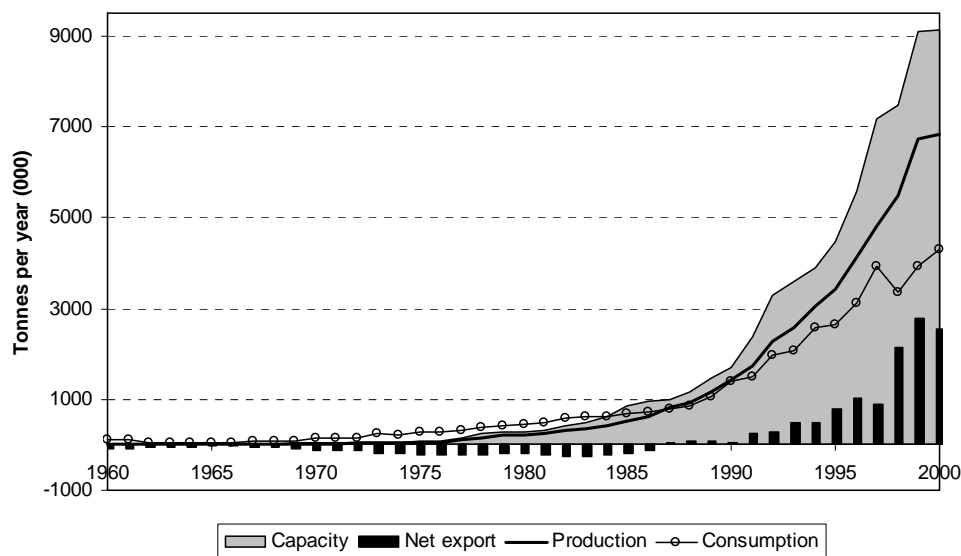
Source: APKI (various issues).

3 The Machine Index (*mach*)

3.1 Dataset

The pulp and paper industry is composed of two interconnected sub-sectors: pulp and papermaking, which can either be vertically integrated within one mill or separated into two. In the pulp sector, the raw material, mainly wood, is transformed into pulp. In the papermaking sector, the pulp is transformed into paper, basically through the use of one very large single piece of equipment, the paper machine (PM). Paper manufacturing is a very scale and capital-intensive process. Presently, state-of-the-art PMs may cost more than US$ 400 million apiece and typically account for over 50 per cent of total investment costs of new

paper mills.[6] It can therefore be regarded as the 'core technology' in the papermaking process (Szirmai *et al.*, 2002).

We have constructed a comprehensive database, containing most, if not all of the PMs in operation since the installation of the first machine in 1923 up to 2000. Details on the sources used are provided in the appendix. For almost all machines the database contains information on: owner characteristics; year of start-up; brand or country of origin; type of paper produced (printing and writing paper, cartonboard, containerboard, newsprint, specialty paper or tissue); design speed, width and capacity.

Generally data are only available for two to four datapoints per PM. We assume that width and class (i.e. the type of paper produced on the machine) remain unchanged during the lifetime of the PM. To interpolate data on speed for the lifetime of the machine, a combination of four strategies has been used: (1) For most PMs, intermediate years could be easily estimated because there was no retrofitting and capacity and speed remain constant over time;[7] (2) If there is only one PM at the mill site or capacity of all other PMs is known, trends in aggregate mill capacity are used to extrapolate individual PM data; (3) For a few PMs detailed information was available about the year and extent of retrofitting; and (4) If all other strategies could not be applied, compound growth rates are used to estimate the intervening years between the data points. In total, the dataset includes the records of 158 PMs.

Figure 2 shows the total number of PMs in Indonesia between 1923 and 2000 by class. The picture shows a steep rise in the number of PMs as well as a pattern of diversification at the beginning of ISI in the mid 1970s. During EOI, the number of PMs increased gradually till the crisis in 1997, when growth stagnated. Since 1923, not a single machine has been scrapped because of obsolescence or for other technical reasons. This is illustrated by the fact that the first three PMs in Indonesia, installed by the Dutch paper manufacturer in 1923, 1931 and 1939, respectively, are still in operation today. The 9 PMs that stopped producing belonged to paper mills that went bankrupt.

Figure 2: Number of PMs by Class, 1923-2000
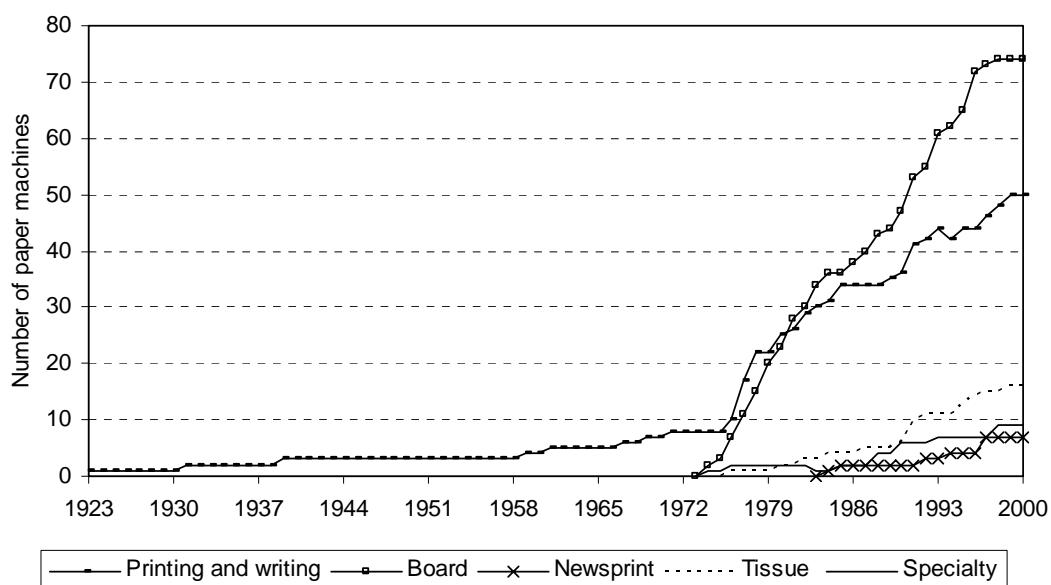
Note: board is sum of container and cartonboard PMs.
Sources: See appendix.

3.2 Construction of the Machine Index

There are various approaches to the measurement of technology diffusion and adoption depending on data availability and the nature of the technology studied. Frequently used measures for diffusion are the number of adopters divided by the number of total potential adopters (the rate of imitation) or the percentage of output attributable to the new technology (the overall rate of diffusion) (Lissoni and Metcalfe, 1994). For the analysis of adoption, a common approach is to relate the adoption decision of a firm to various firm and market characteristics, such as size and concentration, using a probit model (e.g. Davies, 1979). If panel data is available more sophisticated analyses are possible using duration analysis, which takes into account the lag before a firm adopts the technology (Levin *et al.*, 1987; Stoneman and Karshenas, 1993).

These standard methods suffer from the major drawback that technology adoption and diffusion is reduced to the analysis of technological substitution in which an 'old' technology is replaced by a 'new' technology. Using such an approach one can only address radical technological change, such as for example, hand vs. mechanical reapers (David, 1975) or open hearth furnaces vs. basic oxygen furnaces (Oster, 1982). Incremental change in design, e.g. improvements within mechanical reapers or blast furnaces, is neglected. This criticism is particularly relevant for the analysis of diffusion and adoption in process industries, where incremental technical change is more important than radical innovation (Enos, 1962; Hollander, 1965; Utterback, 1994).

Furthermore, in the context of a developing country, it is probably not very relevant to limit the analysis to the diffusion or adoption of radical innovations. Many firms are operating far behind the technology frontier and only a few adopt best-practice technology. A large part of the capital goods in developing countries are second-hand or in other ways already obsolete when they are purchased. Nevertheless, it has been shown that such equipment can still be operated profitably in a developing country context because of low labour costs or limited demand (Stewart, 1977; Pack, 1987; Navaretti *et al.*, 2000). Interviews with technology suppliers and other sources indicated that this phenomenon also occurs in the Indonesian pulp and paper industry. Thus, in order to measure diffusion and adoption of technology in developing countries, one should take into account that variability in technological sophistication of capital equipment might be high.

Since its origin, the PM has followed a technological trajectory (Dosi, 1984) of incremental technical change resulting in a gradual increase in speed and width (see Figure 7 and Figure 8 in the appendix). Radical technical change has been absent and the current design of the machine still strongly resembles that of the original 'Fourdrinier' model developed more than 200 years ago (Clapperton, 1967; Diesen, 2000). Hence, conventional methods to measure technology diffusion and adoption are difficult to apply because it is not easy to identify major changes in the design of the PM, which can be regarded as "new" technology.[8] Therefore, we have constructed a machine index (*mach*), which measures the distance (gap) between each machine and the world technological frontier at each point in time.[9] In this way technological levels of PMs can be compared over time and between classes of machine, which have broadly followed the same trajectory.[10] The index captures both embodied technical change (radical and incremental) and technological catch up with the frontier. It is defined as:

$$mach_{it} = \frac{p_{it}^{c}}{F_{t}^{c}},\qquad(1)$$

the ratio between the technological parameter p_{it}^{c} observed for each PM i of class c at year t and the world technology frontier (i.e. the global maximum parameter value) F_{t}^{c} for the same year and class. In this paper, we measure the key technical parameters speed and width. The appendix describes the sources and procedure for the construction of the world technology frontier. The final *mach* index used in the remainder of the paper is defined as the unweighted average of speed and width based indices, using equation 1.

Note that the technology frontier is defined as absolute *global* best-practice, i.e. a composite measure of all technologically most advanced PMs in the world which are not necessarily active in the same country. This is different from most productivity based technology gap studies which take the performance of one country (mostly the USA) as benchmark (i.e. Szirmai, 1994; Timmer, 2000). Hence, in this measure, even best performing countries may still show a technology gap with the world frontier as it is unlikely that they will have adapted frontier technology continuously, given the long lifespan of paper machinery.

In order to derive insights in the overall pattern of technology diffusion and embodied technological catch up we also construct an aggregate industry index of technological sophistication (*MACH*). Similar to the standard measures for technology diffusion (i.e. rate of imitation or overall rate of diffusion), an increase in *MACH* indicates the spread of more advanced technology across the economy. We present two versions of the *MACH* index. The first version is an unweighted *MACH* index, which is computed as the simple annual average of all the machine indexes *mach$_{it}$*. This version of the index tends to understate the technological sophistication of the machine park as small obsolete machines with low capacity receive equal weight to vast state-of-the art machines which account for most of output. To accommodate this problem we also compute a weighted *MACH* index, using the values of maximum capacity output per machine (market price times capacity output) as weights.[11] This provides a more realistic picture of trends, however one should realise that the weighted measure involves some degree of double counting, as the machine index itself is already based on maximum machine capacity. The weighted and unweighted *MACH* indices must therefore be regarded as upper and lower boundaries of the "true" *MACH* index. Both indices are reproduced in Figure 3. They show similar patterns of catch up, but catch up in the most recent period is more pronounced using the weighted index.

4 Analysis

4.1 Industrial Policy Regime and Technology Diffusion

Figure 3 presents *MACH* for the period 1923-2000. The figure suggests a close relationship between the prevailing industrial policy regime and the technological level of paper making machinery as measured by *MACH*. During the colonial period (1923-1958) PMs installed were of reasonable sophistication. However, the underlying data indicates that this was more so in terms of width than in terms of speed. From 1940 till 1959 no new PMs were installed while the existing machines were not upgraded. As a consequence Indonesia was falling behind world best-practice, reflected by a decrease of *MACH* from about 25 till 17. The subsequent period of state-led industrialisation (1958-1974) is characterised by stagnation. State-owned companies installed in total 5 new machines, which were of relative low technological level vis-à-vis world best-practice. During ISI (1975-1983) the industry started

to gain dynamism and some signs of catch up become visible at the end of the period. Despite the introduction of a large number of new machines (see Figure 2), PMs are initially slower than some of the equipment installed earlier, illustrated by the slightly U-shaped pattern during this period. Overall, our database indicates that most machines installed during ISI were second hand or produced by Taiwanese manufacturers, who have specialised in the manufacture of less-advanced equipment for the Asian market. Throughout the EOI phase (1984-1997), the industry started to catch up rapidly. *MACH* was moving upward swiftly, caused by investment in state-of-the-art equipment. Many of the new machines were manufactured by Beloit-Mitsubishi, Voith Sultzer or Valmet/Metso, the three leading PM producers in the world. On average, the technological level of Indonesian PMs reached around 60 percent of world best-practice at the end of the 1990s (using the weighted MACH index). During the crisis (1997-2000), only a few new PMs were installed and catch up stagnated.

**Figure 3: Average Technological Level of PMs (*MACH*), 1923-2000**
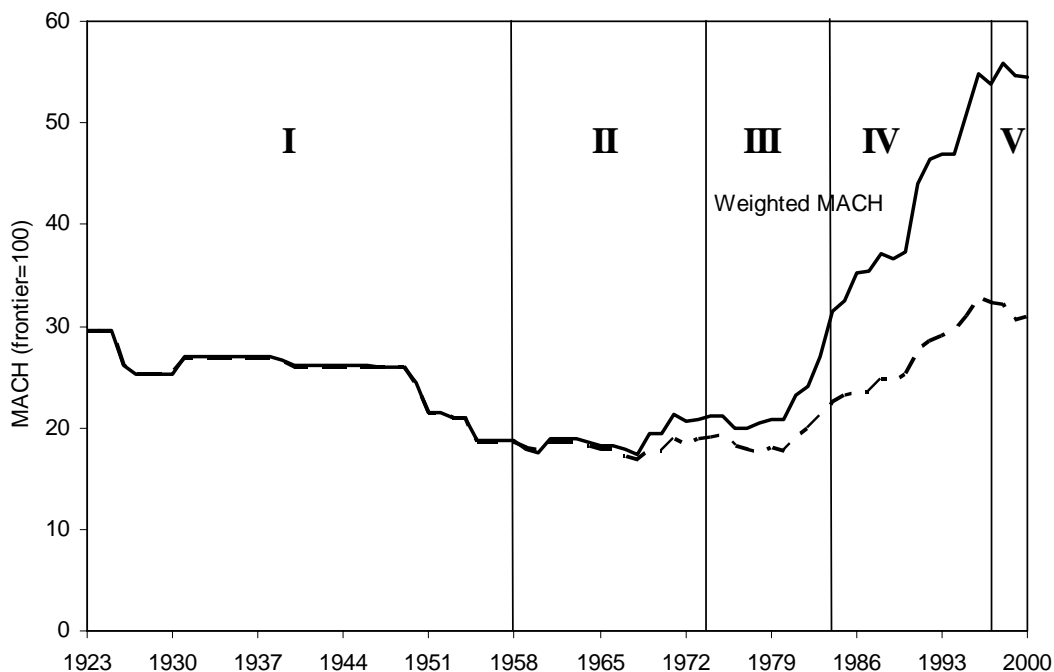
Note: MACH is based on 140 PMs; The five periods distinguished correspond with the industrial regimes described in section 2: I colonial industrialisation (1923-1958); II state-led industrialisation (1958-1974); III import substituting industrialisation (1974-1984); IV export-oriented industrialisation (1984-1997); and V crisis and reform (1997-...).
*Source: S*ee appendix.

4.2 Micro-level Variation in Technological Level

In this and the subsequent section, we will go beyond the aggregate figures and investigate technology diffusion and adoption at the micro level. First the distribution of the machine index (*mach*) is analysed over time. Figure 4 depicts a three dimensional diagram of kernel density for *mach* for the period 1977-2000 and Figure 5 presents corresponding kernel density plots for 1977, 1984 and 2000, based on 31, 72 and 129 PMs, respectively.[12]

Figure 4: 3D Kernel Density Plot of *mach*, 1977-2000
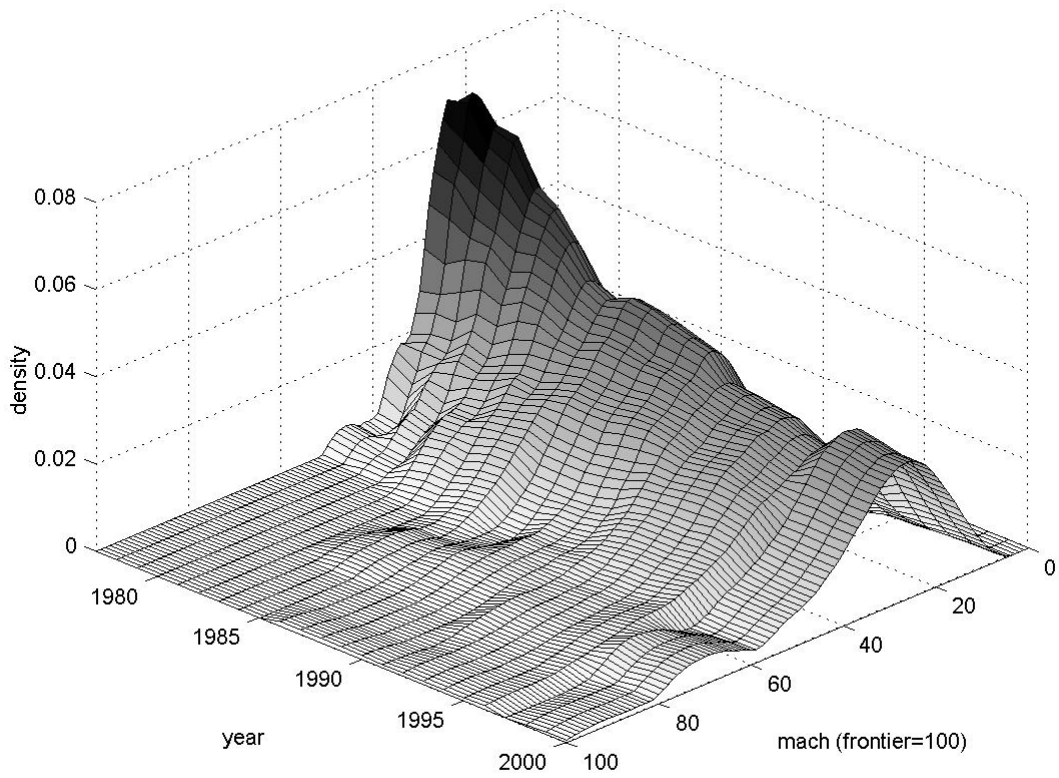
Source: see text.

Figure 5: Kernel Density Plot of *mach*, Selected Years
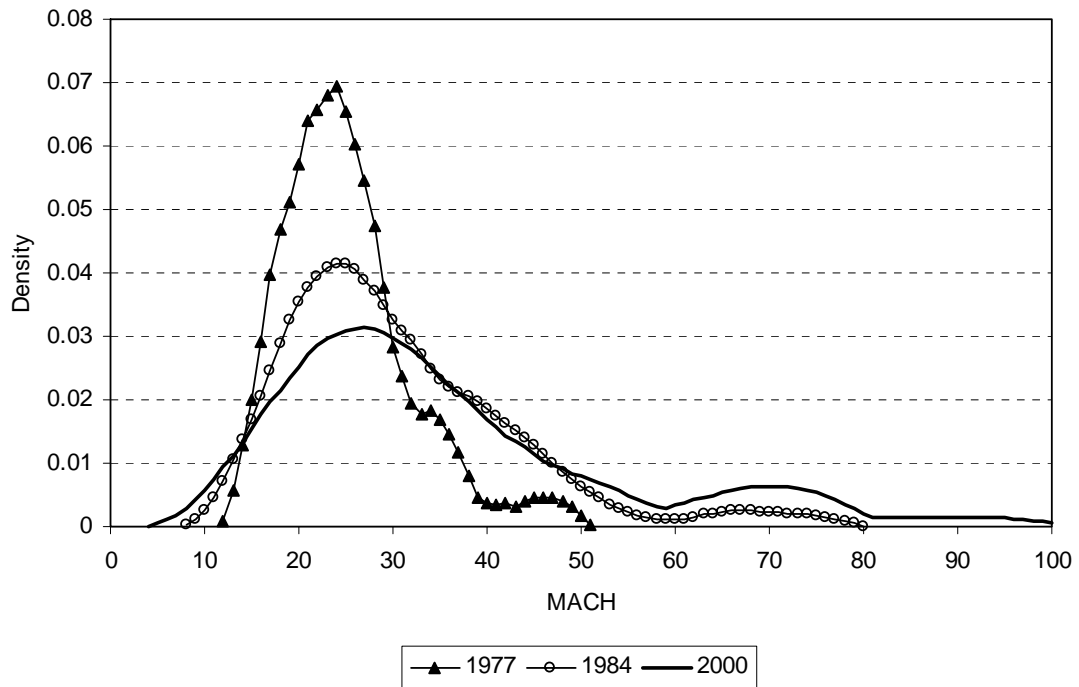
Source: see text.

Before 1977, the number of PMs is insufficient to estimate meaningful kernel densities. The graphs show a trend from a more-or-less normal distribution around a *mach* value of about 25 in 1977, towards a dual structure with twin peaks around 25 and 70 per cent. The peaks emerged at the onset of the EOI phase in 1984 and became even more pronounced by 2000. This confirms the qualitative evidence that throughout ISI investment was mainly in outdated and second-hand technology, while during EOI some companies adopted state-of-the-art machinery. It also qualifies the aggregate trends in Figure 3 by showing that technological catch up has not been an industry-wide pattern. In reality, a few very modern PMs have pushed the industry machine index (*MACH*) upwards.

4.3 Ownership, Industrial Policy and Technology Adoption

The distributional analysis suggests the emergence of a techno-dualistic structure in which only a few plants are responsible for catch up. In this section, we investigate the relationships between ownership structure, industrial policy and technology adoption in the Indonesian pulp and paper industry. Three ownership structures can be distinguished in the Indonesian pulp and paper industry: conglomerates, public mills and independently operating companies. Except for the first three PMs installed in Indonesia by the Dutch producer, no foreign companies were active in the paper sector.[13]

For two reasons we expect that conglomerate-affiliated producers will adopt more advanced equipment than the other two types of companies. First, business groups are better capable of financing the modern large-scale pulp and paper mills, than independently operating firms. Because of their size, they can raise substantial amounts of funds in the national or international capital markets to finance modern equipment. This is further facilitated by the fact that most large Indonesian conglomerates own their own banks. In addition, familiarity with the execution of large investment projects, presence of internal engineering departments and experience in dealing with international equipment vendors also contributes to their advantage. Second, it is well known that most of the businessmen heading the large business groups were well connected with the Suharto family (MacIntyre, 1994; Schwartz, 1999).[14]. Hence, these companies were in a much better position to get access to the wide range of subsidies offered by the government as part of the EOI policy.

Figure 6 plots *mach* for the year the machine was installed, by ownership structure. The three PMs installed during colonial industrialisation by the Dutch paper producer are considered as conglomerate-owned mills. In 1977, Sinar Mas was the first conglomerate to move into paper manufacturing by installing two second-hand Taiwanese PMs at its Tjiwi Kimia caustic soda plant (Pappens, 1993). During the ISI and EOI phases a wide range of machines were installed. However, the figure shows that it were predominantly the conglomerate business groups which purchased PMs close to the technology frontier and independent companies, which installed outdated technology. The technological sophistication of the public PMs is mixed. During state-led industrialisation, the PMs installed by government-owned mills were obsolete and after 1975 three of the five new PMs installed had a *mach* lower than 50, whereas two others exhibit a *mach* of over 60.

Figure 6: *mach* at Time of PM Installation by Ownership, 1923-2000
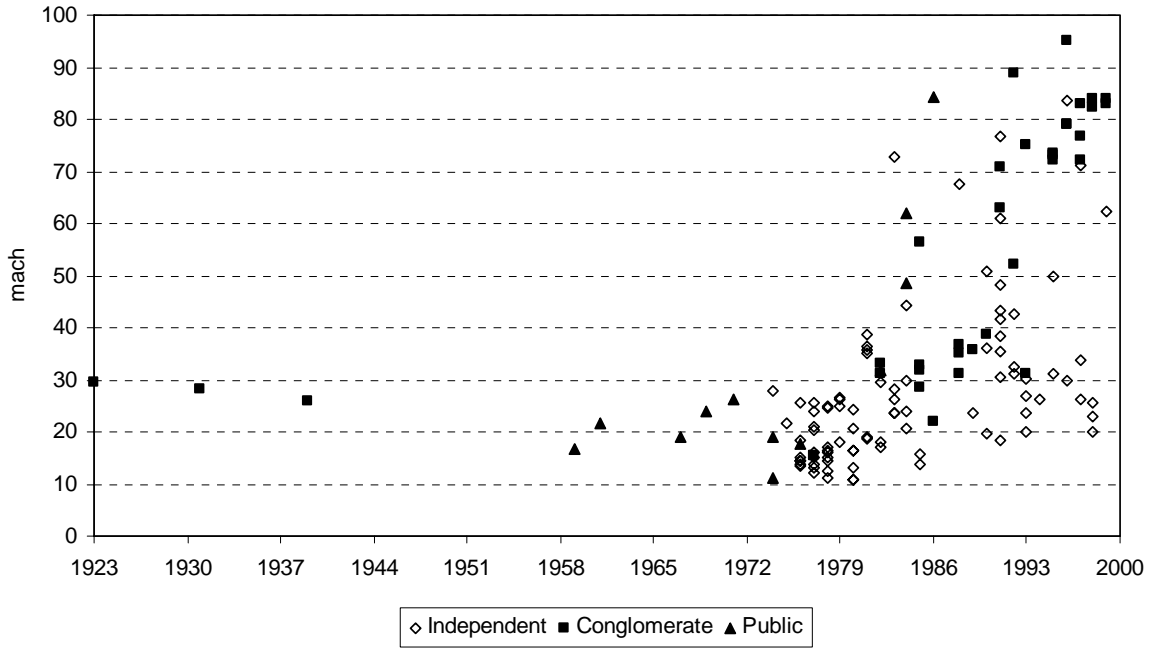
Note: In total 140 PMs are depicted.
Source: See appendix.

Figure 6 suggests that the conglomerate-owned producers are likely to be responsible for the emergence of the right-hand peak in the dual distribution found before. We estimate the following equation to test the relationship between the adoption of advanced machinery, ownership and industrial regime.

$$mach_{it} = \beta_0 + \beta_1 INT_{it} + \beta_2 DNEWS_{it} + \beta_3 DBOARD_{it} + \beta_4 DTISS_{it} + \beta_5 DSPEC_{it} +$$
$$\beta_6 DCON_{it} + \beta_7 DPUB_{it} + \quad\quad\quad (2)$$
$$\beta_8 DI + \beta_9 DII + \beta_{10} DIV + \beta_{11} DV$$

In this equation the dependent variable *mach$_{it}$* refers to the machine index at the time of installation of each machine depicted in Figure 6. As *mach* is a fractional variable, bounded between zero and one, using it directly in ordinary least squares estimation would introduce a bias. To solve for the boundary problem we apply the logistic transformation (ln(*mach*/(1-*mach*)) to make *mach* continuous (Ramanathan, 1989). The independent variables in equation three can be divided into three groups:

❖ *DINT, DNEWS, DBOARD, DTISS, and DSPEC* are control variables for integrated mills (including pulping facility), newsprint, board, tissue and specialty machines, respectively. Printing and writing machines form the control group.

❖ *DCON* and *DPUB* are ownership dummies for conglomerate and independent mills. The control group is independent mills.

❖ *DI, DII, DIV,* and *DV* are dummies corresponding to the following four industrial regimes: colonial industrialisation (1923-1958), state-led growth (1959-1974), EOI

(1984-1997) and recession (1998-2000). ISI (1975-1983) is the reference period. They can be regarded as indicators for the specific industrial policies underlying each phase.

Besides ownership and the control dummies we are not able to analyse the influence of other firm characteristics on technology adoption because the installation of new PMs often coincides with the start-up of the mill itself. In such cases (69 out of 163 PMs in our sample) plant size, age or export are (in part) endogenous to a firm's decision to adopt new technology and are therefore not yet known at the time of installation.

Table 1: Relationship between Technology Adoption, Ownership and Industrial Regime

	A	B	C	D
Constant	-0.917**	-1.460**	-1.518**	-1.787**
	(5.80)	(9.34)	(10.48)	(13.37)
DINT	0.415*	0.385	0.502**	0.455*
	(1.99)	(1.96)	(2.80)	(2.57)
DNEWS	1.102*	0.766	0.374	0.193
	(2.23)	(1.82)	(0.96)	(0.56)
DBOARD	0.209	0.624**	0.127	0.443**
	(1.06)	(3.46)	(0.81)	(2.97)
DTISS	0.347	0.598	-0.040	0.186
	(0.95)	(1.93)	(0.14)	(0.74)
DSPEC	-0.451	-0.277	-0.966**	-0.763**
	(1.12)	(0.82)	(3.05)	(2.73)
DCON	-	1.445**	-	1.110**
		(7.27)		(6.47)
DPUB	-	0.092	-	0.387
		(0.29)		(1.11)
DI	-	-	0.063	-0.732
			(0.12)	(1.55)
DII	-	-	-0.079	-0.224
			(0.24)	(0.60)
DIV	-	-	1.312**	1.028**
			(8.61)	(7.32)
DV	-	-	1.840**	1.464**
			(5.59)	(4.89)
Observations	140	140	140	140
adj. R-squared	0.05	0.32	0.44	0.57

Note: ** significant at 1 per cent level;
* significant at 5 per cent level;

Table 1 summarises the results of our estimation using various combinations of independent variables. The results are in conformity with prior expectations. *DCON* is highly significant and positive in models including and excluding period dummies, indicating that irrespective of the period and, hence, industrial policy, it have been the large business groups which were able to adopt large and sophisticated process technology. Public firms have on average installed PMs of similar sophistication to those purchased by independently operating paper producers.

The period dummies point at some relationship between technology adoption and industrial policy for some industrial regimes. The insignificant values for *DI* and *DII* indicate that the ISI policy did not result in the installation of relatively more advanced equipment in comparison with the two previous industrial policy regimes. The rapid catch up in technology during EOI, which continued even just after the crisis, is confirmed by the highly significant and positive values for *DIV* and *DV*.

5 Conclusions

This paper deals with embodied technical change in the Indonesian pulp and paper industry. It analyses the diffusion of PMs - the core technology used in paper manufacturing. The paper makes both methodological and substantive contributions.

At the methodological level, we argue that conventional methods focusing on the diffusion and adaptation of new technologies are not appropriate for process industries, where technical change is largely incremental. As an alternative, we have developed a machine index (*mach*), which measures the technological distance of each PM to the world technological frontier. In this way, it is possible to compare the technological level of PMs over time and space. This index could be used to analyse embodied technical change in other process industries, such as blast furnaces, cement kilns or petrochemical industries.

The documented trends in the industry machine index (*MACH*) suggest that industrial policy has played an important role in the speed and nature of diffusion of paper machinery in Indonesia. The first PMs, installed by the Dutch in the colonial period were of reasonable quality. During the state-led and ISI periods relatively less advanced equipment was adopted, in the form of second-hand machinery or machinery produced in Taiwan. At the end of the ISI period and in particular during the expansion phase, the Indonesian paper making industry experienced rapid technological catch up. This catch up was spurred by the installation of a number of state-of-the-art PMs manufactured by leading PM suppliers.

Investigation of the spread of *mach* at machine level points to the emergence of dual technological structure. The analysis indicates that conglomerate owned mills adopted advanced PMs close to the technological frontier, while independent and publicly owned mills have installed relatively obsolete equipment. Technology diffusion in paper making has therefore been a highly polarised phenomenon, limited to only a few firms, which had the finance and capabilities to adopt large-scale modern machinery. These findings are in line with the theory on industrial dynamics in developing countries, which argues that preferential access to government subsidies, niche markets, and abundant labour and scarce capital, result in dualistic market structures.

The stated aim of Indonesian industrial policy was to transform Indonesia into one of the leading paper manufacturers exporters. To this end, industrial policy encouraged the installation of world-class technology. We conclude that in many respects the type of policy implemented during EOI has been successful in promoting capital embodied technological change in the pulp and paper sector. It confirms that government support in the form of subsidies or grants is of particular relevance to promote the diffusion of embodied technology in scale- and capital-intensive manufacturing industries.

However, as evidenced by the experience of the Asian tigers, the process of successful industrialisation and catch up involves more than embodied technological change. It requires the building of complementary skills, capabilities and the facilitation of linkages and

spillovers to other sectors. It seems that in this respect, the Indonesian experience has been less positive. Ongoing research (Van Dijk and Bell, 2004) indicates that little has been done in the field of capability building and the industry remains overly dependent on imported technology, spare parts, ancillary machinery and expatriate skills. Also, the dual structure found in the data, indicates that technology diffusion has been partial and incomplete. Finally, the recent work of Barr (2001a; 2001b) showed that the expansion of the pulp and paper industry has been accompanied by substantial deforestation. Industrial policy aiming to foster the establishment of resource-based manufacturing sectors, such as the pulp and paper industry, should also take into account possible negative effects on the environment.

6 Appendix: Data Sources

6.1 Indonesian PM Database

Unpublished data from PM manufacturers, Jaakko Pöyry (1984); FAO (1984); CIC (1990); World Bank (1991); Asia Pacific Papermaker (1995); PPI (1997); master theses Eindhoven University of Technology (Minderhoud, 2002; Jonker, 2002) and the Institute for Research and Development of Cellulose Industries (IRDCLI) in Jakarta; Paperloop.com (Paperloop, 2003); specialised trade journals; websites and interviews with companies and technology suppliers. Full information is available for 140 out of the 163 PMs in the database.

6.2 World Technology Frontier

Figure 7 and Figure 8 depict the world technology frontier for speed and width respectively. It is mainly based on the Beloit Paper Machine List (Finishingnet.com, 2003), containing the technological specifications of 927 machines produced by Beloit between 1862 and 1999. Beloit was one of the three leading PM manufacturers in the world until it went bankrupt in 1999. The database was complemented with data from Lehtoranta (1994), specialized industry journals and internet sources, mainly paperloop.com (Paperloop, 2003) As the Beloit Paper Machine List does not distinguish between newsprint, and printing and writing machines the frontier for these classes was combined. This is not an unreasonable assumption as the speed and width of both classes of machines is moving in conjunction. Due to the high level of specialisation (e.g. cigarette or money paper) it has not been possible to construct a separate technology frontier for specialty PMs and therefore the frontier for newsprint/printing and writing has been used instead as many specialty machines are retrofitted machines of these two classes. The *mach* values for this type of machines are therefore probably biased downwards.
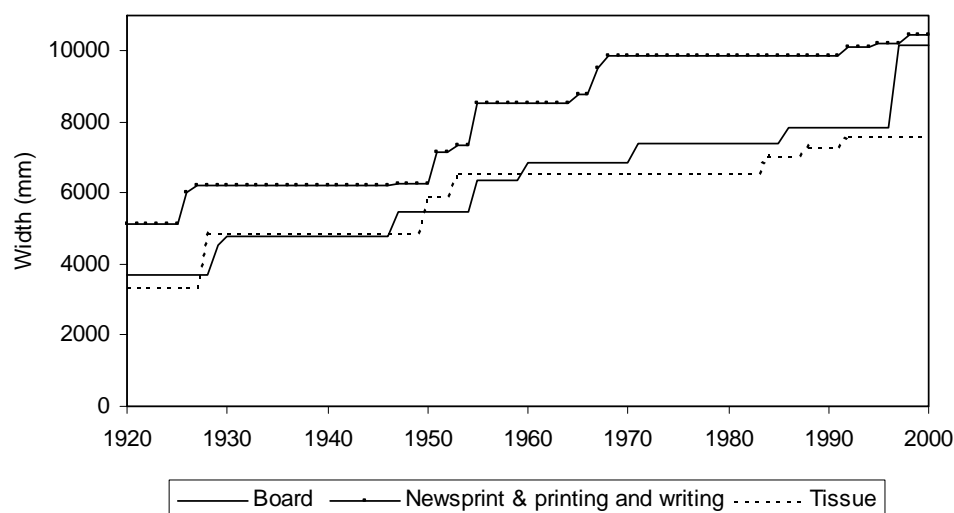
Figure 7: PM Speed Frontier by Class, 1920-2000
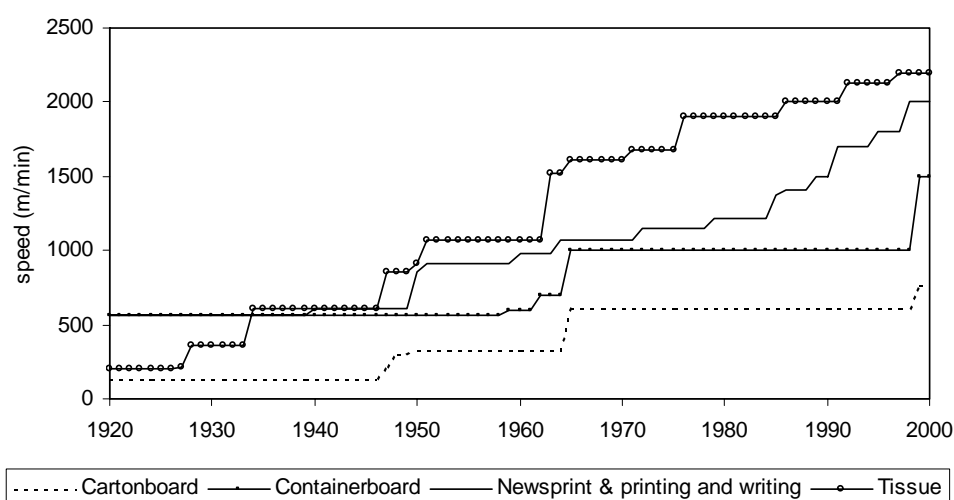
Note: The jump in containerboard speed in 1999 is the result of the first application of gap former technology to board making.
Source: See text.

Figure 8: PM Width Frontier by Class, 1920-2000

Note: Board is combination of containerboard and cartonboard machines
Source: See text.

References

Alcorta, L. (2000) New Economic Policies and the Diffusion of Machine Tools in Latin America. *World Development* **28**(9), 1657-1672.

Amsden, A.H. (1989), *Asia's Next Giant*, Oxford University Press, New York.

Asia Pacific Papermaker (1995), *Asia Pacific Pulp and Paper Directory*, Martin Bayliss Marketing Pty Ltd, Australia.

Auty, R.M. (1987) Backward versus Forward Integration in Resource-Based Industrialisation: Malaysia and Indonesia. *Tijdschrift voor Economische and Sociale Geografie* **78**(2), 82-93.

Barr, C. (1998) Bob Hasan, The Rise of Apkindo, and the Shifting Dynamics of Control in Indonesia's Timber Sector. *Indonesia* **65**(4), 1-35.

Barr, C. (2001a) Profits on Paper: The Political Economy of Fiber and Finance in Indonesia's Pulp and Paper Industries. In *Banking on Sustainability: Structural Adjustment and Forestry Reform in Post-Suharto Indonesia*, ed. C. Barr Center for International Forestry Research (CIFOR) and WWF Macroeconomic Program Office, Washington DC.

Barr, C. (2001b) The Political-Economy of Fiber, Finance, and Debt in Indonesia's Pulp and Paper Industries. *The Indonesian Quarterly* **29**(2), 173-188.

Blomström, M. and Wolff, E.N. (1997) Growth in a Dual Economy. *World Development* **25**(10), 1627-1637.

CIC (1990) *Pulp and Paper Industry in Indonesia*, CIC, Jakarta.

Clapperton, R.H. (1967), *The Papermaking Machine*, Pergamon Press Ltd., Oxford.

David, P.A. (1975), *Technical Choice, Innovation and Economic Growth*, Cambridge University Press, Cambridge.

Davies, S. (1979), *The Diffusion of Process Innovations*, Cambridge University Press, Cambridge.

Diesen, M. (2000), *Economics of the Pulp and Paper Industry*, Fapet oy, Helsinki.

Dosi, G. (1984) Technological Paradigms and Technological Trajectories. *Research Policy* **11**, 147-162.

Edquist, C. and Jacobsson, S. (1988), *Flexible Automation: The Global Diffusion of New Technology in the Engineering Industry*, Basil Blackwell Ltd, Oxford.

Enos, J.L. (1962), *Petroleum Progress and Profits*, The MIT Press, Cambridge, Massachusetts.

Fane, G. (1999) Indonesian Economic Polices and Performance, 1960-98. *World Economy* **22**(5), 651-668.

FAO (1984) *Indonesia: Status of the Pulp and Paper Industry and Trade*, Working Paper, 32, Jakarta.

Finishingnet.com (2003), *Beloit Paper Machine List*, http://www.finishingnet.com/machines/pmmenu.htm.

Gerschenkron, A. (1962), *Economic Backwardness in Historical Perspective*, Harvard University Press, Cambridge MA.

Griliches, Z. (1957) Hybrid Corn: An Exploration in the Economics of Technical Change. *Econometrica* **48**, 501-522.

Hill, H. (2000), *The Indonesian Economy*, Cambridge University Press, Cambridge.

Hollander, S. (1965), *The Sources of Increased Efficiency*, The MIT Press, Cambridge, Massachusetts.

Ibnusantosa, G. (2002), *Recent Position of Indonesian Pulp and Paper Industry*, mimeo.

Jonker, M. (2002) *Building Technological Capabilities to Improve Performance. A Case Study of the Paper Industry in West Java, Indonesia*, M.Sc. Research Report, Eindhoven University of Technology, Eindhoven.

Jorgenson, D.W. (1995a), *Productivity. Volume 1: Postwar U.S. Economic Growth*, The MIT Press, Cambridge, Massachusetts.

Jorgenson, D.W. (1995b), *Productivity. Volume 2: International Comparisons of Economic Growth*, The MIT Press, Cambridge, Massachusetts.

Kenny, J. (1997) APP Aims for Pole Position. *Pulp & Paper International* **39**(9), 22-23.

Kim, L. (1997), *Imitation to Innovation: The Dynamics of Korea's Technological Learning*, Harvard Business School Press, Boston.

Koehler, K.G. (1972) Wood Processing in East Kalimantan: A Case Study of Industrialisation and Foreign Investment in Indonesia. *Bulletin of Indonesian Economic Studies* **8**(3), 93-129.

Lehtoranta, O. (1994) *Technology Diffusion and the Lifetimes of Paper Machines*, C 70, ETLA.

Levin, S.G., Levin, S.L. and Meisel, J.B. (1987) A Dynamic Analysis of the Adoption of a New Technology: The Case of Optimal Scanners. *Review of Economics and Statistics* **69**(1), 12-17.

Lissoni, F. and J.S. Metcalfe (1994) Diffusion of Innovation Ancient and Modern: A Review of Main Themes. In *Handbook of Industrial Innovation*, eds. M. Dodgson and R. Rothwell pp. 106-144, Edward Elgar Publishing Limited, Cheltenham.

MacIntyre, A. (1994) Power, Prosperity and Patrimonialism: Business and Government in Indonesia. In *Business and Government in Industrialising Asia*, ed. A. MacIntyre pp. 244-267, Allen & Unwin, St. Leonards.

Mansfield, E. (1961) Technical Rate and the Rate of Imitation. *Econometrica* **29**(4), 741-766.

Manurung, E.G.T. and Kusumaningtyas, R. (1999) *Pembangunan Hutan Tanaman Industri di Indonesia*, Draft report prepared for WWF-Indonesia, Jakarta.

Minderhoud, S. (2002) *Technological Performance in Indonesian Paper Industry*, M.Sc. Research Report, Eindhoven University of Technology, Eindhoven.

Navaretti, G.B., Soloaga, I. and Takacs, W. (2000) Vintage Technologies and Skill Constraints: Evidence from U.S. Exports of New and Used Machines . *World Bank Economic Review* **14**(1), 91-109.

Nelson, R.R. (1968) A 'Diffusion' Model of International Productivity Differences in Manufacturing Industry. *American Economic Review* **58**(5), 1219-1248.

Ofori-Amoah, B. (1993) Technology Choice and Diffusion in the Manufacturing Sector, The Case of the Twin-Wire in the Canadian Pulp and Paper Industry. *Geoforum* **24**(3), 315-326.

Ofori-Amoah, B. (1995) Regional Impact on Technological Change: The Evolution and Development of the Twin-Wire Paper Machine from 1950-1988. *Environment and Planning A* **27**, 1503-1520.

Oster, S. (1982) The Diffusion of Innovation Among Steel Firms: The Basic Oxygen Furnace. *Bell Journal of Economics* **13**(1), 45-56.

Pack, H. (1987), *Productivity, Technology, and Industrial Development*, Oxford University Press, New York.

Pagan, A. and Ullah, A. (1999), *Nonparametric Econometrics*, Cambridge University Press, Cambridge.

Paperloop (2003), Http://www.paperloop.com.

Pappens, R. (1993) Sinar Mas: Growth Won't Stop at Home. *Pulp & Paper International* **35**(8), 21-22.

Pöyry, J. (1984) *Strengthening the Structure of the Indonesian Pulp and Paper Industry*, Annex II, Helsinki.

PPI (1997), *International Fact & Price Book*, Miller Freeman, Brussels.

Quah, D.T. (1995) Twin Peaks: Growth and Convergence in Models of Distribution Dynamics. *Economic Journal* **106**(7), 1045-1055.

Ramanathan, R. (1989), *Introductory Econometrics with Applications*, The Dryden Press, Orlando.

Rudd, N. (1999) Most U.S. Paper Machines Need Significant Technology Upgrades. *Pulp & Paper* **September**, 55-60.

Schwartz, A. (1999), *A Nation in Waiting: Indonesia's Search for Stability*, Allen and Unwin, St. Leonards.

Silverman, B.W. (1986), *Density Estimation for Statistics and Data Analysis*, Chapman and Hall, London.

Stafford, B. (2000) Indonesia: Debt and Disappearing Wood Challenge Pulp and Paper Mills. *Papermaker* **September**, 19-22.

StataCorp (2001), *Stata Reference Manual: Release 7.0, Volume 2*, Stata Corporation, College Station.

Stewart, F. (1977), *Technology and Underdevelopment*, The Macmillan Press Ltd, London.

Stoneman, P. (2002), *The Economics of Technological Diffusion*, Malden, Blackwell Publishers Inc..

Stoneman, P. and Karshenas, M. (1993) Rank, Stock, Order and Epidemic Effects in the Diffusion of New Process Technologies: An Empirical Model. *Rand Journal of Economics* **24**(4), 503-528.

Sutopo, E. (2000) *Indonesian Pulp and Paper*, Paper prepared for the 4th Annual Summit for Recovery of Pulp & Paper Market in Asia.

Szirmai, A. (1994) Real Output and Labour Productivity in Indonesian Manufacturing, 1975-1990. *Bulletin of Indonesian Economic Studies* **30**(2), 49-90.

Szirmai, A., Timmer, M.P. and Van der Kamp, R. (2002) Measuring Embodied Technological Change in Development. The Core Machinery Approach. *Journal of Development Studies* **39**(2), 155-177.

Timmer, M.P. (2000), *The Dynamics of Asian Manufacturing: A Comparative Perspective*, Edward Elgar Publishers, Aldershot.

Tybout, J.R. (2000) Manufacturing Firms in Developing Countries: How Well Do They Do, and Why? *Journal of Economic Literature* **38**(3), 11-44.

Utterback, J.M. (1994), *Mastering the Dynamics of Innovation*, Harvard Business School Press, Boston.

Van Dijk, M. (2005) *Industry Evolution and Catch Up: The Case of the Indonesian Pulp and Paper Industry*, ECIS Dissertation Series, Eindhoven.

Van Dijk, M. and Bell, M. (2004) *Industrial Policy, Crony Capitalism and Technological Learning: The Case of the Indonesian Pulp and Paper Industry*, Paper Prepared for the Second Globelics Conference, Beijing, China.

Van Dijk, M. and Szirmai, A. (2005) Technical Efficiency and Embodied Technical Change in The Indonesian Pulp and Paper Industry. *Journal of International Development* **forthcoming**.

WALHI/ YLBHI (1992), *Mistaking Plantations for the Indonesia's Tropical Forest*, Wahana Lingkungan Hidup Indonesia, Jakarta.

World Bank (1981) *Indonesia: Pulp and Paper Subsector Review*, World Bank Industry Study, World Bank, Jakarta.

World Bank (1991) *Industrial Efficiency and Pollution Abatement (IEPA) Project Data Collection Study: Volume 2*, World Bank, Jakarta.

World Bank (1993) *The East Asian Miracle, Economic Growth and Public Policy*, Oxford University Press.

World Bank (2001) *Indonesia: Environment and Natural Resource Management in a Time of Transition*, Working Paper, 23149, World Bank, Jakarta.

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[1] Griliches (1957) and Mansfield (1961) are seminal studies. Also see Lissoni and Metcalfe (1994) and Stoneman (2002) for overviews.

[2] Notable exceptions are Alcorta (2000) and Edquist and Jacobsson (1988).

[3] This section is based on chapter 5 from Van Dijk (2005).

[4] See Fane (1999) and Hill (2000) for an historical overview of the development of the Indonesian economy and the manufacturing sector.

[5] Barr (2001a, p.23) provides sources for such estimates.

[6] See Kenny (1997) for the costs of some the largest paper machines installed in Indonesia.

[7] In the world technology leader, Finland, retrofitting and adaptation of existing machinery is also an important source of embodied technological change (Lehtoranta, 1994). But, in the Indonesian context hardly any retrofitting and adaptation takes place.

[8] An exception would be twin-wire or gap former technology (Ofori-Amoah, 1993; Ofori-Amoah, 1995).

[9] Also see Van Dijk and Szirmai (2005) who use the machine index to investigate the relationship between plant level technical efficiency and embodied technical change in the Indonesian paper industry.

[10] Another option would be to use the age of the PM as an indicator for technological vintage. However, precisely because many PMs in Indonesia are second hand, their true age is difficult to find out.

[11] It would be better to use the rental prices of the PMs as weights but these were not available. See Jorgenson (1995a; 1995b) on the use of rental prices as weights to construct a measure for aggregate capital stock.

[12] A kernel density plot can be regarded as smoothed version of a histogram generated using non-parametric analysis (Silverman, 1986; Pagan and Ullah, 1999). This technique is now increasingly used in economics to investigate changes in distribution (e.g. Quah, 1995). We have used the standard command for kernel density in STATA 7.0, assuming optimal width and an Epanechnikov kernel function (StataCorp, 2001).

[13] This depends on the definition used. For instance, Asian Pulp and Paper, the largest company in the industry has a foreign status because its headquarters are located in Singapore. However, it is owned by the Sinar Mas Group, one of the largest Indonesian business groups. If conglomerate ownership is taken into account, there appear to be no foreign-owned companies (Van Dijk, 2005).

[14] The most notorious example is probably Mohammad 'Bob' Hasan, a long time business associate of Suharto, who even became minister of economic affairs in 1998 (Barr, 1998). Kiani Kertas, one of the largest pulp mills in Indonesia, owned by Hasan's Kalimanis group, was able to obtain at least US$ 400 million in state subsidies excluding additional tax holidays and large wood concessions (Barr, 2001a). Currently Bob Hasan is in jail on allegations of corruption.

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