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International Trade and Recycling in Developing Countries: The Case of Waste Paper Trade in India

Edited by
Pieter van Beukering
Vinod K. Sharma

vrije Universiteit amsterdam

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International Institute for Environment and Development

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Environmental Economics Programme
IIED, 3 Endsleigh Street
London WC1H 0DD, UK
Tel (44 171) 388 2117; Fax (44 171) 388 2826
e-mail: JSIIED@aol.com

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IVM, Vrije Universiteit
De Boelelaan 1115
1081 HV Amsterdam
The Netherlands
Tel: (31 20) 444 9555; Fax: (31 20) 444 9553
e-mail: ies@sara.nl

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INTERNATIONAL TRADE AND RECYCLING IN DEVELOPING COUNTRIES: THE CASE OF WASTE PAPER TRADE IN INDIA

Pieter van Beukering and
Vinod K. Sharma (eds.)

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Institute for Environmental Studies (IVM)
Vrije Universiteit
Boelelaan 1115
1081 HV Amsterdam, the Netherlands
tel: (+31) 20 - 444 9524 (direct)
tel: (+31) 20 - 444 9555 (secr.)
fax: (+31) 20 - 444 9553

Indira Gandhi Institute of Development Research (IGIDR)
Gen. Vaidya Marg, Goregaon (E)
Mumbai 400 065, India
tel: (+91) 22 840 0919
fax: (+91) 22 840 2752

Intervention India Ltd.
#2, Haudin House
13, Haudin road, Ulsoor
Bangalore 560 042, India
tel: (+91) 80 559 9092
fax: (+91) 80 547 1250

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Chapter 1.

THEORETICAL FRAMEWORK FOR TRADE AND RECYCLING

Pieter van Beukering

1.1 Background

As in the North, recycling in the developing countries too can be considered as a key strategy for alleviating the pressure of society on the environment. A variety of environmental justifications can be put forth for recycling. The consumption of both energy and finite resources is reduced by the recycling processes. At the same time, water pollution and air emissions are controlled and the problem of solid waste disposal is mitigated. Likewise, recycling can be considered an important activity in the developing countries for economic reasons. First, the extreme poverty and massive unemployment in the developing countries can be lowered by activities such as recycling. The high degree of labour intensity of the reclamation process enables numerous people to gather some kind of income. At the same time, an increased rate of recycling will reduce the costs for raw materials in the production process and will thereby result in a wider range of low cost products, which can serve the needs of the underprivileged. Secondly, ecological vulnerability allows only limited exploitation of local natural resources. Since the shortage of foreign currency imports of certain raw materials are always in short supply. Consequently, it is necessary to extend the life cycle of existing resources. Thirdly, particularly in Asia, the anticipated high growth in GDP will significantly increase the waste disposal burden in most metropolises. Besides generating negative impacts on the environment, the increasing economic costs of solid waste disposal will absorb a substantial amount of the municipal budgets. Recycling will reduce the quantity of solid waste. Finally, the technological requirements for recycling are generally lower than those for primary production processes. Given the low knowledge and investment intensity, recycling fits well in a developing society where capital and technical information are relatively scarce.

Is recycling in the South any different from recycling in the North? To answer this question it is important to clearly understand the different features of recycling. In common parlance, recycling is used as a general term for all activities which are related to the reclamation of waste. However, a distinction should be made between the recovery of solid waste and the utilisation of secondary materials in the production process. The technical and economic aspects of the actual utilisation process do not differ significantly from production in industrialised and developing countries. Yet, the motivation to recover differs substantially. Recovery in most developing countries is mainly a market driven phenomenon with a comprehensive domestic trade system. It is expanding and developing rapidly without any governmental support. In contrast, recovery in the industrialised world is mainly motivated by environmental compulsions. Public participation and government involvement play a much more important role. Apart from the motivation for recycling in the respective regions, differences occur between the configuration of demand and supply in recyclable waste. Given the high levels of per capita waste generation, the supply of secondary waste materials is generally abundant in the North. Especially, with governments promoting the separation of waste at source, this has lead to a boost in supply of secondary materials. In developing countries, however, conditions are different. Relatively low levels of waste generation and the long life span of products depress the quantity and quality of the supply of secondary materials. Therefore, the recycling industry contends with lack of raw materials.

These distinctive features of supply of waste in the North and demand for waste in the South, demonstrate the potential of international trade in secondary materials. This rationale is confirmed by empirical findings. As is well known from Yates (1959), the bulk of the trade is in the intermediate products. In addition, Walter (1975) showed convincingly that a non-negligible part of trade consists of secondary materials. Further investigation reveals that, whereas most other intermediate goods are transferred between countries in the North, a more than proportionate share of secondary materials move from the North to the South, which is gradually increasing. In theory international trade can perform much the same function in the secondary materials sector as it does with virgin materials by matching variations of supply in industrialised countries and of demand in developing countries. Through a more efficient allocation, both regions can move to higher levels of social welfare than they may otherwise attain.

The attitude of international organisations, national governments and non-government organisations (NGOs) towards international trade of secondary materials is far from uniform. Two contrasting ideologies underlie the disagreement. First, trade liberalisation is recognised as a desirable process which facilitates a more efficient global allocation of goods and services. Secondary materials are considered no different from other intermediary or final goods. As for the other view, secondary materials are not considered as normal intermediary goods but as a burden which requires appropriate processing. Waste should be taken care of by the polluters themselves, which in this context are the countries or states which generate the waste. International waste trade is considered as an easy way out for countries to dump their waste. Especially in the case of hazardous waste, such short term solutions are defective. This emphasises the importance of the distinction between hazardous and non-hazardous waste.

Several other ambiguities exist which obfuscate the issue of trade liberalisation of secondary materials. For example, the precise socio-economic impact of the increase in recyclable waste are unknown. If imported secondary material substitutes domestic recyclable waste materials, the local recovery sector may suffer from free waste trade. If, on the other hand, imported waste can form the basis for a stable growth of a local recycling industry, the recovery sector may benefit from imports. Also the environmental implications are unknown. For example, it is not clear whether the environmental damage resulting from increased transportation outweighs the environmental gains from an increase in overall recycling.

1.2 Objectives of the research

In order to increase the accessibility of the issue, this study focuses on one case study: waste paper trade and recycling in India. Waste paper is a traditional commodity at the international market which is increasingly being collected in both industrialised and developing countries. India is selected for two reasons. First, India is a large industrialising country with a great demand for raw materials and several metropolitan cities in which comprehensive recycling networks already exist. Secondly, waste paper import is already taking place for several years and in the early 90's many paper industries in India are switching from virgin materials to imported waste paper.

The main objective of this project is to address the economic, environmental and social challenges and threats posed by increased international trade of waste paper to India. The following specific objectives can be identified:

- Assess the patterns of international trade of waste paper for recyclable purposes between industrialised countries and India.
- Determine the economic, social and environmental impact of international trade of waste paper between industrialised countries and India.
- Identify the type of economic, regulatory, juridical, and informational constraints which limit this type of trade.
- Develop recommendations for international and national decision makers with regard to international waste trade and recycling.

The outcome of this project will be particularly relevant to institutions and governments in developing countries to ensure that their international waste trade policies generate the desired impact on the local economy and on its domestic recycling sector in particular. Similarly, the results can support industrialised countries in their decision to prohibit or encourage international waste trade.

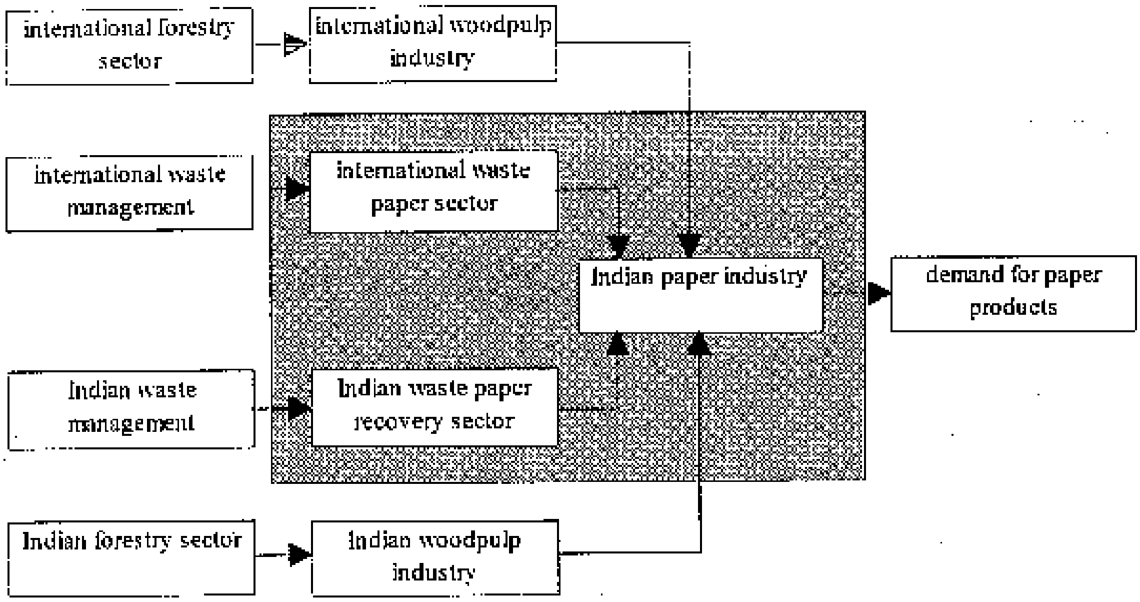
1.3 Boundaries, methodology and structure

As depicted in Figure 1.1, a large number of economic sectors are directly or indirectly related to the issue of waste paper recycling in India. For example, both imported and local woodpulp can serve as a substitute for waste paper. Therefore, the local and international forestry sectors are related to the waste paper cycle. Alternatively, the supply of waste paper in the international market may increase as a result of government policies in the North to promote recycling. This can drive down the waste paper price on the world market and thereby crowd out the local waste paper sector in India. Thus, government policies in the North are relevant to this study. Also the waste management in Indian cities can be either the victim or the cause of developments on the local waste paper trade. Finally, a relationship exists between the demand for paper products in India and the recycling rate. For example, changes in consumer preferences may drive up the demand for recycled products.

It is beyond the scope of this study to perform a full cradle-to-grave study. Therefore, the most relevant sectors are selected in order to determine the impacts of international trade of waste paper on the Indian recycling sector. The boundaries of this research are indicated by the grey area in Figure 1.1. Three main sectors can be identified: i) the world market of waste paper, ii) the local waste paper market, and iii) the Indian paper industry. Sectors outside this area will only be discussed in passing.

The major constraint of research on secondary materials in developing countries is the unreliability and the limited availability of data. Research in this field is scarce so that the transparency of the international flows of secondary materials and its determinants is blurred. For this reason, various field surveys have been conducted in each of the three sectors in India. In the following sections, it is examined how this issue can be explained by the traditional and modern trade theories. Next, a conceptual analysis is presented in which the effect of trade liberalization on recycling is demonstrated. In addition, the conceptual analysis is extended by internalising social and environmental effects.

Figure 1.1 Material balance of international trade and recycling in India



1.4 Theories applied to trade and recycling

The basic objective of the study is to determine what the exact determinants are of the distinct empirical pattern of increasing waste paper trade to developing countries. For this purpose it is useful to briefly review the explanatory value of the existing theoretical trade models. As mentioned earlier, in analysing recycling and international trade, a clear distinction must be made between recovery rates (collection of recyclable waste from consumers) and utilisation rates (the production process of converting waste to finished products). This distinction in recycling links well with the existing differentiation in trade theories which separate supply and demand driven models. Making such a distinction does not necessarily imply that only one theory holds. Instead, it is well possible that the two types of trade models can be complementary.

Within the supply-oriented trade theories, the Heckscher-Ohlin theorem forms the most appropriate basis for application to recyclable waste trade. This theorem focuses on factor endowments as the main cause of differences in comparative advantage and therefore of the emergence of foreign trade. The model argues that a country will export that commodity which it produces in abundance, called the abundant production factor, when compared with other countries. So, if recyclable waste is assumed to be the abundant factor, it follows that waste paper will be exported by countries with abundant waste production. Clearly, these are the countries in the North. It could also be argued however that it is, for instance, not the *waste paper* but the product *recycled paper*, that will be exported.

In this respect, Linder (1961) provides a satisfactory explanation. Instead of focusing on supply factors, Linder emphasises variations in demand as the driving force of international trade. Linder draws a sharp distinction between trade in materials and commodities (e.g. waste paper) which he argues would be determined on the basis of factor endowments, and trade in manufacturers (e.g. paper and paperboard). For the latter, he argues that factor intensities are much the same, and that the determinant of the trade pattern is to be found in the structure of demand. Linder defines the structure of demand in terms of qualities of demanded products which are strongly linked to the level of per capita income. Countries with high real income levels would not just tend to consume *more* products but also *better* products. As recycled products are generally of a lower quality than primary produced goods, this would imply that demand for recycled products is relatively large in developing countries. Linder argues that each country confines its production to goods within the range of product qualities consumed domestically. This implies that developing countries would tend to focus relatively more on recycling than on primary production. He states that only after several caveats are overcome, such as limited information and transportation costs, domestic production may extend its focus to the export market. The problem in explaining recycling through the Linder model, is that the actual recycling rate is lower in developing countries than in industrialised countries. For this deficiency, Vernon provides a feasible solution.

The trade model by Vernon (1966), called the product cycle model claims that new products are first produced in the most advanced economies. Two reasons underlie this comparative advantage of industrialised countries in the initial production phase: technical skills are well developed and consumer demand is large. The demand spreads abroad which is met by exports. As the production process becomes standardised, it becomes more attractive for the importing countries to adopt the production. As the product goes through its natural cycle, from being research and skill intensive to intensive in unskilled labour, world production moves to the less advanced countries. Recycling production technologies have particularly prospered in the last decades, and have largely been adopted by the developing countries. Thus, Vernon's product life cycle provides an additional explanation for the increasing flow of recyclable waste to developing countries.

An alternative approach to analysing the relationship between trade and recycling are the general equilibrium (GE) models. The advantage of GE models is that these models take into account economy-wide effect based on explicit micro-economic relationships. In contrast to the traditional trade Heckscher-Ohlin models, the multi-country GE models allow trade to be not only determined by intercountry differences in relative factor, endowments, but also by differences in production and demand parameters (Beers *et al.* 1995). Yet, because everything depends on everything else in these models, the GE models become extremely complex. Pethig (1976) developed a GE model which addresses the issue of trade and recycling. It shows how the liberalisation of waste trade flows between countries so that it benefits all sides. In other words, theory teaches that it would be in the interest of all partners - importers and exporters of recyclable waste - to liberalise the trade, because markets would be bigger, thus making recycling operations more attractive and ultimately leading to sizeable savings in natural resources. Clearly, GE models seem to provide the optimal framework to analyse the issue of comparative advantage in recycling and international trade of secondary materials, yet its complexity is a major drawback in the empirical application.

The application of theoretical models with a high degree of abstraction and simplification to recyclable waste trade leaves ample room for criticism. First, due to technological innovations the quality difference between recycled products and primary products is declining rapidly. This tendency alleviates the explanatory value of Linder's model. A critique on the product life cycle could be that recycling technologies are constantly under development and therefore developing countries always have arrears compared to the industrialised world. Though not further elaborated here, the Heckscher-Ohlin theorem has also been criticised extensively (see the Leonief Paradox, the Solper-Samuelson Theorem and the Rybczynski Theorem). In other words, neither of the models provides an all-encompassing and satisfactory explanation of international trade secondary materials. Still, these models give some insight in the fundamentals of recycling and trade in developing and industrialised countries.

1.5 The effects of trade liberalisation in secondary material

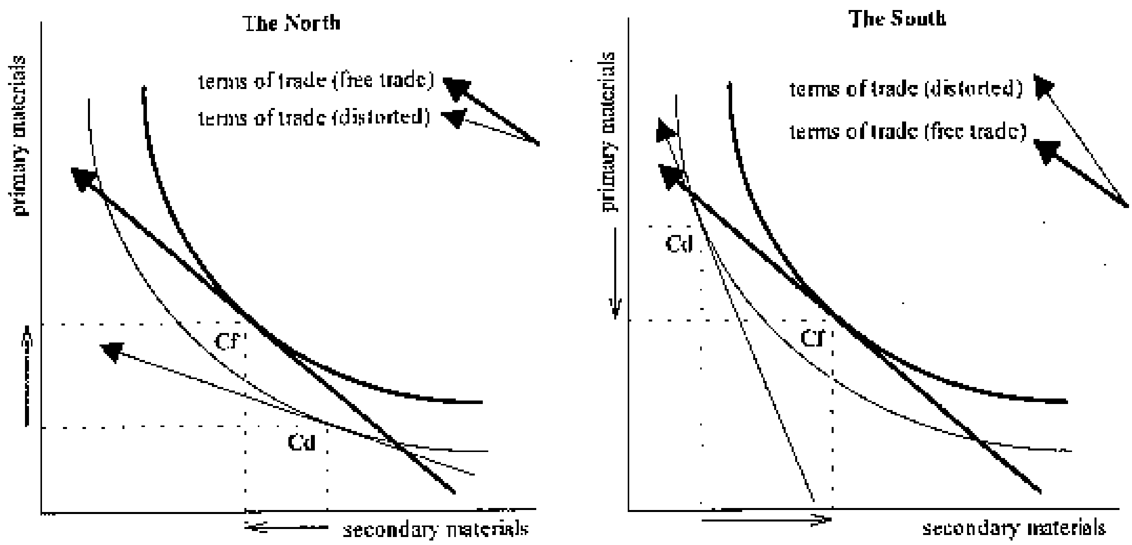
In spite of the above critiques and the well-known drawbacks of the models, one could still conclude that industrialised countries have a comparative advantage in the supply of waste paper, while developing countries have an advantage in the actual recycling process. What would be the impact of trade liberalisation on the overall (global) rate of recycling and thus on the global economy and environment? To illustrate these effects, the demand and supply of waste in both developing and industrialised countries are analysed.

The starting-point of the analysis is a situation in which two commodities, virgin and secondary materials, form the supply and demand in two regions, industrialised and developing countries. The existing trade barriers are assumed to have the following characteristics. Market distortions in the North include a ban on export of secondary materials and free trade of virgin materials. These barriers cause an undervaluation of secondary materials in the Northern market. In the South, trade barriers comprise the lack of market information and duties on import of secondary materials. In addition, export of virgin materials in the South is promoted by their government. As a result, secondary materials are overvalued in the South. What are the effects of the removal of these barriers on supply and demand?

First, the impact of the elimination of trade and other barriers on the *recovery* or *supply* of secondary materials will be examined. Since the recovery of secondary material is positively related to the market price, the collection of recyclable waste stays behind the optimal level in the North, while the opposite situation exists in the South. Assuming the absence of transaction costs, the removal of trade distortions leads to a uniform global price of secondary materials. Because the North dominates the supply of secondary materials, the average world price will soar. This encourages the recovery of waste and thus increases the global supply of secondary materials.

The elimination of trade barriers will also have an impact on global utilisation or demand of secondary materials. The major incentive to use secondary instead of virgin materials arises from relative price differences between these commodities. An abstract illustration of the current utilisation of secondary and virgin materials in the production process is presented in Figure 1.2. The difference in consumption patterns is depicted by the point of contact between the isoquants and the terms of trade lines. As a result of the abundance of secondary materials and the existence of market distortions, the internal price of waste materials in industrialised countries is relatively low. This is illustrated by the flat angle of the internal terms of trade. As a result the consumption by the industry in the North is biased towards secondary materials (**Cd**). In contrast, waste in developing countries is relatively scarce and therefore the internal terms of trade line is steep. Their consumption is dominated by virgin materials.

Figure 1.2 Isoquants for the demand of virgin and secondary materials in the North and the South, with and without free trade



If distortions are eliminated, the terms of trade will be equal in both regions, as a result of which two effects will emerge. First, the relative change in price will cause the input mix to change. This can be seen as a shift **on** the isoquant. Given the relative change in prices, the South will use more secondary materials in production while the North trades off secondary materials for virgin materials. Note that it is the relative price change and not by definition an absolute change in price that causes the shift. Second, an overall increase in efficiency is gained from free trade. This economic gain is depicted by a shift of the isoquant away from the origin. A new equilibrium in both regions will be reached in Cf.

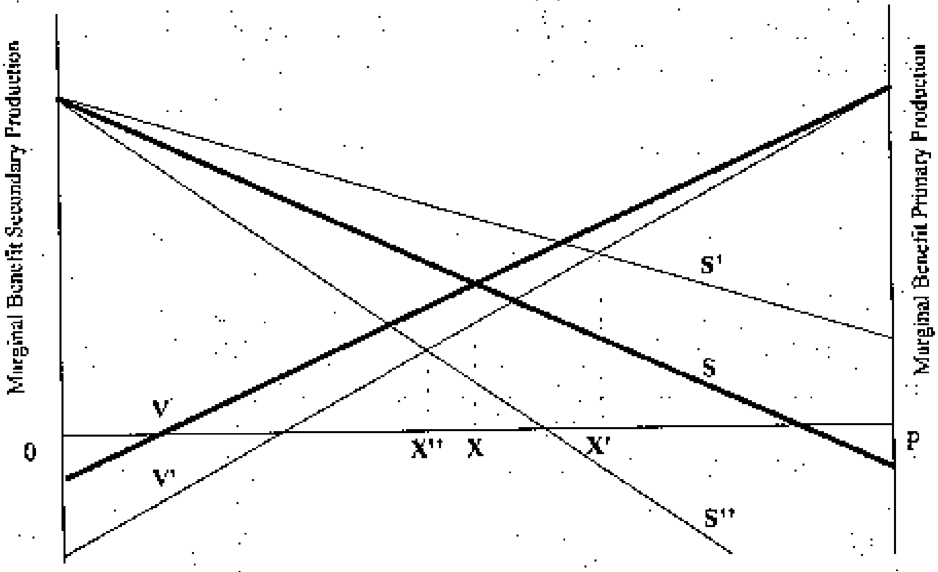
The new equilibrium between supply and demand can be considered more sustainable if the overall environmental impact is reduced by the change over to free trade. It is important to remember that virgin materials are harvested from natural resources while secondary materials are mined from consumers instead, thereby preventing environmental damage caused by disposal or mining. Another positive feature of secondary materials is the fact that recycling processes generally require less energy than virgin production processes. However, a factor that could offset the positive effects of free trade is the environmental costs arising from international transportation, which in this example are ignored. Another risk of the free trade scenario is that the increase in the use of virgin materials in the North exceeds the decrease of virgin materials usage in the South. Yet, this situation is unlikely since the North is comparatively more efficient than the South in virgin production and moreover it is technically more difficult to switch from secondary to virgin materials than the reverse. For this reason the overall consumption of recyclables will increase while the overall consumption of virgin materials will decrease.

1.6 The effects of internalising externalities on recycling

In the foregoing assessment of the effects of trade liberalisation on the overall rate of recycling, environmental and social effects of the material flows are virtually ignored. In order to derive the societal optimal rate of recycling, such externalities should also be incorporated in the analysis. This can preferably be achieved through valuing these effects in monetary terms. As economic valuation is not the primary focus of the study, we have not gone into its details. Yet, to illustrate the impact of internalisation of social and environmental effects on the recycling rate in a country, a simple hypothetical case is worked out.

Figure 1.3 depicts a situation in which distribution of virgin and secondary materials determines the production of a fixed quantity of outputs (OP). The vertical axis on the left depicts the marginal benefits of the use of secondary materials for the production of an output. The vertical axis on the right represents the marginal benefits of the use of virgin materials for production. The horizontal axis depicts the quantity used of both raw materials. Two marginal benefit functions can be drawn. The negatively sloped curve V which should be seen from right to left, shows that the marginal benefits will decrease with increasing utilisation of virgin materials. This negative relation results for instance from the increasing scarcity which requires additional harvesting effort and thus higher costs. The negatively sloped curve **S** which should be read from left to right, similarly illustrates that the marginal benefits decrease with increasing use. The higher the degree of the recovery rate of secondary materials, the lower will be the quality of the recovered waste. Both marginal benefit curves intercept with the horizontal axis. This indicates that beyond a certain degree of primary or secondary utilization, marginal costs exceed the marginal benefits.

Figure 1.3 Externalities of virgin and secondary production



In a situation were externalities are ignored, the input allocation of production will be set at **X** where the marginal benefits of recycling and virgin production are equal. In this equilibrium, an amount of **0X** will be produced from virgin materials, while **XP** will be derived from secondary materials. If the cost-benefit analysis is extended with externalities, this equilibrium may shift either way. First, positive as well as negative external effects may be related to recycling. Negative effects include health effects for waste pickers. A positive effect of recycling is for instance a reduction in solid waste. Second, external effects derive from primary production such as the increased rate of depletion of natural resources. In Figure 1.3, the following is assumed. Overall externalities of primary production are negative, leading to a downward shift of the marginal benefit curve of primary production (V→V'). These effects are positive for recycling, shifting the marginal benefit curve of recycling up (S→S'). In the new situation, the equilibrium will shift in favour of recycling (X→X'). Yet, if negative externalities of recycling dominate (S→S''), the opposite shift may occur (X→X''). This exercise demonstrates the importance of a thorough economic valuation of the external effects of primary and secondary production.

1.7 Structure of the study

To verify the above theoretical concepts, an enormous amount of empirical data and a wide range of analysis are required. This study does not attempt to provide an all-embracing explanantion. Only a few key-questions will be addressed. The study is structured as follows.

In Chapter 2, the international trade of waste paper will be described. The origins and the destinations of the waste paper flows are identified, and developments in the last decade are analysed on a global level in general and for India in particular. Economic variables influencing the supply and demand of internationally traded waste paper will be evaluated. Special emphasis will be paid to waste paper import in India.

Chapter 3 focuses on the Indian paper industry. In order to understand the underlying forces determining the demand for waste paper in India, the structure of the industry as well as its input and output composition are described. Recent developments, problems and government policies with regard to the Indian paper industry will also be discussed in this chapter.

In Chapter 4 the local recovery of waste in Bombay is analysed, emphasizing its distinct character, its specific problems and the possibilities for improving waste recovery. Two policy options (a Western approach versus an informal policy) are analysed in terms of efficiency and environmental and socio-economic effects.

In Chapter 5 a cost for the Indian paper industry is estimated in order to determine its substitution behaviour between local and imported waste paper. In addition other elasticities are derived to determine the ability of the paper industry to respond to external shocks such as a sudden price rise of imported waste paper.

Chapter 6 interconnects the three sectors through the development of a material balance flow model. This model aims at investigating whether free trade in waste paper can support economic development and simultaneously reduce environmental degradation. The model describes the various stages of paper production starting from logging to pulping and paper production, transport of inputs and outputs, and waste disposal.

In Chapter 7 general conclusions are formulated. Policy recommendations are given for local NGOs and municipalities, national governments as well as international organisations. Finally suggestions for additional research have been formulated.

Chapter 2.

A GLOBAL ASSESSMENT OF WASTE PAPER TRADE

Pieter van Beukering
Martijn Bennis
Hans Hoogeveen
V. K. Sharma

2.1 Introduction

Imported waste paper is becoming an increasingly important input for the paper industry in India. A similar tendency can also be recognized in many other developing countries. This development suggests a reallocation of waste paper at a global scale. In this chapter, various dimensions of international trade in waste paper are studied. First, an assessment is being made of the flows of waste paper between countries in order to determine whether indeed international trade of waste paper is becoming increasingly important. Next, the underlying causes of this development are analysed. The first section focuses on the international trade of waste paper at a global level, after which the specific situation for India is highlighted.

In analysing the various dimensions of recycling and international trade, it is important to establish a clear understanding of the various features of recycling. In common parlance, recycling is used as a general term for all activities which are related to the recovery and reprocessing of secondary materials. This often causes ambiguity. Therefore, recycling in this chapter will be analysed in terms of recovery or collection of waste paper after paper consumption and utilization or employment of waste paper in the paper production process. This distinction is particularly important in analyzing international trade, because of the different locations of demand and supply of waste paper.

The assessment on recycling and international trade is based on data from various sources. Time-series on international trade, recovery and utilization of waste paper are derived from the Pulp and Paper International Fact and Price Book (PPI 1994). Production and consumption of paper are retrieved from various publications by the Food and Agricultutre Organisation (FAO). Basic indicators such as GNP, population and forest areas are taken from the World Development Report (1995). In general, data on waste paper recovery and waste paper trade are of varying quality across countries. Therefore, other sources may differe from the estimates used in this chapter.

The chapter is structured as follows. In Section 2.2, the international flows of waste paper are described in terms of volumes, exporters and importers, qualities and developments. Section 2.3 provides a framework of factors of supply and demand which determine the volume and the direction of international trade. A qualitative or quantitative explaination of these determinants is given in Section 2.4. The specific trade conditions for India are assessed in Section 2.5. Finally, conclusions are drawn in Section 2.6.

2.2 International trade flows of waste paper

2.2.1 Volumes

During the last decade, the volume of internationally traded waste paper increased substantially, from as little as 2.2 million tonnes in 1973 to approximately 7.1 million tonnes in 1984 to 12.7 million tonnes in 1991 (Grace *et. al.* 1978, PPI 1994, FAO 1994). What is more important is the development of ratio between the the volume of traded waste paper compared to the global level of waste paper consumption. This rate increases from 12.7% in 1984 to 16% in 1992. With respect to future trade, the FAO (1994) states that "in the short term, the expansion of trade in recovered paper may be expected to continue at a faster rate on account of policy measures favouring increase in recovery and increased utilization of recovered paper." Based on this statement, it could be assumed that the traded waste paper as a share of the totally recovered amount will exceed 20% in 2010. In absolute terms this comes to almost 35 million tonnes. This may be caused by various factors. National policies which support recovery and utilisation rates may boost the trade volume simultaneously. Also the tendency of trade liberalization contributes to increased waste paper trade. Finally, the international market of waste paper became more transparent.

2.2.2 Exporters and importers

The general tendency of liberalization of international markets has caused the volume and share of internationally traded wood fibre, wood pulp, paper and paperboard, as well as waste paper, to gradually increase in the last decades. The gradual increase of trade in intermediary materials in the paper cycle, was mainly the result of international trade among Northern countries. With respect to waste paper the situation is different. This can be seen from Table 2.1 in which the direction of the trade flows in the paper cycle for 1991 are summarized. The trade figures on waste paper demonstrate a much greater involvement of developing countries in waste paper than is the case for other paper commodities.

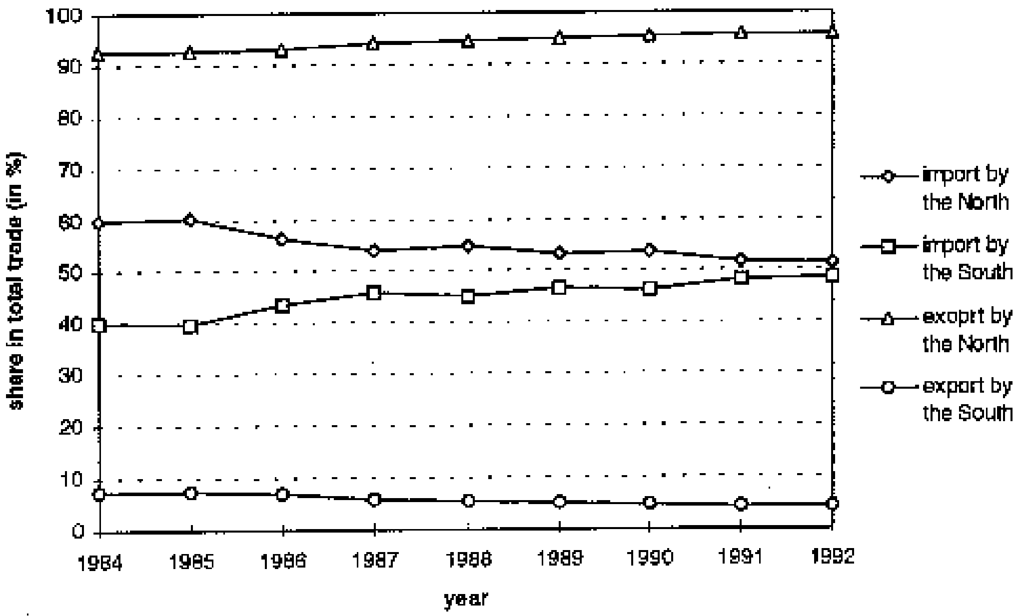
Table 2.1 Direction of Trade Flows in the Paper Cycle (1991)

	Percentage of World Trade			
Direction	**Wood Fibre**	**Wood Pulp**	**Paper**	**Waste Paper**
North-North	82.5%	77.0%	73.9%	51.1%
North-South	2.4%	14.3%	16.7%	39.8%
South-North	12.8%	6.6%	2.6%	0.3%
South-South	2.3%	2.1%	6.8%	8.8%

Source: IIED 1995, PPI 1994

Moreover the share of international trade of waste paper to the developing countries is gradually increasing. This is demonstrated in Figure 2.1. At present, the developing countries import almost a similar quantity of waste paper as do the developed countries. The export of waste paper, on the other hand, is dominated by the supply from the industrialized countries. Export of waste paper from the developing countries is practically non-existent.

Figure 2.1 Development of imports and exports of waste paper (1984-1992)



Source: PPI 1994

Countries have basically two reasons for importing or exporting waste paper: they either have a shortage or excess of waste paper supply, or they do not collect the proper type of waste paper. A typical example of a country which faces the second problem are the Netherlands. The Netherlands rank third in absolute quantities of both waste paper exports and waste paper imports. The Dutch paper industry imports specific types of waste paper such as white cuttings, while exporting the types which are less in domestic demand such as newsprint. This type of trade suggests a certain degree of specialization within the paper recycling industry, as well as a higher degree of sophistication of the international market of waste paper.

The countries which either have an overall excess or shortage of waste paper are listed in Table 2.2. Instead of looking at the absolute volume of imports or exports, the net-import and net-export volumes are shown. This excludes countries such as the Netherlands. In terms of volume, Taiwan and Korea are the largest net-importers of waste paper. The third column in Table 2.2 depicts the dependency of the recycling industry on waste paper import. This is measured in terms of net-import as a share of domestically utilized waste paper. Indonesia turns out to be the most import dependent country with 64% of the recycled paper being produced from foreign waste paper. Countries like China and Japan are relatively much larger net-importers of waste paper, but because of their large local collection and the absence of exports of waste paper they are only slightly dependent on waste paper import.

The supply side of the international waste paper market, which is shown in the second half of Table 2.2, constitutes a much more select group of countries. The United States is by far the largest net-exporter of waste paper. In order to determine the dependency of the net-exporters on international trade, the net-export of waste paper is determined as a share of the total amount of domestically recovered waste paper. These rates are depicted in the second column. In this list two types of countries can be recognized. One group, consisting of the United States, Norway and New Zealand, represents countries with abundant fibre resources. This group tends to use wood-pulp instead of waste paper. The other group which consists of Hong Kong, Singapore, Denmark, Germany and the United Kingdom, has high levels of waste paper consumption but still collects more than what is required domestically.

Table 2.2 Ranking of Main Importers and Exporters of Waste Paper (1991)

Waste Paper Importers	Net Import (MT)	Import Dependency	Waste Paper Exporters	Net Export (MT)	Export Dependency
Taiwan	1906	34%	United States	5874	21%
Korea, Rep.	1390	38%	Germany	1079	14%
Mexico	940	43%	Belgium/Lux.	428	60%
Japan	848	6%	Hong Kong	294	60%
Italy	689	25%	Switzerland	150	20%
China	616	13%	United Kingdom	136	4%
Indonesia	549	64%	Denmark	124	29%
Spain	487	22%	Singapore	80	44%
Austria	457	39%	Norway	35	17%
India	394	53%	New Zealand	27	21%

Source: PPI 1994, FAO 1993b

2.3 Recovery, utilisation and trade of waste paper

International trade allows countries to use more waste paper than is recovered or to recover more than is needed. The possible gap between the two will be filled by trade of either finished paper products or waste paper products. In other words, the paper cycle extends far beyond the national borders. Understanding the country-specific determinants of recovery and utilisation therefore is synonymous with understanding trade flows. In this section, a framework will be developed in which both waste paper trade and trade in finished paper products are defined in terms of the determinants utilisation rate and recovery rate. This framework is adopted from Grace *et al* (1978). Next, actual trade flows and the recycling determinants will be described empirically. In designing a framework, stocks of waste paper are assumed to remain constant over time.

2.3.1 Theoritical framework

The recovery rate (R) is defined as the share of waste paper which is domestically recovered (W_d) from the consumption of paper and paperboard in a particular country (equation 1). The total consumption of paper and paperboard consists of the domestic production of paper and paperboard (Q_{dp}) plus imports minus exports of paper and paperboard (M_p - M_p).

(1) $$R = W_d / (Q_{dp} + M_p - X_p)$$

The utilization rate of waste paper (U) is defined as the amount of waste paper used for the paper and paperboard as a share of the total production of paper and paperboard (Q_{dp}) (equation 2). The amount of waste paper used is determined by the domestically recovered waste paper (W_d) plus the net-import of waste paper (M_w - X_w).

(2) $$U = (W_d + M_w - X_w) / Q_{dp}$$

From (1) and (2) a definition which describes the waste paper trade can be derived:

(3) $M_w - X_w = U \cdot Q_{dp} - R \cdot (Q_{dp} + M_p - X_p)$

If U= xR, (x is the ratio of U / R) equation (3) can be written as

(4) $M_w - X_w = (x-1)R \cdot Q_{dp} - R \cdot (M_p - X_p)$

If U=R (or x=1), equation (3) can be written as

(5) $M_w - X_w = -R \cdot (M_p - X_p)$

In other words: if U=R, the trade flows of waste paper and the recovered part of finished paper balance out. A specific case of this situation is a closed economy, where both trade flows are nil. In such a situation, all the recovered waste paper is utilized domestically, and all the paper produced in a country is consumed domestically.

The country will be a net importer of waste paper if:

(6) $(x-1)\, Q_{dp} > (M_p - X_p)$

Suppose U>R (or x>1), the country will be a net importer of waste paper, unless the net imports of final paper products exceed the domestic production by factor (x-1). In other words, if U>R, the country will import waste paper unless a rather extreme amount of finished products is imported. For example, if U=0.6 and R=0.4 (so x=1.5), the country will have to import waste paper to satisfy the utilization requirements, unless the import of final paper products is more than 50% of its domestic production.

The country will be a net exporter of waste paper if:

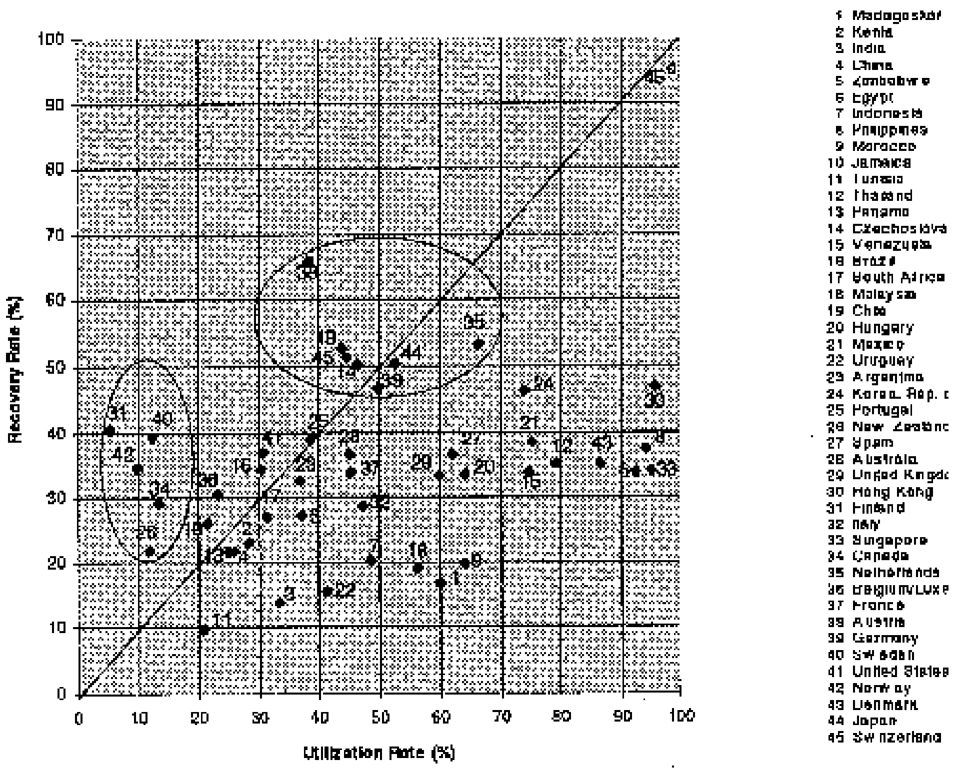
(7) $(x-1)\, Q_{dp} < (M_p - X_p)$

If U<R (or 0<x<1), the country will be a net exporter of waste paper unless the net exports of final paper products exceed a -(x-1) proportion of domestic production. In other words, if U<R, the country will export waste paper unless a rather extreme amount of finished product is exported. For example, if a country U=0.4 and R=0.6 (so x=2/3), it is safe to conclude that the country exports waste paper unless the country exports more than 1/3 of its finished product. In sum, the higher the difference between U and R, the higher the probability that the country can be identified as exporter or importer of waste paper. In all cases, differences between U and R of a country imply trade, either in waste paper or in finished paper.

2.3.2 Empirical evidence

The scatter plot of U and R for various countries is depicted in Figure 2.2. Combinations are largely dispersed at both sides of the 45° line. In general, points above the 45° line represent countries which export waste paper and points below it represent importers of waste paper. The Philippines (point 8) for example, almost solely use waste paper as input for the paper production (94%). Only 37% of paper consumed in the Philippines is recovered. This combination of U and R is a strong indication that the Philippines has to import waste paper in order to meet demand. Evidence indeed shows the Philipines to be an importer of waste paper. At the other extreme we find Norway (point 42): the recovery rate (29%) exceeds the utilization rate (13%). This can be an indication for waste paper export. Table 2.2 indeed shows Norway to be a major exporter. Finland (point 31) is considered, as an example of a case where the difference between U and R is not a strong indication for trade in waste paper. Although the recovery rate of 40% is much higher than the utilization rate of only 5%, Finland's net-trade in waste paper is almost zero. This is explained by the fact that Finland exports a very high proportion (7/8) of its finished paper products. Thereby, Finland does not export it's waste paper directly but in the shape of recycles products. This specific country case indicates the complexities of an empirical analysis in this field.

Figure 2.2 Allocation of utilization and recovery of waste paper (in 1991)

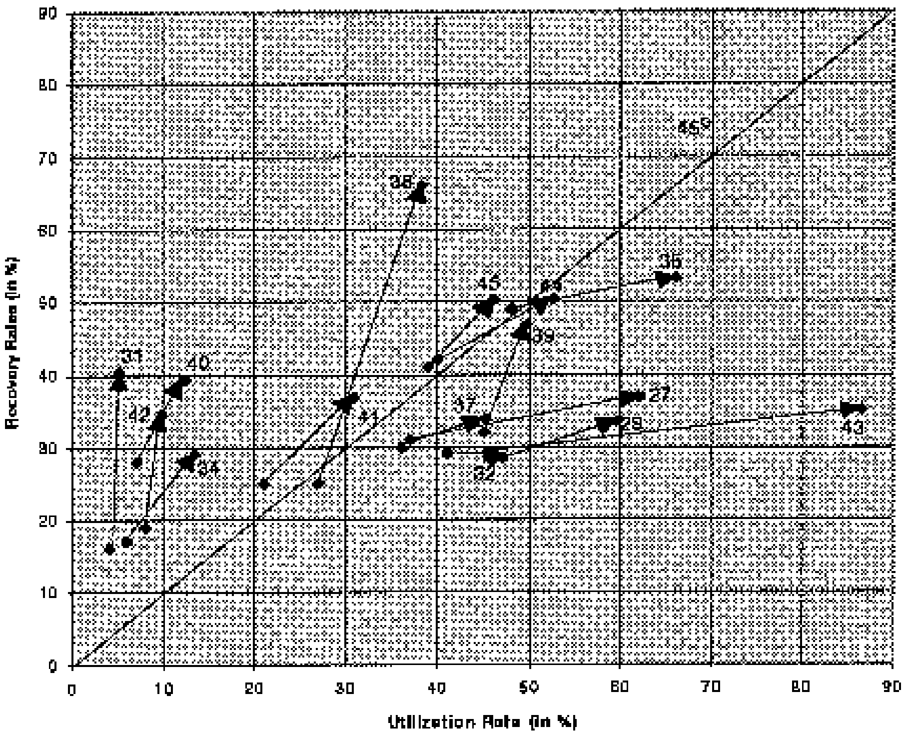


Source: PPI 1994

The above figure displays specific patterns which give a first indication of the possible determinants of the utilization and recovery rate. The most obvious pattern that emerges is the distinction between fibre-rich countries and countries with a low availability of inputs for paper products. The latter group of countries are net-importers of raw materials such as wood-fibre, pulp and waste paper. Most of these countries lie below the 45° line. Net-exporters of raw materials, such as Canada (point 34), Finland (point 31), Sweden (point 40), New Zealand (point 26) and Norway (point 42), are encirled and lie left of the 45° line. Another interesting pattern in Figure 2.2 is the cluster of countries that lie close to the N-E corner, implying a high recovery level as well as a high utilization level. This group, consisting of Austria (point 38), Switzerland (point 45), Japan (point 44), Germany (point 39) and the Netherlands (point 35), are all high-income countries with strict regulations on recycling and solid waste management. This might explain the relatively high level of recycling in these nations. To determine these patterns more comprehensively, and to find other patterns of specific clusters, it is necessary to analyse recovery and utilization performances seperately.

Besides looking at the present distribution of recovery and utilisation rates, it is important to consider the changes in time. Figure 2.3 depicts the changes in recycling levels between 1973 and 1991 for various industrialised countries (data for 1973 for developing countries were not available). Two observations can be made from this figure. First, all arrows are pointed away from the origin (0,0), implying that recycling levels increased over time. The average utilization rate increased from 30% to 42%. The average recovery rate went up from 29% to 40%. Second, a pattern of specialisation emerges as arrows are diverting from the 45° line. Countries lying above the 45° line such as Norway, Canada, Sweden and Finland, shift relatively more towards higher recovery rates, while most countries below it such as Denmark, the Netherlands and the United Kindom, increase their utilization rates. This diversion from the 45° line implies an increasing importance of international trade of both finished paper products as well as waste paper.

Figure 2.3 Developments in recycling in industrialized countries (1973-1991)



Source: Grace et al. 1978, PPI 1994

In Table 2.3 a distinction is made between importers and exporters of finished paper products (more specifically paper and paperboard, P&PB). International trade in P&PB has strongly increased in the period 1973-1991. Although the share of paper and paperboard trade to domestic paper production in the exporting countries increased only modestly from 68% to 71%, the importers almost doubled their dependency on foreign supplies. Their share of net imported paper compared to local production increased from 25% to 50%. Next, if the change in utilisation performance of these two groups is analysed (see second collumn) another striking observation can be made: importers of P&PB can be identified as waste paper users and exporters of P&PB produce mainly on basis of virgin materials. Looking at the third collumn it can be concluded that paper does not seem to be related to the direction of the P&PB trade flow; the average rate is similar in both P&PB importing as well as exporting countries.

Table 2.3 Impact of international trade and waste paper

	net trade as share of production		average utilization rate		average recovery rate	
	1973	1991	1973	1991	1973	1991
P&PB exporters	68%	71%	10%	16%	21%	42%
P&PB importers	25%	50%	40%	56%	34%	42%

Source: Grace et al. 1978, FAO 1993b, PPI 1994

In summary, recycling activity has increased in the past 20 years. This is shown by the increased utility of waste paper in the production process and also the increased recovery of consumed paper. Further, waste paper has become an international commodity. The recovery and the utilisation of waste paper are able to develop indepently from each other, so that a reallocation of waste paper recovery and utilization may transpire at a global level. It is not easy to determine whether trade is the result or the cause of increased recycling activities. In both cases trade accommodates efficient use of increased amounts of waste paper. In the following section, this causality question will be addressed.

2.4 Determinants of international trade

In the previous sections it was found that international trade in waste paper is determined by basically four country specific factors: (1) consumption of final paper, (2) Recovery of waste paper, (3) production of paper, and (4) utilisation of waste paper. In this section the analysis is taken one step further by identifying and analysing the variables which are related to these four factors. Based on these findings, it will be possible to get a better understanding of reason why developing countries are popular destinations for internationally traded waste paper.

A dataset was compiled from the 45 countries depicted. According to the World Bank classification, the dataset includes 24 developing countries (low and middle income) and 21 industrialized countries (high income) (World Bank 1995). The explanatory value of various determinants is estimated through an Ordinary Least Square (OLS) regression. Because of the lack of data, certain relations will only be described in a qualitative manner, using empirical cases for illustration.

2.4.1 Consumption of paper

Consumption of paper varies significantly over the various countries. The weighted average paper consumption per capita in 1991 in the dataset is approximately 56 kg, with a maximum of 298 kg in the United States and a minimum of 1 kg in Tunisia (FAO 1993b). The following variables underlie per capita consumption.

Per capita income: The main factor affecting the consumption of paper products at the national level is per capita income. Per capita income and per capita paper consumption are closely related. Paper consumption increases with incomes, though, this relation is less strong for the high-income countries. This is confirmed by the regresssion. Furthermore, paper consumption can be explained by a number of other variables. They include:

Relative prices: Total paper consumption can be expected to behave normally as a negative function of the price. The impact of paper prices on the total consumption of paper depends on the possibility to substitute for the paper and the per capita income of the consumer. In many types of end-uses of paper the elasticity of demand for paper is derived from the demand for another product, as in the case of packaging. In these instances only a small proportion of the costs of the final product is accounted for by paper, making the demand inelastic (IIED 1995). But in cases where the cost of paper are not a small share of the total cost or income such as in the production of newsprint or the purchase of note-books by the poor in developing countries, the per capita use of paper will depend on its price and the availability of substitutes. Very different products can act as substitutes for paper. In the case of packaging, plastic has the potential to replace paper and the choice between these products depends on their price and technical qualities. Other substitutes for paper can be as diverse as slates or electronic mail.

Literacy: Literacy is an important factor in the consumption of paper. In FAO's 1977 World Pulp and Paper Demand, Supply and Trade, a quantitative assessment of a literacy elasticity was attempted. Their results suggest that a one per cent improvement in literacy will result in a one per cent increase in the annual consumption of paper.

Technological developments: Technological developments can enhance or deter the use of paper. The development of plastics technology for example has led to increased use of paper and paperboard in applications such as laminated/multi layer beverage cartons (IIED 1995). Also, the widespread introduction of photocopiers is likely to generate an increase in the use of paper. On the other hand, the spread of electronic media could have a depressing effect on the use of paper. So far, however, no decrease of paper use, resulting from the introduction of computers, has been observed.

Environmental policy: The effect of environmental policy on paper consumption might go in either direction. Policies can affect the choice between different types of packaging material. Paper may be favoured over plastics for certain types of packaging, but if multi-trip packaging is to be promoted then paper packaging may be substituted by other types (like containers and bottles). The decision to use waste paper is affected by government levies, for example, on packaging.

Table 2.4 presents levies for paper and plastic for a selected number of European countries. Evidently in a country like Belgium, relatively high levies for plastic favour paper use. But the weight of the materials used has to be taken into account as well. Pressures for lightweight packaging to reduce the volume of raw material inputs and of solid waste are detrimental to paper use, especially since the use of recycled fibre causes heavier packaging to offset the loss in strength.

Table 2.4 Packaging levies in selected European countries (pounds/tonne)

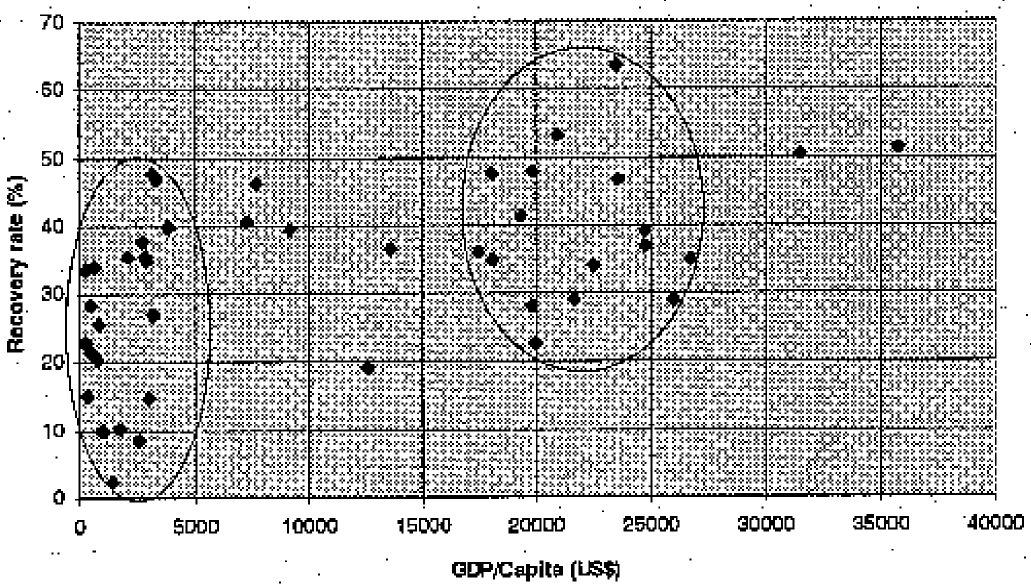
	Belgium	France	Austria	Germany
Paper	9	37	161	170
Plastics	224	30	922	1255

Source: Warmer Bulletin, February 1995a

2.4.2 Recovery rate

In 1992 the average global recovery rate of paper was 37% (PPI 1994). Clearly a precondition for efficient recovery of waste paper is the existence of a recovery system. It has been suggested that the reasons for the existence of such recovery systems differ for developing and developed countries (Beukering 1994). Figure 2.4 confirms this as recovery rates are clustered in two groups: one for countries with per capita income below US$ 5,000 and one for countries with incomes higher than US$ 15,000. Rich countries have an average recovery rate which lies significantly above that for developing countries: 39% versus 28%. Within both clusters vast differences in recovery rates exist. The following factors explain the variation of the recovery rates.

Figure 2.4 Recovery rates in developing and industrialized countries (1991)



Source: PPI 1994, World Bank 1995

Urbanisation: It can be argued that paper recovery is facilitated when people live clustered in highly urbanized countries. This is confirmed by the data. Recovery rates and urbanisation are significantly correlated.

Total paper availability: Recovery of waste paper will be facilitated when paper is available in large quantities i.e. recovery rates could be positively related with per capita paper consumption. On the other hand, it can be argued that, since paper consumption and per capita income are highly correlated, people with higher paper consumption and hence higher per capita incomes have less financial incentives to recover waste paper. This would make the relationship between recovery rates and per capita consumption indeterminate. Still other arguments than financial incentives might play a role in the recovery of waste paper.

Utilization rate: Despite the fact that international trade can always supply or absorb any domestic excess or deficit of waste paper, a domestic recovery system will be enhanced by the presence of a strong domestic demand for waste paper. Manufacturers will, within certain limits, first look domestically before they consider importing their waste paper supplies. Hence a high utilization rate will enhance domestic waste paper recovery.

In order to test the above factors a regression was performed. The following equation (8) was examined for all countries. Urbanization rates and per capita paper consumption are strongly correlated with per capita income. Therefore, only the last factor is included in the equation. It is also interesting to examine this relationship for developing and industrialized countries seperately. These relationships are respectively shown in equations 9 and 10.

R = Recovery rate
R_{DC} = Recovery rate in developing countries
R_{IC} = Recovery rate in industrialized countries
GDP/P = Income per capita / 1000
U = Utilisation rate

$$(8) \qquad \log R = \underset{(5.07)}{18} + \underset{(4.41)}{0.674} \log GDP/P + \underset{(2.85)}{0.186} \log U$$

R^2 = 0.350 (corrected)
n = 45
t = in brackets

$$(9) \qquad \log R_{DC} = \underset{(2.31)}{10} + \underset{(2.89)}{2.970} \log GNP/P + \underset{(3.09)}{0.255} \log U$$

R^2 = 0.469 (corrected)
n = 24
t = in brackets

$$(10) \qquad \log R_{IC} = \underset{(2.67)}{24} + \underset{(1.53)}{0.609} \log GNP/P + \underset{(0.63)}{0.062} \log U$$

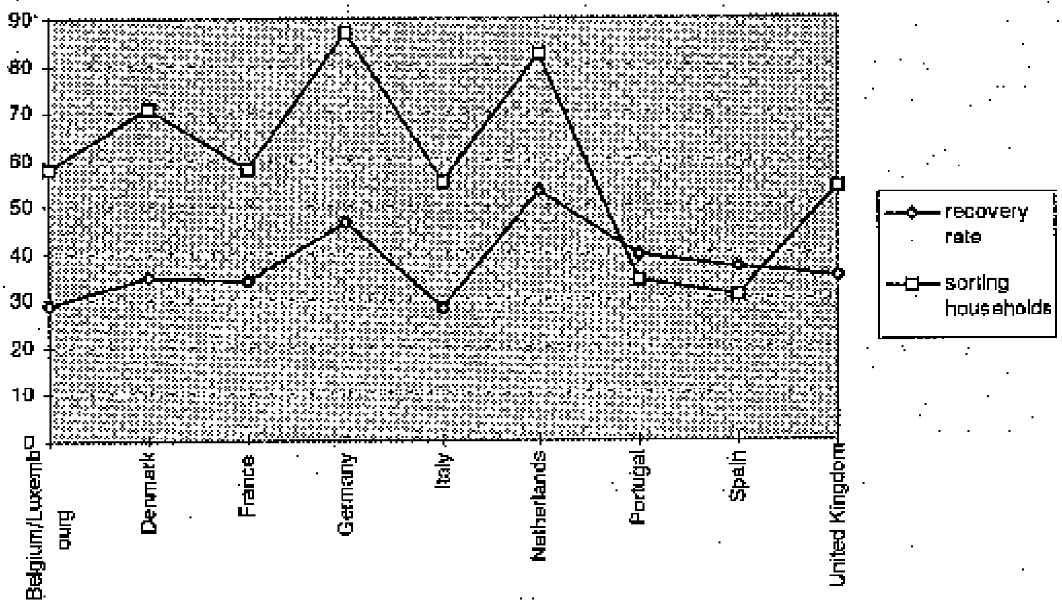
R^2 = 0.051 (corrected)
n = 21
t = in brackets

The OLS-regression shows that utilization rate and per capita paper consumption indeed have the expected effects on recovery rates. For the whole group of countries and for the developing countries alone, both factors are significant (as indicated by a relatively high R^2). Within the group of industrialised countries, these factors are not explanatory. This supports the idea that recovery of waste paper in developing countries is a much more market-driven phenomenon than in the high-income countries: waste paper is collected because there is a local demand for waste paper. Indeed, evidence on price elasticity for the recovery of waste paper shows that in industrialized countries prices are much more inelastic than in developing countries (Edwards 1979, Deadman & Turner 1981).

The finding that utilization rate and per capita paper consumption all explain the recovery rates for the whole group of countries, the differences between developing countries but not the differences between industrialized countries supports the conclusion that recovery rates of waste paper are mainly influenced by these forces, but that once a certain level of paper consumption has been attained other factors become more important. This suggests that other factors might be at play in high-income countries:

Cost of disposal: High disposal costs to the consumer clearly provide him with an incentive not to dispose waste paper as garbage, but to recycle it. Especially in the United States and Europe, the cost of disposal increased rapidly over the past years. Landfill taxes and levies have been introduced in many industrialized countries. Many incompetent landfills have been closed due to environmental risks and capacity limits. As a result the capacity of much more expensive incinerators had to be increased. In countries like Denmark or Germany incineration costs of solid waste are US$ 115 and even US$ 130 per tonne (Bernard and Chang 1995). In developing countries where disposal is often free of charge, the incentives to recycle are absent. Bernard and Chang (1995) found that countries with high costs of disposal tend to export waste while countries with low costs of disposal tend to be importers.

Figure 2.5 Sorting of Solid Waste and Recovery Rates of Waste Paper (1992)



Source: Warmer Bulletin, February 1995b

Government intervention and environmental awareness: Government interventions can be twofold. First, governments play an important role in recycling through the passing of environmental laws. Recycling obligation of packaging material in Germany clearly enhances paper recovery, similar to the 40% recovery goal set for 1995 by the American Forest and Paper Association. Also indirectly by enforcing rules on dumping, governments affect the recovery of waste paper. Second, governments have the task to inform and educate consumers, so that they can support recycling. Europeans and the Environment published the results of a survey on the attitudes of Europeans towards environmental issues, the so called EUROBAROMETER (Warmer Bulletin, February 1995b). Figure 2.5 presents the recovery rate for some European countries and the percentage of households which indicated that they "sort out certain types of household waste (glass, paper, motor oil, batteries) for recycling." The graph suggests a rather strong relationship between the sorting of household waste and recovery rates. Sorting of household waste in developed countries is a voluntary activity which will only be carried out as a result of sufficient information and, if necessary, through coercion by the government. This emphasizes the importance of cultural factors in recovery in the North.

2.4.3 Paper production

More than consumption of paper, paper production process varies significantly among countries. Although the average per capita paper production of 57 kg is almost similar to the level of consumption, the variation in production is much larger. Finland is by far the largest per capita producer with 1,794 kg. Tunisia on the other hand, produces only 0.5 kg of paper per capita (FAO 1993b). The following variables underlie production.

Per capita income, forest area and population density: As was the case for paper consumption, OLS-regression shows that per capita income explains the per capita production of paper to a large extent. Examination of the subsets of developing and developed countries reveals that per capita income only explains the variation in (and not the level of) per capita paper production in developing countries. In the high-income countries paper production typically takes places in scarcely populated countries (hence the negative relation with population density) with large forest reserves. The five largest and traditional paper producing countries (Sweden, Canada, Finland, Austria and Norway) match this description rather well. In developing countries, differences in per capita income explain fully the variation in paper production. Neither population pressure nor forest reserves contribute to the production of paper. This conclusion is in line with the Shell/WWF estimation that only one per cent of wood for pulp comes from natural tropical hardwoods.

2.4.4 Utilisation rate

The decision to use waste paper or an alternative input for the production of paper is primary determined by the rate of return of either production method. The rate of return will differ from country to country and depends upon (input and output) market conditions and factor endowments. In the following papragraphs, several determinants are analysed and discussed which can have an impact on the utilization rate.

Relative price: Under the usual profit maximizing conditions the utilization rate of waste paper is a negative function of its price, and a positive function of the price of its substitutes which in most cases is wood pulp. Availability of waste paper and wood pulp are the most important determinants of the relative price. Not surpisingly, wood pulp is more intensily used in countries with large forest resources while waste paper is particularly popular in countries with a large supply of waste paper. As waste paper and wood pulp are substitutes, the price of wood pulp and wastepaper are closely linked. Various factors exist which have an impact on the relative price of these substitutes. First, the operating costs of the use of waste paper is lower than virgin paper making. The relative price of waste paper is positively affected by the fact that recycled fibre require much less energy than virgin pulp facilities (FAO 1994). This positive effect is partially compensated by the higher usage of chemicals recycling (Clean Washington Center 1993). A disadvantage of the use of recovered paper is the high quality control expenses as contaminants in the waste paper require process adjustments and can lead to increased machine run interruptions. Paper breaks occur more frequently which in turn depresses productivity. However, technological improvements narrow the differences in application between both virgin and recycled paper products. The introduction of more sophisticated techniques for cleaning and grading secondary fibres enhances the ability of paper mills to utlize even the lower grades of waste paper (Ogilvie 1995). The image of waste paper as an inferior input of last resort is changing gradually. More and more, it is being realised that waste paper and wood pulp can serve the same demand.

A second factor positively affecting the relative price of waste paper are the lower investment costs per tonne of output. FAO (1994) figures show that investments in new pulping equipment are much more expensive than the relatively simple equipment for processing waste paper. The investment cost for a new kraft pulp mill is US$ 1200/annual tonne and for recycled fibre production US$ 80/annual tonne without deinking and US$ 400/annual tonne with deinking (FAO, 1994). Such lower investment costs will increase the demand and hence the price of waste paper. Low investment costs lead to relatively high utilization rates of waste paper in developing countries, because capital is usually much more scarce.

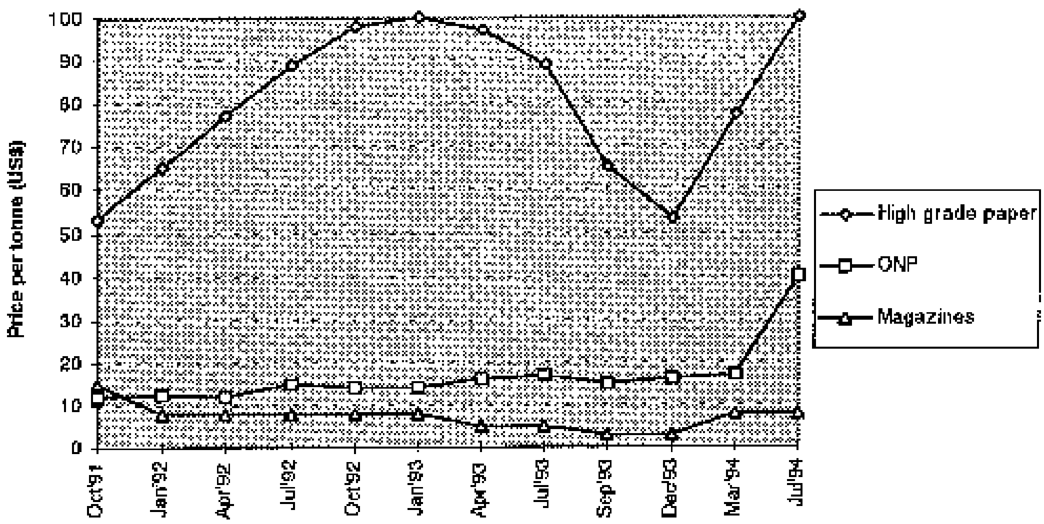
Obviously, the benefits of the operational costs and lower investment costs must be balanced against lower product quality and lower prices of recycled products. Particularly in industrialized countries, quality demands will be more distinct. Yet this is partly compensated by the growing demand for recycled paper because of increased environmental awareness. In general, the price of waste paper is lower than the price for wood pulp. However, under specific market conditions the reverse has been found (Edwards 1979, Yohe 1979). An explanation for this phenomena is, for example, that fixed long term contracts exist for wood pulp but not for waste paper. In times of increased demand, waste paper prices can be temporarily higher than wood fibre prices.

Quality: The relationship between utilization rates and relative prices is obscured by differences in waste paper quality. Numerous qualities of waste paper are distinguished on national and international waste paper markets. These quality differences can be substantial and thereby also influence the price of waste paper (see Figure 2.6). In India, for example, imported waste paper sells at twice the price of domestic waste paper due to quality differences. In practice it is difficult to determine the exact quality of waste paper relative to that of wood pulp. This relationship is further obscured by losses of waste paper during the pulping process. These losses vary and can be substantial. FAO (1993) reports, for example, 20% losses for the U.S.A. versus 10% for Austria and 15% for Germany. In general, it can be assumed that the pulping losses in developing countries are larger than in the high-income countries.

Market structure: On the input side, the relative price of waste paper and virgin fibre is also affected by the organization of the market. Edwards' (1979) report for the United States shows that waste paper prices fluctuate to a much larger extent than wood fibre because of long term contracts in the latter. Deadman and Turner (1981) mention that for the waste paper market in the United Kingdom a trend toward backward integration into merchant supplying by the mills becomes apparent. Recycling mills secure their supply of waste paper by merging with their supplies. Similar tendencies can be recognized in other industrialized countries. This develoment supports the statement that the waste paper market is not free from market distortions.

Also on the output side, consumer preferences affect the firms input choice. Increased environmental awareness for example, forces paper producers to start or increase the use of waste paper, as this can open new markets for them (recycled writing paper) or can give them a competitive edge. Also if consumers demand relatively low quality paper varieties like kraft paper, the utilisation rate of waste paper will increase especially in locations where the technologies to produce high grade paper out of waste paper is absent. This will be particularly relevant for developing countries where low incomes force consumers to be more intrested in price than quality, thus generating a relatively large demand for low quality paper.

Figure 2.6 Average price of different qualities 1991-1994 (US$/Tonne)



Source: Metro 1994

Government regulations: Government regulations affect relative prices and hence utilization rates in various ways. First, in the presence of international trade and in the absence of trade barriers, relative local prices reflect world market prices. In reality, trade barriers are seldom absent. As such utilization rates are affected by import tarriffs, non-tariff barriers and the local availability of waste paper and virgin fibre. Also, government interventions aimed at increasing the collection of waste paper via subsidies or increased environmental awareness affect relative prices.

It is safe to assume that the relative price is the main determinant of the use of waste paper. Unfortunately the prices of waste paper and virgin fibre are unavailable for most countries so that direct estimation of a relationship between utilization rates of waste paper and relative prices is impossible. It can only be done by using instrumental variables. One alternative is to assume that the relative availability of wood fibre and waste paper reflect prices. Thereby forest and the recovery rate provide a satisfying representation of the relative prices. But in the presence of international trade, with given prices for waste paper and virgin fibre, the quantities of imported waste and the relative availability of different goods is difficult to determine. A simple equation was tested which explains the utilization rate (equation 11). Similar to the the recovery rate, separate equations were estimated for developing (12) and industrialized countries (13).

U = Utilization rate
U_{DC} = Utilization rate in developing countries
U_{IC} = Utilization rate in industrialized countries
F = Forest area per capita
R = Recovery rate
GDP/P = Income per capita

(10) $$\log U = \underset{(3.83)}{2.8} - \underset{(-3.27)}{0.164 \log F} + \underset{(2.45)}{0.652 \log R} - \underset{(-2.02)}{0.145 \log GDP/P}$$

R^2 = 0.256
n = 43
t = in brackets

(11) $\log U_{DC} = 2.5 - 0.063 \log F + 0.447 \log R - 0.031 \log GDP/P$
$(3.10) \quad (-0.95) \quad (1.87) \quad (-0.30)$

R^2 = 0.115 (corrected)
n = 23
t = in brackets

(12) $\log U_{IC} = 3.3 - 0.303 \log F + 0.558 \log R - 0.148 \log GDP/P$
$(0.88) \quad (-5.17) \quad (1.08) \quad (-0.36)$

R^2 = 0.591 (corrected)
n = 20
t = in brackets

The results of the regression confirm the hypothesis that waste paper utilisation rates decrease with the availability of forest. This relationship holds especially for the industrialised economies. In developing countries utilization rates are mainly explained by waste paper recovery rates. Tropical forests are generally not ideal for the production of paper. The low overall explanatory value indicates that other factors must play a role in determining the utilization rate.

2.4.5 International trade

In Section 2.3 it has been shown that international trade comes into play in those instances where domestic demand and supply do not match. The analysis of the factors determining domestic demand and supply of waste paper were domestic oriented. Evidently the factors determining local demand and supply also determine international trade. What does this imply for the trade patterns? It was observed already that on a global scale, developing countries are net importers of waste paper and developed countries are net exporters. An F-test on the ratio of net waste paper trade and per capita income strongly confirms this empirical pattern.

In view of the high per capita level of paper consumption and the fact that recovery rates are high and to a large extent governed by non-price incentives, the net exporting position of waste paper of industrialised countries comes as no surprise. In developing countries, where the levels of paper consumption are much less and where the use (re-use) of paper is much more intensive, the quality of the collected waste paper is generally low. High quality waste paper suitable for use in paper production is relatively scarce and has to be supplemented by imported waste paper. This results in a net flow of waste paper from industrialised to developing countries.

How this picture will develop in future is unclear. In the industrialised countries where most of the worlds' paper production is consumed, the waste paper recovery rates seem to be determined by political and cultural factors. This does not necessarily result in net export of waste paper, since paper manufacturers clearly respond to price incentives. To the extent that an excessive supply of waste paper leads to low prices, this supply will eventually be absorbed by the domestic consumers, provided this is technically feasible and given that foreign buyers are not prepared to offer a much higher price. Whether or not that will be the case depends on the domestic availability of wood fibre.

In countries where wood fibre is not available in abundance, but with a paper industry that effectuates a net demand of imported fibre (wood or waste paper), the demand for imported waste paper depends on a number of factors like the relative world market prices of virgin fibre and waste paper (including transportation costs), the quality of output to be produced, the technology used and the investment and operational costs of the paper production facility for both types of inputs. Apart from the typical domestic factors which determine international trade, this trade is evidently affected by typical trade factors such as transport and information costs, insurances and legal enforcement. These factors which are inherent to all international trade will not be dealt.

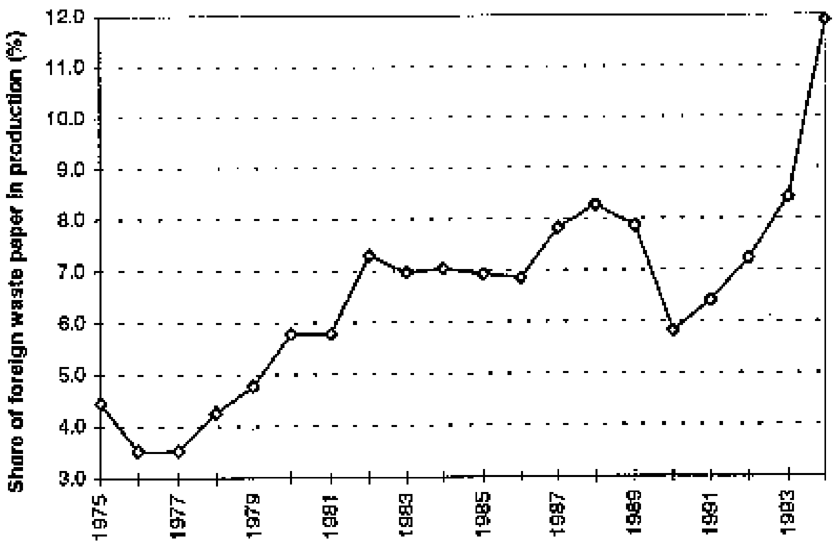
2.5 India and the world trade of waste paper

2.5.1 Trends in the import of waste paper

At present, the Indian paper industry depends for more than half of its waste paper supply on foreign sources. Both quantitatively and qualitatively domestic supply of recovered paper is insufficient. This foreign dependency has increased in the last decade for several reasons.

First, import tariffs have gradually decreased from 40% in 1989 to 10% in 1994 as the Indian government recognised the need for additional supply of raw materials for the paper industry. Second, an input shift of paper manufacturers from agro-residues to waste paper occurred as a result of the stricter environmental law enforcement in India. This resulted in an overall increase in the demand for waste paper. Third, by the late 1980s, governments in the North actively intervened in the recycling sector by introducing a range of "supply-side" and "demand-side" stimuli. Policies and mandates which were aimed at reducing the environmental burden from landfilling and incineration, led to a significant diversion of waste paper from disposal to increased recovery of paper. Consequently, the international waste paper market became saturated with an oversupply which caused a significant drop in the price for recovered paper, leading to a period of sustained market "glut" (Ince 1995). This tendency might have fostered additional investments in the Indian paper industry in its new capacity to use waste paper. Since domestic supply of waste paper remained constant, imports seemed to be the most effective manner to deal with the lack of waste paper. Figure 2.7 illustrates the tendency in waste paper imports of India as a share of the total production.

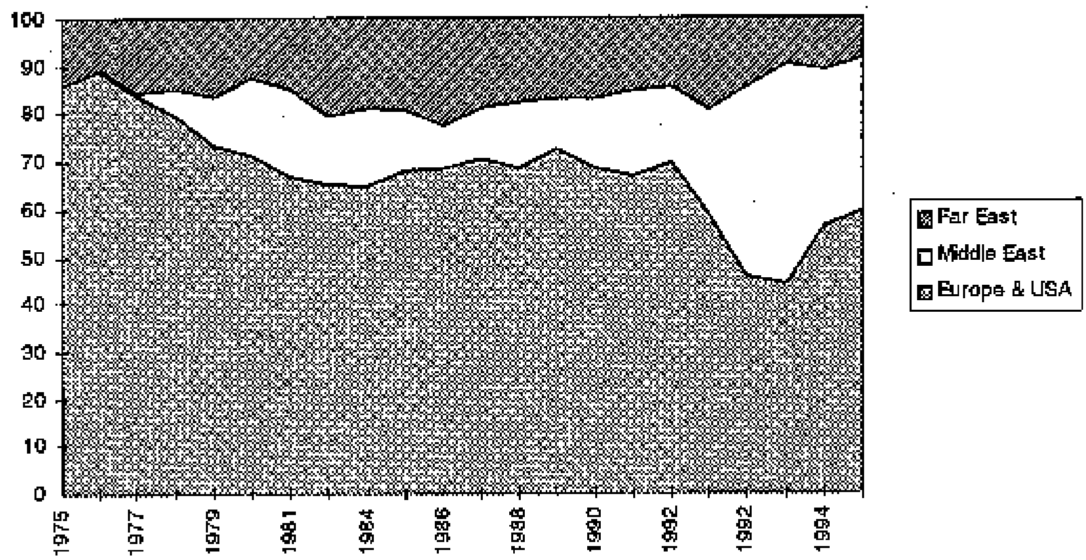
Figure 2.7 Waste paper import dependency of the Indian paper industry



Source: Khanolkar 1995, Worldbank 1994, Informant 1995

In Figure 2.8, the developments of exports to India are illustrated for the period 1975-1992. Clearly, the middle East is becoming a more important exporter to India. The decline in the share of imports from the Far East can be explained by the development of recycling capacity in this region. An interesting development is the gradual decline of the share of Northern countries. Yet in the early nineties this trend is reversed as a result of the oversupply of waste paper by this region. In order to make a prediction of future supply of waste paper to India, developments for the main exporters are evaluated.

Figure 2.8 Country of origin of imported waste paper (in %)



Source: World Bank 1994, Informant 1995

2.5.2 Developments in the supply of waste paper

Various elaborate studies have been conducted on trends in paper recycling or on the impacts of increased paper recycling in Europe and the United States. Generally, these studies emphasise the dynamic nature of technology and markets. Also the interaction with solid waste management often plays an important role. To understand the trends in international waste paper trade, a brief overview of the general outcome of these studies will be presented. An evaluation of these studies is provided by Ince (1995).

In the early 1980s the recovery and utilisation rates in the United States were limited at respectively 27% and 25%. Most studies rightly predicted a fast increase in recycling in the 1980s and 1990s. The glut in the market for recovered paper, which resulted from accelerated programs for collection of waste paper, strengthened this expectation. With sustained low prices for waste paper, investments in recycling capacity in the US increased rapidly. In 1993, the recovery and utilisation rates reached respectively 40% and 34%. The waste paper export by the US increased in this period from 2 million tonnes in 1981 to 5.3 million tonnes in 1993. Recent projections reported the recovery rate in the US to reach between 50% by the year 2000 at which the utilisation rate would be around 40%. Such developments are expected to have a significant impact on the export of waste paper by the US. The projections would lead to a substantial increase of the volume of waste paper export to 12 million tonnes in the year 2000. Yet, the abrupt end to the glut in waste paper markets during 1994-1995 is expected to gradually depress the annual growth rates in waste paper recovery and utilisation. Eventually, the recovery is predicted to plateau at their practical and economic limits in the early millennium. Therefore, the projections on export of waste paper from the US are probably slightly overestimated (Ince 1995). Still, the US can be considered a major future source of waste paper for the Indian paper industry.

Like in the US, recycling programs were the main cause of an oversupply of waste paper in Europe too. Yet, great differences exist within Europe. The Nordic countries have a greater capacity to use their abundant pulpwood resources in paper production while the remainder of Western Europe has a greater capacity to recycle paper. For example, the utilisation rates in Western Europe averaged at 59% compared to only 14% for Sweden. Still, the Nordic mills are certainly not incapable of using waste paper and therefore studies project that waste paper utilisation in newsprint, printing and writing papers, containerboard and other grades are expected to increase much faster than in the rest of Europe. The rest of Western Europe will also increase recycling but to a lesser extent since recycling rates are already relatively high. Ince (1995) rightly comments however, that the ignored increased transport costs resulting from such a trend and the abrupt ending of the waste paper glut in 1994-1995 might actually depress the forecasts in recycling. In terms of waste paper trade Europe is characteristic in trading mainly among neighbouring countries. Therefore, this region is expected not to be a main supplier of waste paper to India in the future.

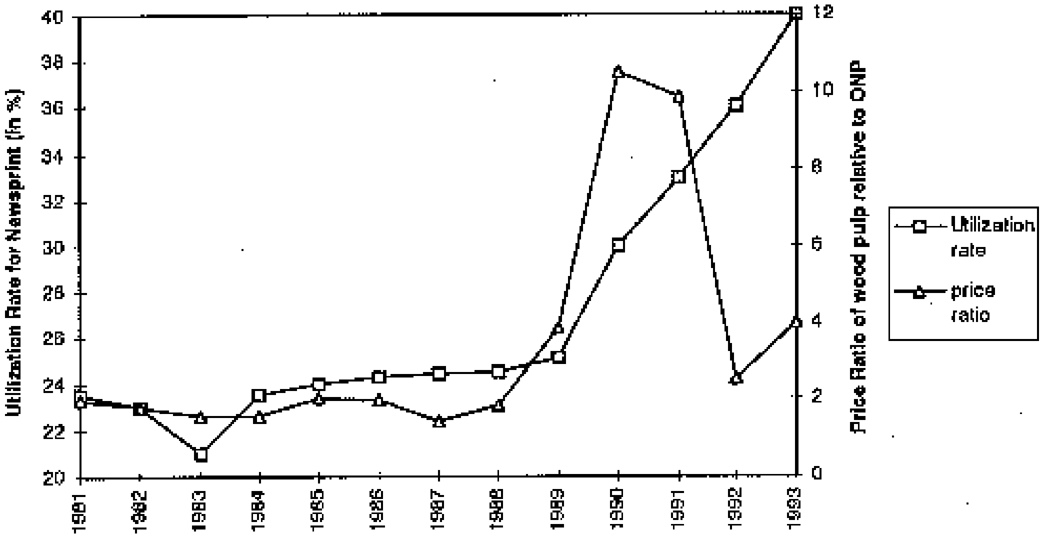
For the Far East and the Middle East, fewer studies are available regarding the recycling trends. Imports from the Far East, which mainly includes Singapore, Hongkong, Indonesia and Japan, show a relative decline in the last few years. This can be explained by the increasing domestic demand for waste paper in these countries. In the case of Japan as well as Indonesia, utilisation of waste paper exceeds domestic recovery, thereby limiting the volume of waste paper for international trade. Singapore and Hongkong trade their waste paper to other countries in Asia, such as China and the Philippines. One possible explanation for the increase of import from the Middle East is the improved recovery in this region while utilisation remains limited. India's geographical location to the west of the Middle East is another advantage. In contrast to the US and Europe, waste paper from the Middle East was found to be popular in India because of the absence of pornographic literature. This type of waste paper unintentionally caused a burden to recyclers who were accused of illegal imports. Given the increasing demand and recovery of waste paper, the Middle East is expected to become a more important source of waste paper for the Indian paper industry.

2.5.3 Other considerations

Technology plays a crucial role in the economics of either utilizing imported and domestic waste paper on the one hand, or wood pulps on the other. The major technological problem in recycling, namely coping with contaminants such as inks, adhesives and plastics, have gradually been overcome. Consequently, these process improvements have helped to establish theoretical costs competitiveness between recycled and virgin fibre paper making processes. The availability of such technologies do not automatically imply immediate substitution from one input to the other. Capital availability and the related capital costs are another dominant factor in paper making. Building modern mills generally requires enormous amounts of capital. Also the service time of such paper mills is rather long. Therefore, input substitution is not an instant affair. Given the severe scarcity of capital in India, modern technologies will only be implemented at a very slow pace. As a result, correlation between the price of wood pulp and waste paper in India, will be lower than is the case in most Western countries.

For India, no studies are known in which the impact of variations in the input price affect the utilisation rates of different inputs. For newsprint production in the US, Ince (1995) convincingly compares the economics of recycled and virgin fibre. Figure 2.9 shows two curves. In the first, which is scaled at the right axis, the trend in the relative prices of recycled and virgin fibre is presented. The glut in the waste paper market is clearly visible. In response to the dramatic increase of the relative price of wood pulp, the US paper industry substantially increased its capacity to produce recycled newsprint.

Figure 2.9 Market value of softwood pulp relative to Old Newspapers (ONP) & the waste paper utilisation rate for newsprint produced in the US



Source: Ince 1995

This development is clearly recognised in the second curve which depicts the utilisation rate of recycled fibre in newsprint production in the US, scaled at the left axis. Although some cases in India confirm this relation between utilisation rate and the relative price of wood pulp and waste paper, aggregate quantitative information is lacking to determine a similar dependence for the Indian paper industry. A relation which is also important to be considered in this context is the impact of variations in the import price of waste paper and the domestic price of waste paper. As a result of differences in quality and freight costs, the Indian waste paper is up to half the price of foreign waste paper.

2.6 Summary and conclusions

In the last decade, a structural change took place in the waste paper market. Initiated by government programs in countries such as Germany and the US, recovery of paper developed rapidly, causing an oversupply on the international waste paper market. Prices collapsed and remained low for a long period. This glut encouraged heavy investments by papermakers in building new recycled-paper mills and adapting old mills for waste paper inputs. This overall global expansion in both demand and supply of waste paper created a much more mature, stable market for used paper. While prices are eventually declining, again observers believe the tremendous paper price crashes seen in previous years are unlikely to recur (Young 1995).

Three reasons underlie this belief. First, technological constraints in the past were the main determinants of the demand for waste paper by the paper industry. These technological limitations have gradually been overcome. Consequently, waste paper and wood pulp have become full substitutes. Recycled fibre should therefore experience future price swings no worse than those experienced by wood pulp, whereas until recently, waste paper markets were far more volatile. Second, a development which might alleviate the uncertainty and unpredictability of the waste prices is the development of a formal trading system for recycled materials. The first steps towards a formal trading system are initiated by the Recycling Advisory Coalition and the Chicago Board of Trade (Young 1995). The project involves product specification that materials will have to meet so as to be traded and the design of an electronic trading system. Also, a procedure will be developed to solve disputes. These are relatively frequent in waste trade for several reasons. Waste is more heterogeneous than traditional materials and thereby often causes disagreement between the trading parties. Also, the volatility of the market provokes traders not to meet their obligations in order to make a better deal elsewhere. Especially for importers from developing countries it is difficult to resolve conflict because they do not have access to the concerned channels. The third argument which supports more stability on the international waste paper market is the fact that the previously existing sources of untapped waste paper have already been exploited significantly in the last decades. As a result the average global recovery rate increased from 29% in 1973 to 40% in 1991. Future improvements in recovery will probably only occur gradually. Supply shocks which caused the glut in the early 1990s are therefore unlikely to repeat.

With increased levels of recycling, international trade of waste paper has also expanded significantly. It was found that, in contrast to trade in virgin fibres which is largely dominated by transactions between neighbouring countries in the North, the share of waste paper which flows to developing countries almost equals the Northern share. By performing a regression analysis for 45 countries, an attempt was made to explain this typical trade pattern by respectively analysing recovery and utilisation of waste paper. Various important conclusions follow from this exercise. First, the recovery rate is found to be significantly lower in developing countries. This is explained by the limited paper consumption and the relatively low utilisation levels of waste paper. In contrast, utilisation rates in industrialised countries do not explain waste paper recovery in their countries. This finding supports the idea that recovery of waste paper in developing countries is a predominantly market-driven phenomenon while in industrialised countries cost of disposal and environmental awareness seem to be the main driving forces of recovery. Second, the utilisation rate is also found to have different determinants in the respective regions. In industrialised countries the regression demonstrated that the waste paper utilisation rate is negatively related with the availability of forest. This relationship is significantly weaker in developing countries where other factors such as capital availability are a more binding factor.

In summary, it can be concluded that the encouragement of governments in industrialised countries to recycle waste paper has significantly helped to reduce market barriers for recycling, particularly those which influenced the supply side. It created a glut in the recovered paper market which in turn motivated the paper industry to build up capacity in the utilisation of waste paper. A similar effect took place in India where the utilisation rate of imported waste paper increased rapidly in times of the market glut. As in other developing countries, this development can be explained for various reasons.

First, using imported waste paper in paper production in the South is relatively more cost-effective than using imported wood pulp. Determinants of this characteristic are limited capital and foreign currency requirements and the relatively high labour intensity of recycling. Second, both in terms of quality and quantity, demand and supply of waste paper are not properly matched in the South. For India it was found that imported waste paper is generally used to upgrade the recycling process in order to diversify the range of paper products which can be produced by recycling factories.

Assuming that increasing rates of waste paper utilisation are desirable, the question remains whether developing countries should continue to increase their dependency on waste paper import. The answer is twofolded. First, the availability of waste paper on the international market should remain stable in the future. If industrialised countries continue to increase their recycling capacity while stabilising their waste paper recovery, the amount of waste paper available for the international market will decrease. Yet, various studies indicate that the volume of waste paper available for international trade will continue to increase in the future. Simultaneously, this trade is expected to show less price fluctuations, which decreases the uncertainties for both importing and exporting countries. A factor which should not be ignored in this consideration is the impact of the international trade on the local recovery sector. If the increased imports crowd out local resources, the gains of recycling are certainly lost. Chapter 5 will address this problem more specifically. Second, developing countries should investigate the potential to satisfy the waste paper requirements domestically. Local waste paper recovery generates various economic and environmental benefits and can save expenditure of scarce foreign currency. However, the problem of quality differences is not solved by this approach. In chapter 4, this issue will be discussed in more detail.

Chapter 3.

THE INDIAN PAPER INDUSTRY

V. K. Sharma
K.V. Ramaswamy
R.R. Vaidya
Nandini Hadker
Pieter van Beukering

3.1 Introduction

In the previous chapter it was explained that international trade of waste paper depends on the difference in the utilisation and the recovery of waste paper across countries. In the coming chapters, these determinants will be studied in more detail for India. To understand the context of utilisation and the import of waste paper in India, the paper industry will be described, with a specific focus on its recycling activities. The paper industry in India is more than a century old. Commercial production of paper was achieved as early as 1879. Limitations with respect to forest-based raw materials forced the Indian paper industry, in these early stages of development, to utilise non-conventional materials. India was the first country in the world to have a paper mill which was entirely based on bamboo as an input. Following this example, various other non-conventional raw materials were introduced such as straw, bagasse, textile and waste paper. Throughout the century, this development was strongly supported by the Indian government with various types of policies.

As a result of these developments, India, after China, most probably accounts for the most number of paper mills in the world. All scales of paper production are performed, varying from handmade paper units to large scale integrated mills. Also with regard to the inputs, the image is still rather heterogeneous. Both woodpulp, waste paper and agricultural residues are widely used in the production process. Also, the heterogeneity in outputs is significant. With the Indian government historically striving for self-sufficiency, all categories of paper are produced, varying from paperboard to speciality paper. At present, the average Indian citizen consumes approximately 4 kilograms of paper each year. Compared to the annual per capita consumption of paper in Japan and the United States which is respectively 234 kg and 298 kg, this figure is very low (FAO 1993). With the prospect of growing urbanisation, increasing literacy rates and increasing general economic growth, the consumption of paper and paperboard products is expected to grow considerably in the coming years. At the same time the Government of India (GOI) initiated a process of liberalisation of the Indian economy, allowing foreign producers to enter the Indian consumers' market or even establish units in India itself.

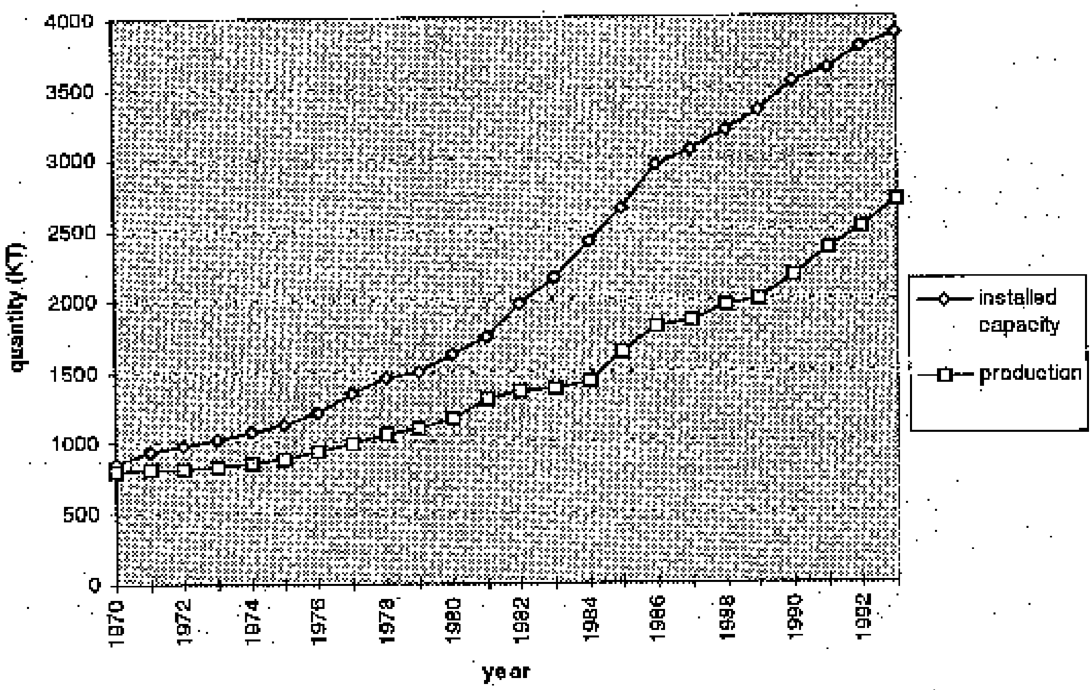
In this chapter the Indian paper industry will be generally described in terms of performance and development. Traditionally, the paper and paperboard industry and the newsprint manufacturers in India have been studied separately since the respective government policies were completely different. However, various reasons exist to treat these two segments in an integrated manner. First, government policies directed to the paper and paperboard industry and the newsprint manufacturers, are converging rapidly. Secondly, from a technical view point the two segments of the paper industry are not very different. As this study has a particular interest in the input requirements of the whole industry, an integrated approach is therefore preferred. Finally, an integrated approach facilitates the comparison with other countries, where generally newsprint and other paper industries are not considered separately. Therefore the paper and paperboard and newsprint will be treated simultaneously.

The structure of the chapter is as follows. In section 3.2 a brief characterisation of the general development of the industry will be given. Secondly, various aspects will be assessed in more detail with regard to output performance (Section 3.3), input utilisation (Section 3.4), market structure of the Indian paper industry (Section 3.5), scale of operation (Section 3.6), and the regional distribution of the paper mills in India (Section 3.7). The environmental impact of the Indian industry is described in Section 3.8. Finally, conclusions are drawn in Section 3.9.

3.2 General performance and developments

Traditionally, the Indian paper industry is divided into two segments: the paper and paper board industry and the newsprint industry (Khanolkar 1995). This division is mainly based on institutional grounds. The pulping and paper making process of the newsprint industry is almost similar to that of the paper and paper board industry, as well as the scale of operation. Therefore, the newsprint industry and the paper and paper board industry will be discussed simultaneously under the general term "paper industry".

Figure 3.1 Capacity and Production of the Indian Paper Industry (1970-1993)



Source: Rao 1989; Khanolkar 1995

Figure 3.1 represents the development of the Indian paper industry in the last three decades. At an aggregate level, both the installed capacity and the actual production seem to grow steadily over this period. If this development is looked into in a more detailed manner, however, conclusions will be different. In the following section, the development of the Indian paper industry will be described, for the period before 1980 and the period after 1980, respectively. 1980 is selected because this was the year in which changes took place in the Indian paper industry which had a significant effect on the performance. This can be seen in Figure 3.1 which shows the widening gap between capacity and production since 1980.

3.2.1 Before the 1980s

The Second World War was the beginning of a long period of growth for the Indian paper industry. Import of paper was heavily restricted, and in 1950 India launched its programme for planned development which resulted in Five Year Plans. At that time only 17 units were operating with a total capacity of 137,000 tonnes. The production was confined to common varieties and there was no production of newsprint. Until then, the country depended heavily on imports of paper products (Rao 1989).

Table 3.1 records the actual growth of installed capacity and production during the period 1950 to 1980. Encouraged by numerous government incentives and growing demand for paper and paperboard, the capacity and production respectively went up from 137,000 tonnes and 116,000 tonnes in 1950 to 1,538,000 tonnes and 1,112,000 tonnes by 1980. This increase in production and capacity did not occur gradually. As indicated by the growth figures, the Five Year Plans resulted in a maximum growth in capacity of 115% in 1955-60 and a minimum growth in capacity of 19% during the 1965-70 period. This minimum growth figure recovered again in the mid 1970s because of the encouragement of the Indian government for setting up small paper mills using non-conventional raw materials and based on imported second-hand machinery. Consequently, the number of paper mills increased rapidly in this period (see Table 3.1).

Table 3.1 Installed Capacity and Production (in 1,000 tonnes)

Period	No. of Units	Capacity (growth in %)*	Production (growth in %)*	Utilisation Ratio
1950	17	137 (-)	116 (-)	0.85
1955	21	186 (36)	185 (59)	0.99
1960	25	400 (115)	345 (87)	0.86
1965	52	644 (61)	539 (56)	0.84
1970	57	768 (19)	758 (40)	0.99
1975	74	1,042 (36)	829 (9)	0.79
1980	123	1,538 (47)	1,112 (30)	0.72

* *Growth rates over the previous five years*
Source: Rao 1989

The highest growth rates in capacity were recorded for in late 1950s and early 1960s. Typical for the Indian industry is the fact that most of the units which were established in this period are still in operation. It is therefore not surprising that one of the major problems of the mills today is the immense backwardness in technology, leading to substantial inefficiencies and inferior products. This problem can also be recognised by the decline of the utilisation ratio, which started in the early 1970s and further decreased during the 1980s.

The Government of India (GOI) intervened in the paper industry in various ways. Inflationary conditions and rising costs of inputs led to the imposition of price control, recommended by the Tariff Commission in 1960. In 1974 the GOI enforced paper manufacturers to produce white paper and supply it at a concessional rate to the educational sector and to the GOI departments. Another important policy of the GOI was to establish relatively high import duties on imported paper and paperboard to reduce import dependency.

Although the decline in the utilisation ratio in Table 3.1can be interpreted as a policy failure of the GOI, India succeeded in her aim to reduce the import dependency on paper and paperboard. While India was importing 43% of its paper consumption in 1950, this share declined considerably during the following period under the import-substitution regime (Rao 1989). In 1980 only 21% of the paper consumption was imported and this rate declined even more in the 1980s and 1990s.

3.2.2 The 1980s and the 1990s

For the Indian industrial sector the 1980s was a period of growth and change. A process of deregulation was initiated by the GOI which had many favourable effects for the industrial economy. The paper industry too was freed from many of the requirements of production, price and distribution controls. Thus, at present, the paper mills can take up the manufacture of any variety of paper. This process of reform, which is called "broad banding", has increased the sensitivity of the Indian paper industry to market incentives.

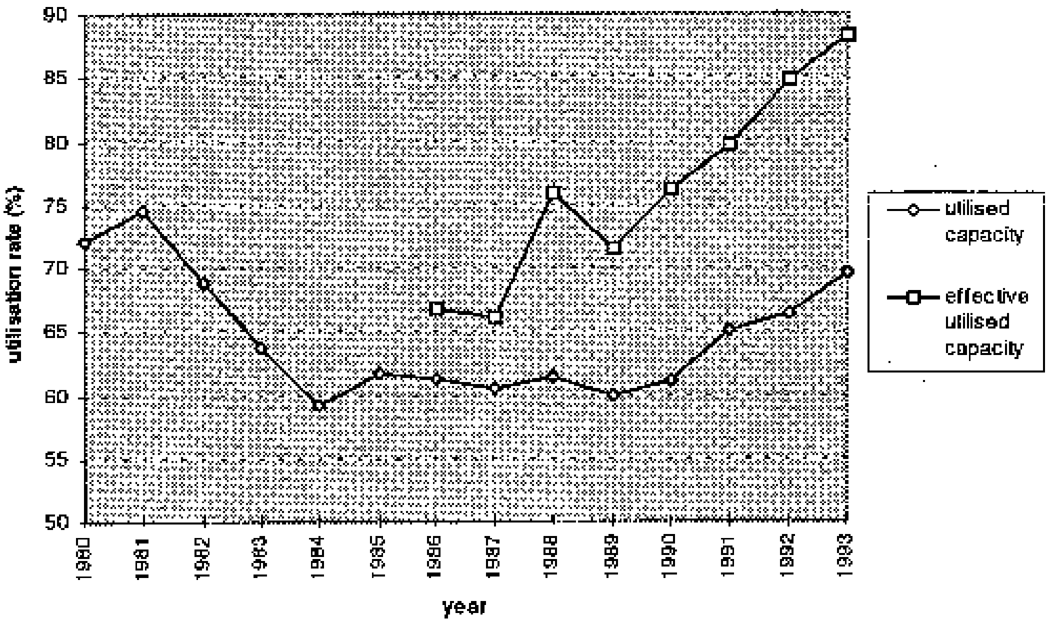
As during 1950-80, the Indian capacity and production of paper and paperboard continued to rise (see Figure 3.1). Although the increase in capacity and production is continuous, the economic performance of the industry has been rather unsatisfactory. Increasing costs of raw materials, power and fuel reduced the average operating profits of mills. Mills were forced to modernise their units. To offset the increased costs per unit, capacity was added to gain scale benefits (Rao 1995). Production, however, was constrained by other factors and took place only at a relatively slow pace.

As a result the production performance of the paper industry reached its lowest point in the mid-1980s. Rising input costs and an overall economic recession were the main causes of this crisis. Many paper mills no longer complied with the paper control orders Since difficulties were encountered in the enforcement of this order, the GOI revised the paper control and regulation orders in January 1987. Gradually, the capacity performance started to recover, simultaneously with the deregulation of the Indian economy.

These developments are depicted in Figure 3.2. The performance is shown in two ways. First, the most common measure is the utilised capacity of the paper industry, which is the total production divided by the total installed capacity in a particular year. But this value is misleading because it also takes those mills into account which are not in operation. For example, of the 345 mills registered in 1993, over a 100 mills where closed down representing a total capacity of 700 KT. This group of sick paper mills conceals the true performance of those mills which are actually in operation. Therefore, the second measure, the total effective capacity, may be a better indication of the true performance of the Indian paper industry.

For the period of 1960-86, the paper industry experienced the maximum number of statutory controls. The efficiency of the Indian paper industry, measured by an index of total factor productivity, declined at the rate of 0.7% per annum. Although the average annual labour productivity growth of the paper industry was 1.5%, the negative annual capital productivity growth of -2.0% dominated the aggregate efficiency performance (Ahluwalia 1991). This negative total factor productivity suggests a declining resource-use efficiency of the Indian paper industry. This is consistent with the observed obsolescence of technology in Indian paper mills (BICP 1987; DPCT 1990).

Figure 3.2 Capacity utilisation

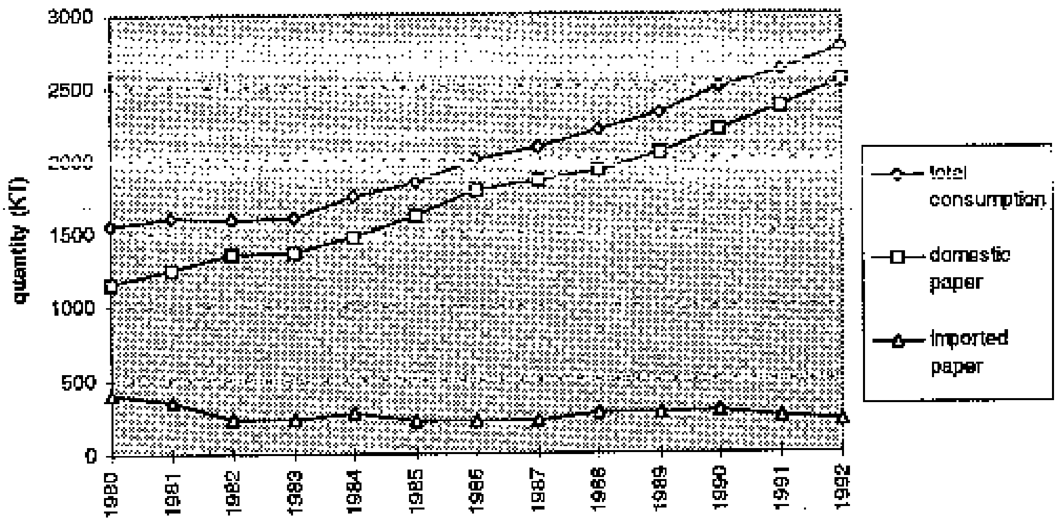


Source: Khanolkar 1995

Figure 3.3 demonstrates the increasing self-sufficiency with regard to paper products in the period 1980-92. Although consumption grew faster in this period than before, the import dependence for paper products declined from 26% in 1980 to a minimum of 8% in 1992. It is doubtful whether this ratio will decrease any further, during a time in which the economy is liberalising. Import duties will be additionally reduced and the Indian paper industry will be faced with more foreign competition. The imports of paper are increasingly dominated by newsprint. The share of newsprint in the total consumption remained relatively constant at 25% during the period 1980-92. The share of newsprint in the total import of paper, however, was 79% in 1980 and even increased to 96% in 1992. This development indicates that the demand for newsprint has been so overwhelming that the local production has failed to keep up, despite the supporting role of the GOI.

In summary, it can be concluded that the development of Indian paper industry as a whole was rather unsatisfactory. The liberalisation of the Indian economy did force the mills to produce more efficiently. Partly because of their technological arrears, a significant number of paper mills were not fully able to face this challenge. But technology is certainly not the only problem of the industry. Throughout the total chain of production, constraints of all kinds exist which hamper the performance. In order to comprehend these factors, the Indian paper industry will be described systematically for input dependency, the scale of production, and the type of output. In addition, emphasis will be laid on the geographical distribution of the industry over various regions in India.

Figure 3.3 Consumption and import of paper (1980-1992)



Source: Khanolkar 1995

3.3 Outputs

The outputs of the Indian paper industry can be generally classified into two categories, namely cultural and industrial papers. Cultural paper is produced for printing or writing purposes, and thereby is often used for direct consumption. Industrial papers cover different functions such as packing and wrapping, and is much more linked to industrial production. As a result, the two categories react differently on economic recession. In general, industrial papers get affected first by an economic downfall but also recover sooner. Cultural papers usually get affected at a later stage but recovery from an economic recession takes more time. This is illustrated by the recovery of the Indian paper industry in the early 1990s. The year 1992/1993 was difficult for the industry. While duplex board, which is an industrial variety, already started recovering in the second half of 1993/1994, the writing and printing segment was still suffering from a negative growth. It was months later when the cultural paper industry started picking up (Capital Market 1994).

The cultural and industrial categories can be basically classified in five varieties. These will be defined by sequence of importance. The first variety is writing and printing paper which falls under the cultural category. This type of paper is mainly produced by large mills based on wood or agro-based pulp as raw material. All other varieties of paper fall under the heading of industrial paper. Kraftpaper, usually known as "brown paper", is the second important variety of paper. It is used for making sacks, composite containers, corrugated boxes and liners. Production can be achieved on a very small scale based on waste paper.

The third variety is paperboard which is also known as duplex board. As the name suggests, it ideally comprises two layers, the upper one of pulp and the bottom layer of waste paper. However, the high pulp prices and the limited availability of imported pulp, have forced Indian manufacturers to introduce a third layer made of Indian white cuttings to reduce pulp consumption. These boards are mainly used in various types of cartons and as liners for kraftpaper. The fourth variety of paper is newsprint. It can be broadly defined as a paper capable of being run through a modern high speed press and of producing an acceptable sheet of newspaper at a reasonable cost. Newsprint has been one segment in the industry where capacity increase has not been in consonance with the ever-increasing demand. This is proven by its important share in the total imported paper. Until recently, newsprint was only manufactured by the public sector. The variety of paper of least significance to the Indian paper industry is the speciality paper. This category consists of security papers, tissues, etc. Although the growth of production of speciality paper is in line with the increasing demand, its share in the total paper production will remain very small in the future because of the required minimum efficient scale of production. Figure 3. and Figure 3. respectively illustrate the absolute and the relative production distribution by output for 1980-93.

Figure 3.4 Absolute production distribution by output

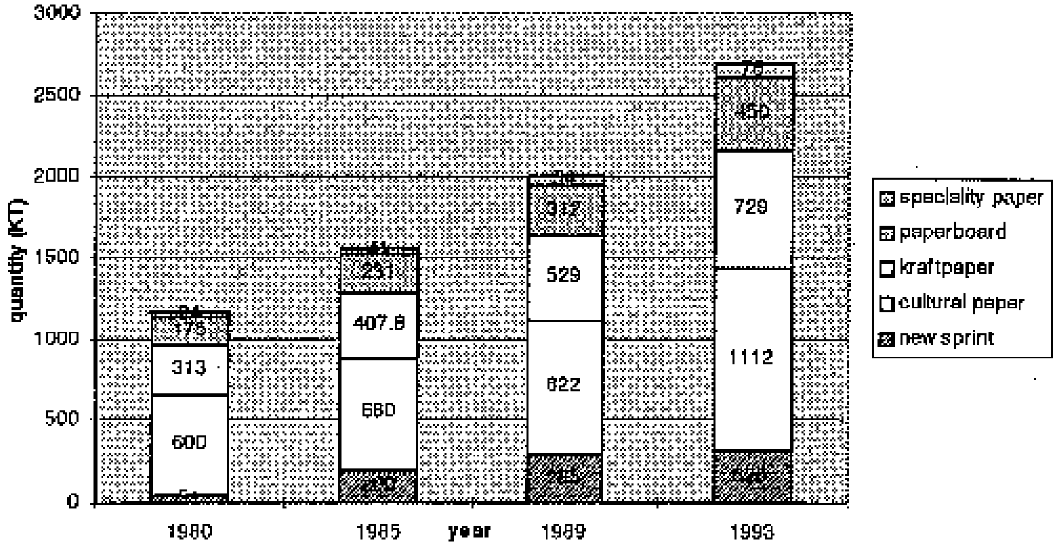
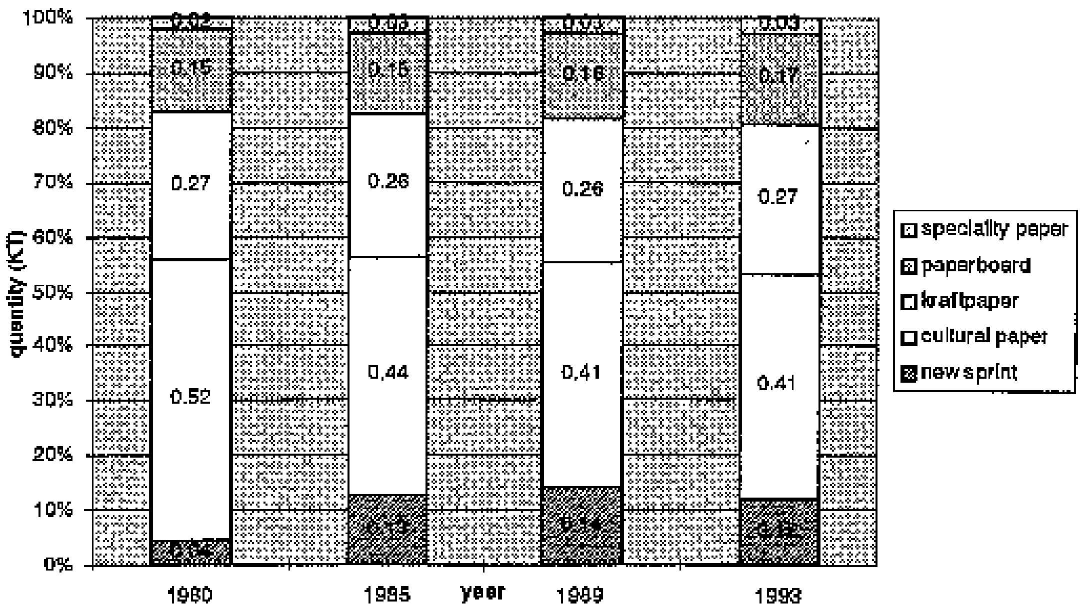


Figure 3.5 Relative production distribution by output



Source: Rao 1989; Khanolkar 1995.

3.3.1 Cultural Paper

Clearly cultural paper constitutes the major share of the total output. Although its importance declined in the 1970s, its share in the total paper production stabilised in the 1980s around 41%. Of the cultural paper production of 1,112 KT in 1993, nearly 90% is accounted for by large firms (Capital Market 1994).

Writing and printing paper has always been subject to considerable government control. In 1974, the GOI issued an order according to which manufacturers were to produce white paper to the tune of 30% of the total production, and supply it at a concessional levy rate to the educational sector and to government departments (Rao, 1989). Although the levy prices were revised from time to time, after taking into consideration the rise in input costs, the divergence between the levy price and the market price increased, which adversely affected the financial performance of the producers of writing and printing paper. Non-compliance by firms increased, after which the GOI repealed the paper control on white paper in 1987. To compensate for the lack of supply of cultural paper, a contract was given to the public sector unit, Hindustan Paper Corporation (HPC), who received subsidies to supply paper at a fixed price. Today, HPC is the largest producer of writing and printing paper in India with a production of 114,793 tonnes in 1992/93.

3.3.2 Kraftpaper

Roughly, two types of kraftpaper are produced in India; the packaging grade and the absorbent kraft which is used in laminates. The packaging grade is mainly manufactured by small mills, while the large ones concentrate on absorbent where the value-addition is higher (Capital Market, 1994). As can be seen in Figure 3.5, kraft paper remained remarkably constant in the period 1980-93 at a share of 26% or 27%. Nevertheless, market conditions fluctuated during this period. Similar to other paper industries, the kraft segment suffered from the economic recession. However, unlike, for instance the duplex segment, the recovery was slow and hesitant.

The GOI, played an important role in this development. An indirect impact came from the enforcement of environmental standards by the Central Pollution Control Board. In particular, the small agro-based mills, those could not afford to invest in expensive effluent treatment, switched to waste paper because of its lower emission levels. The proportion of waste paper used in the production of kraft paper increased from 22.7% in 1985 to 30% in 1992 (Khanolkar 1995). When the industry showed signs of revival in demand in the beginning of 1993, the GOI introduced an additional import duty on waste paper over the existing 20%. This mainly affected the small units which were entirely dependent on waste paper. Although the extra duty was reverted after one month, and even halved to 10% in the beginning of 1994, the damage was already done to these units. The kraft paper segment was again affected through government policies by a decrease in demand caused by an excise of 20% on boxes and containers. These products form the major destination of kraftpaper.

3.3.3 Paperboard

The share of the duplex board industry in the total paper production is slowly increasing. Although in a slowly modernising society of India, such a development is not unforeseen, the prevailing market conditions during this period certainly do not facilitate the paperboard industry. Particularly in the early 1990s, a three-year long economic recession frustrated the performance of the paperboard industry. Supported by an all-time low of the international prices of waste paper, recovery came in early 1994.

Government interference mainly involved policies directed to raw materials and small scale production. Duplex board in India consists of 70% non-conventional input. In the 1980s, the GOI exempted paper units from excise, provided the paper is produced using 75% (by weight) of non-conventional raw material. Many units, which currently manufacture duplex board, switched over to this method, but were unpleasantly surprised to notice that the exemption was abolished recently. This inconsistency in government policy can have harmful effects for the paperboard industry in the long run. However, with the growth in industrial production expected to be 5%, the packaging segment is projected to grow by 10%. Especially because of the possibility to produce duplex on a relatively small scale, many existing units are focusing their attention on this board (Capital Market, 1994).

3.3.4 Newsprint

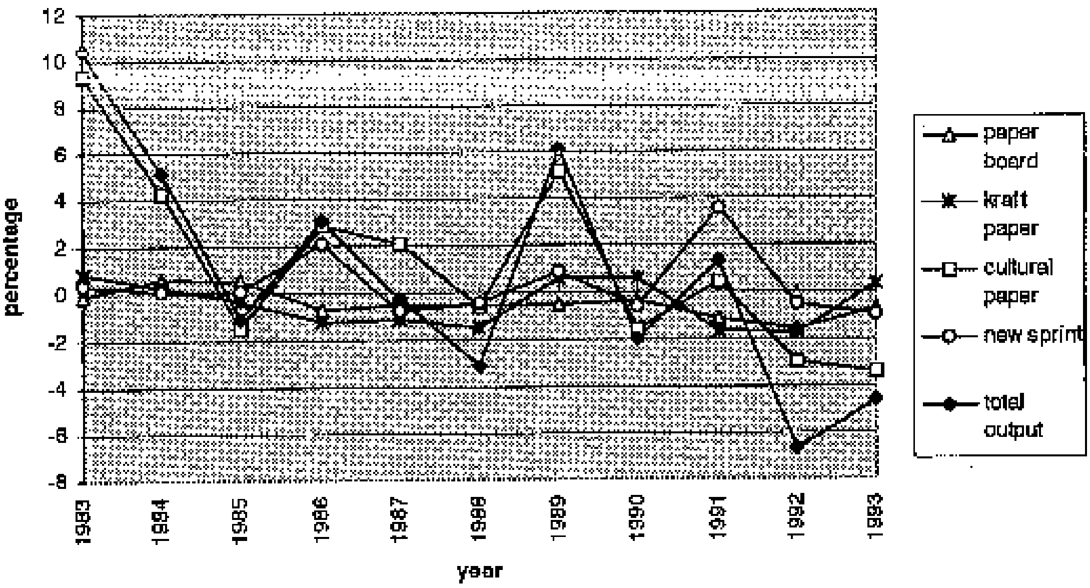
The figures above the sudden increase in newsprint production. Until the 1980s the only newsprint mill in India was the National Newsprint and Paper Mills (NEPA Mills), a public enterprise. Only in the 1980s, the capacity of newsprint was expanded by setting up three other public mills. All these mills were based on wood or agricultural residues. Only in 1991 the first private paper mill based on waste paper started producing newsprint using de-inking technology (Capital Market, 1994). Since newsprint should possess characteristics such as high strength, opacity, absorbency and low grammage, the pulping and manufacturing process is complex and expensive. As a result, the MES of production is high. Therefore, this segment of the paper industry is dominated by a few large paper mills.

The increasing gap between demand and supply of newsprint forced the GOI to "decanalize" the import of newsprint in 1992. The actual user of over 200 tonnes was allowed to import one tonne of newsprint against purchases of 200 tonnes of local newsprint. Because originally this concession was only restricted to newsprint produced from wood pulp, the newly established waste paper based newsprint manufacturers suffered from this exclusion. When the GOI eventually decided that waste paper based newsprint producers should also be allowed in the concession, the Soviet Union started dumping cheap newsprint, which brought down the price and again worsened the market conditions for the domestic manufacturers. This explains the relative decrease of the share of newsprint from 14% in 1989 to 12% in 1993.

3.3.5 Output price behaviour

Output price behaviour is considered to be an important aspect of industry performance. An attempt is made to analyse the aggregate (i.e., for the industry as a whole) wholesale price indices of different types of paper. The behaviour of prices is studied in relation to the general level of prices (the wholesale price index of manufactured products). In Figure 3.6 the difference in the percentage change over a year in the price index of a particular type of paper and the percentage change in the wholesale price index of manufactured products over the same year is depicted.

Figure 3.6 Paper price fluctuations in India (1983-1993)



Source: Report on Currency and Finance, Reserve Bank of India, various volumes

White Writing paper: A discernible pattern does seem to emerge between the period prior to the decontrol i.e., 1982 to 1987 and the post decontrol years. Real prices have fallen in the post decontrol period, except in the year 1988-89. We may recall that white printing paper is primarily produced by large integrated mills. It is important to note that the post decontrol fall in relative prices has not adversely affected the profitability of these mills.

Paperboard and Kraft paper: Real prices of paperboard have been falling consistently from the year 1985-86 onwards. Real prices of Kraft paper do not show any consistent pattern though they fell substantially in six out of the eleven years under consideration. As these types of paper are primarily produced in the small mills, this seems to have adversely affected their performance.

Newsprint: The price of newsprint is still an administered price (by the GOI) and the real prices reflect this phenomenon. The real prices rise in abrupt jerks in years when they are revised upwards and fall in other years.

3.4 Inputs

The main categories of inputs used in the Indian paper industry are forest-based pulp, agro-based pulp and waste paper. Forest-based raw materials consist of bamboo and mixed tropical hardwood extracted from natural forests. In the last decade plantations for wood-based paper production have also been developed. A more common input in India is agro-based pulp. India is one of the largest users of agricultural residues for paper production in the world. Together with China, India produces 73% of the so-called non-wood pulp in the world. It consists of cereal straw, grass and sugar cane bagasse (IIED 1995). Also waste paper can be considered a popular input in India.

Figure 3.7 and Figure 3.8 represent the developments of the input composition of the production of the Indian paper industry. With the increasing depletion of forest-based raw materials, since the 1970s, agro-residues and waste paper began to play a crucial role in meeting the increasing demand for paper. The amount of non-conventional raw materials increased substantially. During the period 1985-1992, both non-wood pulp and waste paper became more important in the furnish.

Figure 3.7 Absolute production distribution by input

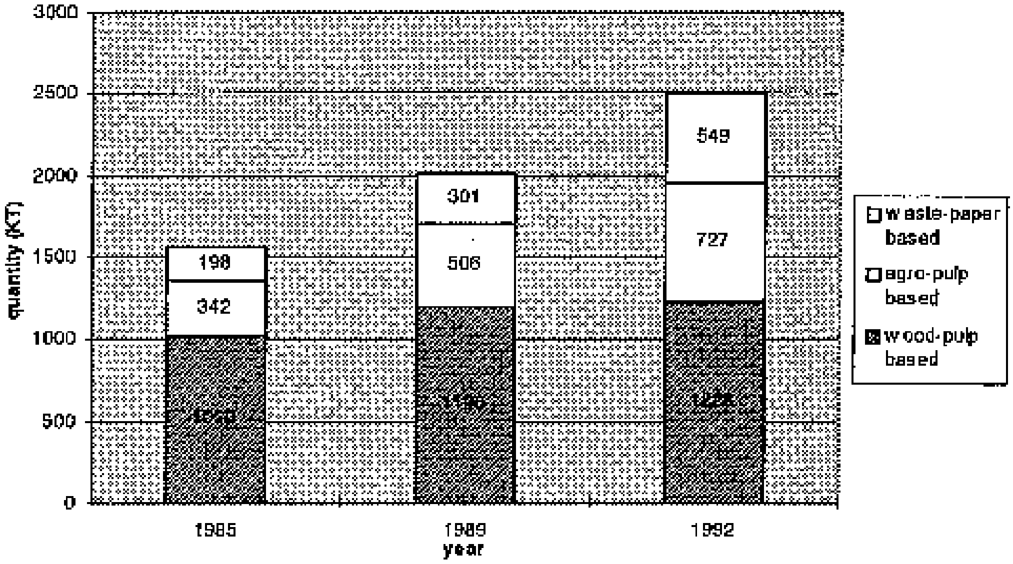
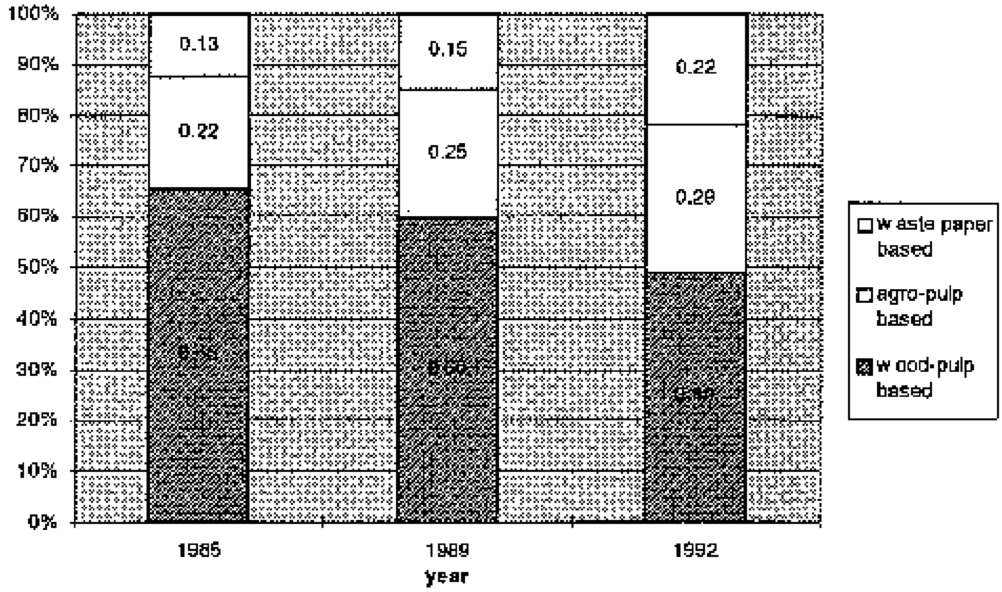


Figure 3.8 Relative production distribution by input



Source: Rao 1989; Khanolkar 1995.

3.4.1 Forest-based raw material

Forest is not an abundant natural resource in India. In 1993 only 19.5% of the total land surface was covered with forest. The world's average is 26% (FAO 1993a). In most regions of India, forests are the largest remaining land bank which can absorb large-scale extensions of areas needed for crop production, hydroelectric projects or rehabilitation programmes (Rao, 1989). It is therefore not surprising that the remaining area of forest is declining rapidly; in the 1980s the annual deforestation rate in India was 0.6% (World Resources Institute 1994). Another factor which frustrates sufficient indigenous supply of wood-fibre is the low productivity of the Indian forest. While forests in Europe and the US increase approximately 2.5 m^3 per hectare each year, the Indian forests grow no more than 0.5 m^3 per hectare (Rao 1989). Taken together, India's natural endowment does not seem to be very suitable to support a large wood-based paper industry. Nevertheless, wood-based production still dominates the paper industry.

Based on projections of the Development Council for Paper, Pulp and Allied Industries for the total demand for paper in the year 2000, the availability of forest raw material will be 3.85 million Air Dry Tonnes (ADT) short of the required 6.70 ADT (Rao 1989). This lack of forest-based supply has encouraged the development of pulpwood plantations. In the 1980s, these production forests which are mainly based on eucalyptus, grew approximately 10% every year (WRI 1994). Nevertheless, factors such as low yields, inadequate management and unsuitable geographical distribution of the plantations have restrained the supply significantly. As a result and in spite of the import-substituting policies of the GOI, imports of wood-pulp are therefore still not eliminated. In fact, given the liberalization trend, an increase in the usage of foreign pulp is expected.

3.4.2 Agricultural residues

Because of the severe shortage of forest raw material, the utilization of agricultural residues has increased substantially in the last decades. Especially in the 1970s, the capacity to use agro-based pulp expanded. While the world's average agricultural input accounts for only 9.8% of the total furnish for the paper industry in 1992, India produces 29% of its paper from agricultural residues (IIED 1995; Khanolkar 1995).

The most important non-wood fibres are cereal straw (rice and wheat), bagasse and other crop fibres (jute, hemp and flax). Although these inputs seem to be abundantly available, utilization is constrained for various reasons. First, it should be adequately available on a long term basis. Very often, however, climatic conditions hamper the continuity of the supply. Also, competing uses of agricultural residues prevent it from being available for paper production. Especially, bagasse becomes scarce as a result of the increasing utilization for fuel in sugar factories (NPC 1986). Second, the input should be available within a reasonable distance. Because of the high volume, transportation costs are often substantial. Finally, the processing of the material should be economically and environmentally feasible. Especially in the last decade, government policies not only strengthened the pollution standards but also intensified the enforcement of these standards. Given the harmful effluent properties and the absence of treatment systems in most small mills, the agro-based paper is significantly more polluting than for example waste paper based production. It is therefore often concluded that agricultural residues can supplement conventional raw materials, but are not capable of completely substituting them (Rao 1989).

3.4.3 Waste paper

Waste paper has always been used as one of the principal raw materials for the manufacture of paper in India, particularly by small mills. Despite the relatively high collection costs, it is a cheap source of fibre. Another typical advantage of waste paper is the relatively limited capital requirement as the pulping process is simple. Also the energy consumption of the paper production process is substantially lower than wood-based or agro-based production.

Compared to the global average of waste paper utilization, which was 39% in 1992, India's utilization rate of 22% is very low. A possible explanation for this is the fact that the recovery rate in India is rather low. Whereas the global recovery rate was 37% in 1992, India recovered only 15% of its total paper consumption (IIED 1995, Khanolkar 1995). In other words, the limited availability of local waste paper depresses the waste paper utilization rate in production. The main cause for this low level of recycling is the fact that much paper is diverted from recovery for cheaper packing and other uses. Still, the waste paper recovery system in India offers considerable scope for improvement, by adopting more rational and scientific methods of collection (Rao 1989).

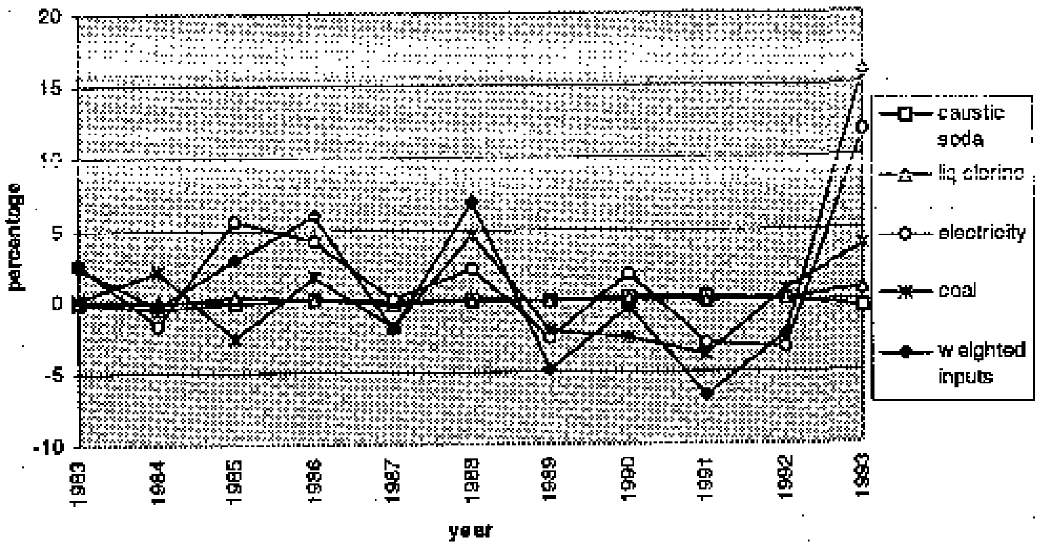
Part of the problem of the limited availability of indigenous waste paper is compensated for by the import of waste paper from abroad. As mentioned in the previous chapter, imported waste paper is popular because of its relatively long fibre length. Because of the better quality of the output of foreign waste paper based production, the amount of input required to produce a unit of output in India is comparatively less. Therefore, the relative share of imported waste paper in the Indian furnish increased slightly in the 1980s. Depending on the world market for waste paper, which is rather volatile, this increase is expected to continue in the 1990s. Nevertheless, the need to improve the local recovery of waste paper in India is evident.

3.4.4 Input prices

To illustrate the cost developments in the paper industry, the real price changes are assessed by using aggregate wholesale price series of various inputs net of changes in the price for paper products. The cost of paper production can be divided into primary input costs (raw materials) and secondary input costs (such as energy and chemicals). Unfortunately, the price developments of the first category are only known for woodpulp and to a certain degree for imported waste paper. Local waste paper price developments were impossible to collect. Primary inputs make out almost 75% of total material costs. Figure 3.9 depict the fluctuations in input prices over the last decade.

Secondary Input Prices: Costs of paper production are affected by fluctuations in input prices of energy and chemicals. As can be seen in Figure 3.9 paper production is rather energy intensive. In this figure, changes in real prices are captured by using aggregate wholesale price series for coal, electricity, liquid chlorine and caustic soda net of changes in the price of paper and paper products. Primary inputs are not included. Real price of Electricity rose 5 times till 1988. Prices of caustic soda initially fell but showed a strong positive change from 1988 to 1992, thus negatively affecting the financial performance in the 1990's. In brief, large scales changes in the input prices observed in the 1990's aggravated the paper industry's problems.

Figure 3.9 Fluctuations in input prices and costs (1983-1993)



Source: Reserve Bank of India, Various Volumes

Primary Input Prices: The prices of wood-pulp have on the whole risen much slowly compared to prices of paper and paper products. Though there seems to be a marked increase in 1993. The prices of imported waste paper have been much more volatile than woodpulp prices. In recent years the rupee prices of waste paper have risen sharply. This is likely to have an adverse impact on firms using imported waste paper as the primary input. There seems to be less price fluctutations for domestic waste paper.

3.5 Market structure

In this section, the various aspects of market structure of the paper industry are discussed. Subsequently, the seller concentration, the market shares and barriers to entry are described.

3.5.1 Seller concentration

The size distribution of firms is an important aspect of market structure as it indicates the nature of oligopolistic interdependency between firms and the likelihood of collusive behaviour. As mentioned earlier, about 52% of capacity exists in the large firms. In Table 3.2 the four firm concentration ratios between 1983-84 and 1992-93 are presented. The four firm concentration ratio is defined as the sum of the market shares of the largest four firms in the industry. The concentration ratios are not very large. Especially, compared to most other Indian industries the paper industry is relatively less concentrated (Mani 1992).

Table 3.2 Four firm concentration ratios in the Indian paper industry

Year	Four Firm Concentration Ratio (%)
1983	28.7
1989	29.7
1990	23.7
1991	25.1
1992	29.3

Source: Markets and Market Shares, CMIE, Bombay, Various Volumes.

Between 1983 and 1990 the four firm concentration ratio fell from 28.7% to 23.7%, though there was a marginal rise in 1989. The ratio rose fast thereafter. In 1992 it was 29.3%. It is important to note that the concentration ratio was unstable in this period. Generally speaking, the paper industry can be characterised by low and unstable concentration ratios over the period, which indicates that the industry is in a state of flux.

Table 3.3 Market shares of the largest 10 firms (in percentage)

Firm	1989	1990	1991	1992
Ballarpur Industries	11.9	9.1	10.9	12.6
Orient Paper and Industries	6.9	5.7	5.9	5.9
Hindustan Paper Corporation	6.0	5.0	4.4	6.3
Andhrapradesh Paper Mills	4.9	3.9	3.9	4.3
ITC Bhadrachalam	4.6	3.7	3.8	4.5
West Coast Paper Mills	3.9	3.0	3.3	3.5
Straw Products	3.3	3.1	3.3	3.4
TN Newsprint and Papers	3.1	2.2	2.6	2.5
Sirpur Paper Mills	3.0	2.2	2.4	2.4
Seshasayee Paper and Boards	2.4	2.1	2.2	2.4

Source : Markets and Market Shares, CMIE, Various volumes.

3.5.2 Market shares

Table 3.3 presents the market shares of the ten largest firms between 1989 and 1992. Ballarpur Industries is by far the largest firm whose market share has risen over the period. The second largest firm has about half the market share of Ballarpur Industries. Thus there is little doubt that Ballarpur Industries is and would continue to be, in the foreseeable future, the market leader. An important point to note is that amongst the first ten largest firms a large number of firms are well diversified into other products. For example, Ballarpur Industries also manufactures chemicals, tin containers and soaps. Orient Paper Industries and Straw Products are both important manufacturers of cement.

3.5.3 Barriers to entry

The condition of entry into an industry is another important feature in the assessment of competition in the Indian paper industry. If barriers to entry are low (i.e. entry into an industry is easy) this influences the performance of firms in the industry by restricting their behaviour. Firms always have to contend with the fact their successful strategies can easily be replicated and excess profits competed away both by new firms and firms already in the industry. There are two major sources of barriers to entry that seem relevant in the paper industry; namely, economies of scale and large capital requirements.

Economies of scale as a barrier to entry

Significant economies of scale at the plant level can be said to exist if its output is at the minimum efficient scale and is a significant fraction of total industry capacity. If the ratio of MES to total capacity is large, then an addition of output, corresponding to an MES plant, by a new entrant would significantly lower post entry prices and profits, thus making entry into this industry unattractive.

The height of this barrier can be measured by the ratio of output corresponding to MES plant to total capacity in the industry. The current officially recommended size of an MES plant is 33,000 TPA. The ratio of output corresponding to an MES plant to total capacity in 1991-92 was about 1% (total capacity in 1991-92 was 3.28 million tonnes). As this ratio is rather small, the height of this barrier can be considered to be low, for potential entrants contemplating entry at or slightly above the MES plant. For entrants planning entry at very high levels of capacity, this barrier may become moderately high.

Capital requirements as a barrier to entry

Large capital requirements may influence the type of firms which can enter the industry. If capital requirements are large, then only those firms already existing in other industries, with sizeable internal funds, or those capable of raising money from the capital market, can enter the industry. Moreover, if expansion is very expensive, not all firms existing in the industry can hope to expand over time. Thus the height of this barrier would influence the nature of dynamic competitive rivalry in this industry. The lower this barrier, the larger would be the extent of competitive rivalry. To get an idea of the height of this barrier, the capital outlays for (i) a new firm of an MES plant, (ii) a large new plant, (iii) a substantial expansion of an existing plant and (iv) a large plant based on bagasse and waste paper, are presented in Table 3.4.

Table 3.4 Capital outlays of new entrants and expansion of old firms

Company	Product	Incremental Capacity	Capital Outlay (in mill. Rs.)
Aminsons (New Firm)	writing printing & wrapping Paper	33,000	300
Birla Paper Industries (New Plant)	Writing & Printing Newsprint	80,000 35,000	5250
Andhra Pradesh mills (bagasse/wp based)	writing & printing Paper	60,000	1150
ITC Bhadrachalam (Expansion)	Writing & Printing	62,500	650

Source : Shape of Things to Come 1993, CMIE, Bombay.

The capital outlay for an MES plant is only Rs 300 million which is not a very large amount. Thus this barrier is not very high for a new entrant contemplating entry with an MES plant. For larger plants the capital outlay increases substantially. ITC Bhadrachalam has plans of doubling its existing capacity of 62,500 tonnes p.a. at a cost of Rs. 650 million. Thus major expansions by existing large firms do not seem to be exorbitantly expensive. The medium and small firms of course may find it relatively difficult to expand capacities if they do not have sufficient internal funds and financial institutions are reluctant to lend to the firms with poor past performance.

The above data seems to suggest that entry at an MES plant and expansions of capacity by large firms can be achieved at a reasonable cost. This conclusion is admittedly impressionistic and is based on a general understanding of Indian industry. However, this must be cautiously interpreted in view of the difficulties paper firms face in raising finance in the capital market, because paper industry ranks fourth in terms of share of credit outstanding in sick units in India and the raw material shortage is a well known problem of the industry. In addition, a legal barrier to entry exists as the paper industry is under the list of industries which require industrial licensing.

3.6 Size

The paper mills in India can be divided into three categories; large, medium and small. Various definitions are used to measure the scale of capacity. Particularly on the international comparisons the terminology can be misleading. While the average capacity of a paper mill in Scandinavia and the US is in the order of 100, 000 tonnes per year, the Indian average is many times lower (Ewing 1985). Also, within India different classifications of size are employed. `With increasing scales of production, the classification system is also changing over time. However, the historical data are based on the traditional classification. Therefore, the following classification was chosen.

Figure 3.10 Absolute capacity distribution by size

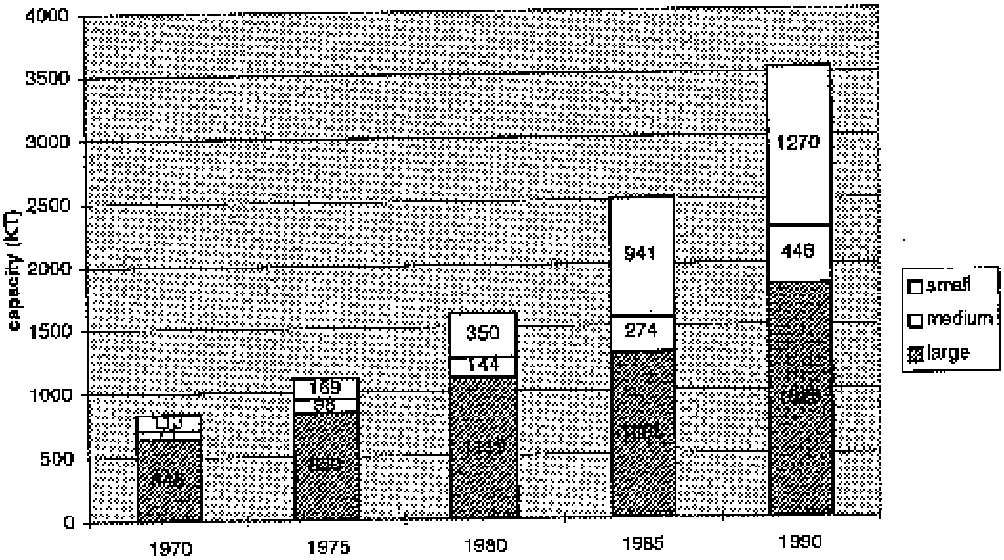
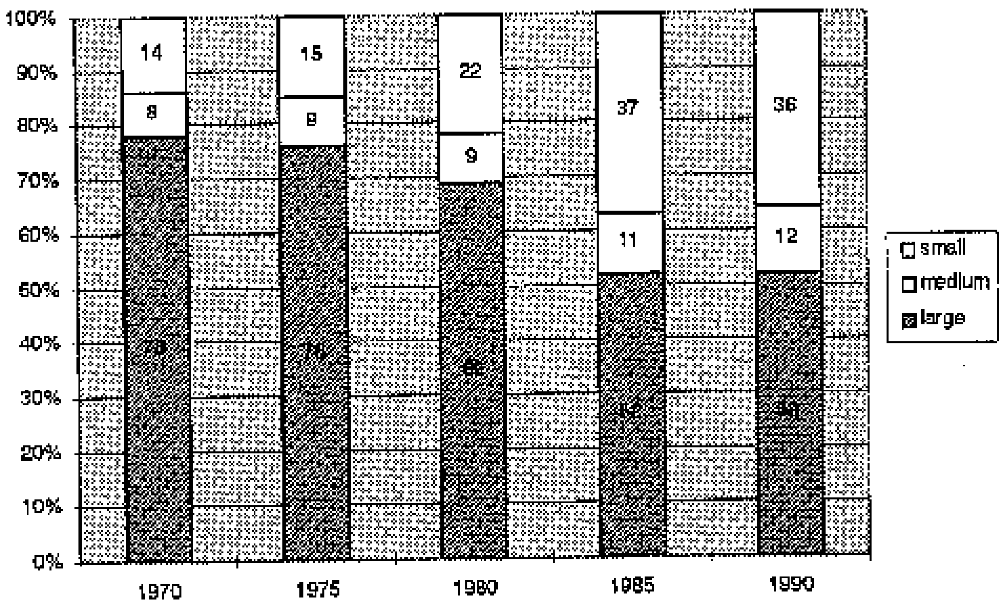


Figure 3.11 Relative capacity distribution by size



Source: Rao 1989, Khanolkar 1995.

Large mills are defined as mills with an installed capacity exceeding 20,000 tonnes per year (TPA). Mills with capacity between 10,000 TPA to 20,000 TPA are medium paper mills. Those with a capacity of less than 10,000 TPA fall into the category of small mills. Another category of paper industries is the group of hand-made paper units. Their maximum production is 300 tonnes per year. The hand-made paper units, which are abundant in India, are excluded from this assessment since they make up less than 3% of the total production (Subramanian et al. 1994, Rao 1989). Figure 3.10 and Figure 3.11 illustrate the development in time of the distribution of small, medium and large mills over the total capacity of the Indian paper industry. In the early 1970s, most of the capacity was still based on large scale production. Small mills entered the industry in large numbers in the 1980s since government policy encouraged them to do so through fiscal concessions and liberal imports of second hand machinery. Consequently, the capacity distribution changed in favour of small and medium mills.

3.6.1 Large mills

According to the above definition, 48 large mills were present in India in 1990, representing 52% of the total capacity (Khanolkar 1995). The range in terms of size within this category is considerable, with variation in capacity from 20,000 tonnes per year to more than 100,000 tonnes per year. In general, large mills are based on wood-fibre inputs. A typical problem for the large mills is that they were often set up in locations which could originally draw upon adequate raw material resources which have since diminished rapidly. Because of this it is not surprising that the effective capacity of the large mills in 1990 was only 84%. Of the 48 large mills, 8 units were closed and 5 were considered under revival (Khanolkar, 1995).

Besides inadequate availability of raw material, various other problems contributed to the relatively poor performance of the large mills. First, as in the case of the small mills, obsolescence of equipment is also a problem for many large mills. A majority of the mills were established 30 to 50 years ago. Modernisation and rebuilding of the existing large mills is an urgent requirement. This raises the second major problem of large mills, namely their deteriorating financial situation. Upgrading of large mills is a very capital intensive operation, requiring large funds. Since the rates of returns of this group have been low in the last decade, possibilities of the industry retrieving external funds are limited. An important reason for this is that the profitability of the paper industry has been below the composite industry average during the 1980s. Therefore, external financers have not been very eager to invest in paper. Since at present the performance is slowly recovering, investors may change this reserved attitude (Capital Market 1994).

3.6.2 Small and medium mills

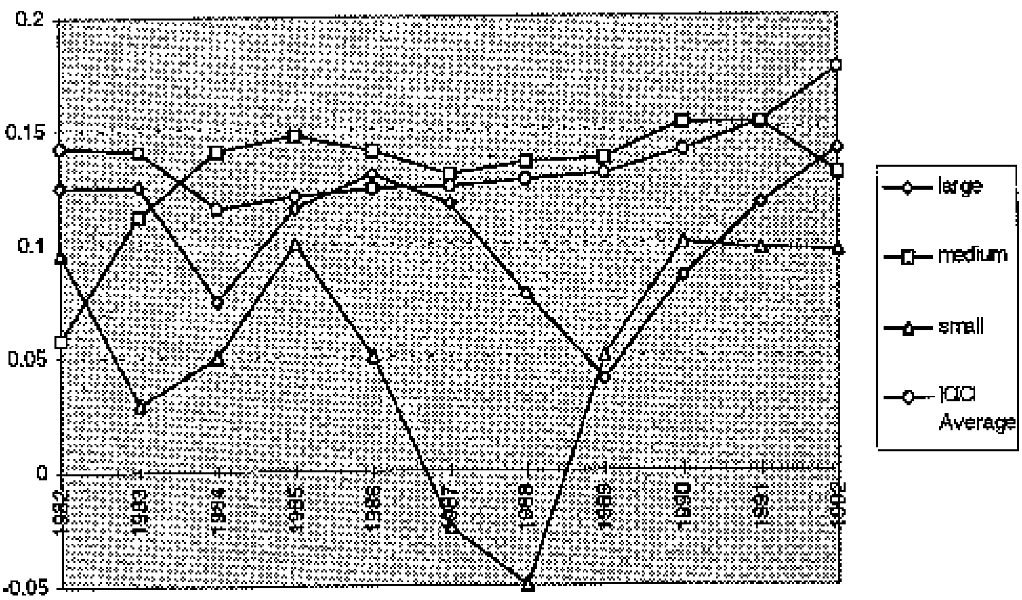
In 1992, 296 of the 345 paper mills in India were small and medium paper mills. This group contributed 48% to the total capacity (Khanolkar 1995). In 1970 this ratio was only around 22%. Several factors have attributed to the growth of small and medium mills in the 1970s and the 1980's in particular with regard to the non-conventional inputs. First, the limited availability of agricultural residues and indigenous waste paper, which was caused by changing external conditions and problems of collection and transportation, precluded the setting up of large mills for these inputs. Secondly, mills located near the source of the raw material in rural areas had to cope with problems such as the lack of skilled labour and inadequate infrastructure. Setting up a small mill is therefore preferred. Finally, as mentioned earlier, setting up a smaller mill requires less investment and therefore comprises less economic risks than starting a large mill (Rao 1989). Especially in rural areas, this favours small mills because capital availability in these areas is even less.

Although the growth in capacity and production by small and medium mills was the expected result of the policy measures taken during the decades, operational figures of small paper mills have generally fallen short of expectations. In 1992, among the 296 small and medium mills, 63 were closed and 5 were considered under revival. In terms of capacity, only 81% was in operation (Khanolkar 1995). Various problems underlie this poor performance of the small and medium paper mills. First, small paper mills are facing a major problem with regard to availability and costs of waste paper. As mentioned earlier, the recovery rate is too low in India to guarantee a continuous supply of input. Especially now that large mills have also started using waste paper, this problem has become severe. With regard to the agro-based mills, a similar problem occurs with competitive application of agricultural residues in other sectors. Second, because small scale production of paper is typical to India, no economically viable and technically feasible chemical recovery process has yet been developed. As a result, chemicals are not recycled for production which increases the costs. Third, given the obsolescence of equipment in the small mills, coupled with the uncertain availability of power, the production is well below the anticipated level.

3.6.3 Performance by size

In this section, a comparative picture of profitability performance of a sample of 29 firms in the Indian paper industry is provided. This sample of firms contains only non diversified firms because the financial statements of diversified firms cannot be analysed meaningfully in the present context. The total capacity of these 29 firms was about 6,86,000 TPA i.e. about 19% of the total installed capacity in 1991. The sample does not contain newsprint industries. Figure 3.6 displays the profit rate (operating profit) of the three groups of firms and an average profit rate for the corporate sector.

Figure 3.4 Operating profits as a share of the sales (%)



Source: Official Directory of the Bombay Stock Exchange

Profitability is defined as follows: Sales - [stocks consumed + wages and salaries + direct manufacturing expenses + general expenses] as a ratio of sales. We consider profits gross of interest so as to make the profitability ratio comparable across firms with differing debt equity ratios. Depreciation is another item which is not subtracted from the numerator because depreciation conventions are likely to differ across firms. The numerator includes the amount of money a firm has out of which it pays interest and taxes, charges depreciation, pays dividends, and reinvests a part. The profit thus defined is normalised by net sales following the usual convention.

The following points may be noted:

1. The performance of the medium firms is superior to that of large and small firms. In 7 out of 10 years medium firms have performed better than the corporate sector average profitability measured by ICICI sample. Paper control was not imposed on medium firms and perhaps they took advantage of market prices. Their wages per unit of sales is found to be the lowest among the three groups of firms.
2. The worst performers have been the small firms. Most of them imported second hand machinery. Their technological inefficiency and scale disadvantages in the form of absence of chemical recovery systems must have adversely affected their performance.
3. The large firms, profitability is lower than the corporate sector average in 10 out of the 11 years. After price decontrol in 1987 their profits have shown an upward trend.
4. Looking at the profitability after interest, small firms can be recognised as having negative profits. This is consistent with the widespread sickness and closures observed among small mills.
5. In brief, while the process of decontrol seems to have a positive influence on the industry's performance in terms of operating profits, the wide fluctuations from year to year are not conducive from the view point of attracting new investment.

3.7 Region

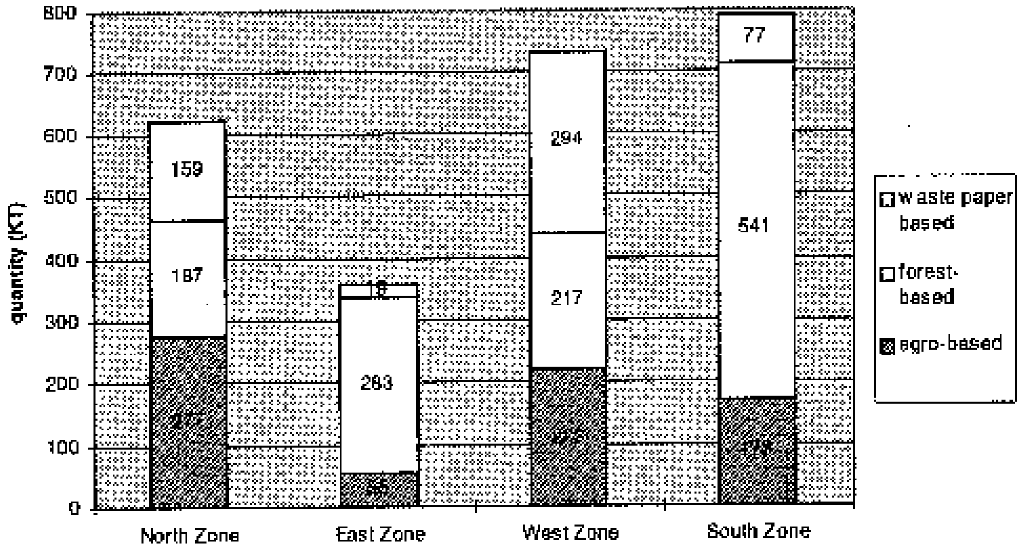
The final assessment which is relevant for the status of the paper industry in India is its zone-wise distribution in the country. Not only does such an assessment contribute to our knowledge with respect to the importance of various regions in paper production in India, it also provides an insight into the different forces driving the Indian paper industry. Various factors can be relevant for the location of paper mills. Natural endowment, supply of waste paper, consumer market and the availability of other production factors such as skilled or unskilled labour and water supply, all play a crucial role in the type of paper production which will be taken up.

The most obvious division is North, South, East and West. According to Khanolkar (1995), the North zone consists of Uttar Pradesh, Haryana, Punjab, Rajasthan, Himachal Pradesh, Chandigarh, Jammu and Kashmir. Although this zone has a substantial forest area needed for the infrastructure, these natural resources is lacking. Therefore the economy in the North is largely dependent on agriculture. The East Zone consists of West Bengal, Bihar, Orissa, Assam, and Nagaland. This region is not very well endowed with forest, but the extensive bamboo production does form a solid basis for fibre supply. Gujarat, Maharashtra and Madhya Pradesh form the West Zone. This industrial region is rather densely populated. It also houses the main sea-port of the country in

Mumbai. Finally, Andhra Pradesh, Karnataka, Tamil Nadu, Kerala and Pondicherry make up the South Zone. Like the North zone it still comprises large areas of forest, although this is declining rapidly. This decline is partly compensated for by the raising of various pulpwood plantations.

Figure 3.12 depicts the regional distribution for the various zones. With a total production of 794,000 tonnes of paper, the South Zone was the largest producer in India in 1992. In terms of capacity, however, the West Zone with a total installed capacity of 1,137,000 tonnes, was the largest region. Yet the capacity utilization of the West Zone at 64% was much lower than in the South Zone (74%) and the North Zone (74%). The performance of the East Zone was even worse (45%). The large differences in capacity utilization can be attributed to the composition of the furnish relative to the availability as well as the scale of production.

Figure 3.12 Regional distribution of production by input



Source: Khanolkar 1995

In order to illustrate the importance of the natural endowment of the region, the total production is subdivided by input. Typically, manufacturering in the East Zone is mainly based on forest raw materials (79%). Given the relatively poor infrastructure of the region, waste paper consumption is very low (6%). The dependency on wood fibres can also be recognised in the average paper mill size of 19,461 tonnes per annum, which is the largest average capacity in India. However, the capacity utilization indicates that forest has become more scarce in the East Zone. A similar pattern is seen in the South where 68% of the furnish is based on wood and only 10% is comprised by waste paper. The average size is 15,642 tonnes. The better performance can be attributed to the pulpwood plantations in South India. The Northern region's forest dependency is relatively low (30%). However, agro-based pulp take account of 44% of the furnish, which is the highest in India. The average size of the mills in the North is only 6,280 tonnes. Typical for the West Zone is the high consumption of waste paper, which can be largely explained by the relatively high population density of the region and the presence of the Mumbai sea-port through which more than 80% of the countr's waste paper imports enter. However, the technological obsolescence of the industry and the volatility of the waste paper market did have a negative impact on the performance. On an average, paper mills in the West have a capacity of only 9,071 (Khanolkar 1995).

3.8 Environmental impact

Compared to other industries, the paper industry has always been an industry which puts a heavy pressure on the environment. A wide range of environmental stresses can be identified. First of all, the industry consumes large quantities of raw materials and energy, which, among other things, leads to depletion of natural forests. Second, the industry generates various types of pollutants such as the emissions of air pollutants, discharge of wastewater, the generation of sludge, and causes noise and occupational hazards. In this section, these characteristics of the Indian paper industry will be discussed in detail.

3.8.1 Energy consumption

Paper making is an energy intensive process and both thermal and electrical energy are used. Furnace oil, coal and black liquor are used to generate steam at high pressure and to maintain high temperatures during the various stages of production, in the vacuum dryers and chemical transporting ducts. A wide variation in energy consumption is observed across mills due to a number of reasons. Energy consumption varies due to differences in process, product mix, raw material input, capacity utilization, type of equipment, degree of integration, size and type of mill, etc.

It is not clear whether large or medium/small mills are more energy efficient due to the above differences. The size of the mill also determines the percentage of internal fuel used (recycled fuel, black liquor fuel, etc.). A Government of India study suggested that it was only the large mills that used internal fuel to the extent of 22% of their total fuel use. In the case of medium and small mills, only external fuel was used. While large mills used energy equivalent of about 20 million kilo-calories of heat, medium/small ones used only about 15 million kilo-calories of heat equivalent. However, this number does not comment on energy usage per unit of production (BCIP 1987).

The wide fluctuations in energy consumption across mills is explained by a number of factors. First, the average energy efficiency of 58% in the Indian paper industry is rather low. The highest energy efficiency was recorded at 65% while the lowest had been only 30%. This is very low compared to 78% efficiency as recorded by Scandinavian mills (Rao 1989). Low efficiency is attributed to inefficient boilers, turbines, heat recovery systems, poor firing system and distribution losses. For example, heat transfer in old and poor quality steel rather than stainless steel has negative implications for energy usage.

In addition, interruptions in production affect energy utilization and efficiency seriously. Energy lost due to interruptions is estimated at a staggering 10% to 32% of total energy consumed (BICP 1987). Interruptions are frequent for a number of reasons, both internal and external. Internal reasons account for a large portion of such a loss and stem from poor maintenance of machinery, labour trouble, raw material shortage and power cuts due to internal problems. In the case of small mills, down-time due to internal reasons is estimated at 50-60%. Externally, power supply and the quality of coal dictate down-time.

The quality of coal used also affects efficiency. Poor quality coal wears out the system, aggravates clinker formation, and leads to poor ignition. It has been reported that about 4-11% of efficiency is lost on account of poor quality of coal. Efficiency is sacrificed when mills lack proper instrumentation systems and control over parameters such as excess air and CO_2 to oxygen ratio in flue gas. Besides the use of conventional fuels such as coal, furnace oil and electricity, black liquor which is segregated from the effluent stream of the pulping process, is used as a source of energy. For every tonne of pulp, $10m^3$ of black liquor is generated. In large plants, black liquor is mostly separated in evaporators and then fired into the recovery boilers. One tonne of black liquor is equivalent to 2.2 tonne high pressure steam, which is capable of pulping roughly 1.5 tonne of agricultural residues (BCIP 1987).

Table 3.5 Environmental impact of paper production (per tonne of output)

	Wood-based inputs	Agricultural Residues	Waste Paper
Consumption			
a. Energy			
- Power	High	High	Low
- Steam	n.a.	6.25 tonnes	2.75 tonnes
- Coal	1.1-4.1 tonnes	3.35 tonnes	1.45 tonnes
b. Raw material	2.20-3.70 tonnes	2.20-3.00 tonnes	1.15-1.30 tonnes
c. Water	250-440 m^3	275 m^3	125 m^3
Pollution			
a. Wastewater			
- BOD	65 kg	176 kg	20 kg
- COD	246 kg	741 kg	70 kg
- TSS	168 kg	160 kg	60 kg
b. Air pollution	Process and stack emissions	Process and stack emissions	Stack emissions
c. Solid waste	n.a.	1.50-2.00 tonnes	0.15-0.20 tonnes

Sources: CBP & CWP 1986, CID 1986, CPCB 1991

Besides the type of fuel used in the production process, the type of raw material also affects the energy consumption and its efficiency. The quality of chips in the digestor dictates the digestor time. Energy consumption could be lower if waste paper is used instead of wood chips or agricultural residue. The higher the waste paper content, the lower is the energy used for pulping and digesting. By the same argument, water and air pollution is also lowered. Table 3.5 compares the standard energy consumption and other environmental impacts of a waste-paper based production process with the average wood and agro-based production process in India. Using waste-paper requires about 2.5 times less energy than a similar production process based on other inputs. The bulk of this difference in energy consumption comes from the less intensive pulp stage of the production process of waste paper.

3.8.2 Water pollution

Water consumption and pollution can be considered the most important environmental problem caused by the paper industry in India. The paper industry has traditionally been one of the main industrial users of fresh water for processing systems and since most of this process water is discharged, the industry is a major source of liquid effluent. Large integrated paper mills are mostly located near rivers which provide water and receive the waste water. Apart from using river water, numerous small mills also pump ground water. Average water consumption ranges between 100 and 425 m^3 per tonne of paper produced, depending upon the raw material used (Rao 1989). Especially in periods of drought, paper industry's large water consumption can be considered a problem for its surrounding environment.

The chemical pulping process contributes to 80% of total effluent pollution load. The wastewater generated contains high biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS). BOD is the amount of oxygen required to biologically oxidise the water contaminants to carbon dioxide, and is thus a measure of the amount of suspended, colloidal or dissolved organics. If the BOD is too high, the oxygen concentration in the receiving river or pond can decrease so much that aerobic organisms are adversely affected, in extreme cases acutely. Since more than half the organic materials in the effluent are not biodegradable, BOD is not an ideal measure. Therefore, COD is increasingly replacing BOD as a pollution parameter. COD is a measure of the amount of oxygen required to chemically oxidise the contaminants to carbon dioxide. By definition, the COD will always be higher than the BOD. TSS mainly consists of bark and wood fibres which are normally biodegradable within 30 days (IIED 1995). Through the formation of fibre mats on ocean bottoms, elimination or alteration of the bottom dwelling organisms may occur (Rao 1986).

Compared to international levels of effluent pollutants, India is not performing very well. Sample levels from North American mills and Scandinavian mills indicate that they generally discharge BOD of 45-65 kg/tonne and 25-75 kg/tonne, respectively (IIED 1995). As can be derived from Table 3.5, most Indian mills most probably do not meet such levels. Although the figures are estimates of concentration levels before effluent treatment, the general lack of appropriate treatment equipment implies that the concentration levels of Indian mills are much higher than the average international levels, especially as small mills in India generally do not have a soda recovery scheme, hence water pollution and overuse is observed. Often, all waste water is discharged into one channel, so that relatively clean water that could have been used elsewhere, also gets polluted and is simply drained off.

The GOI has regulations on effluent discharge from pulp and paper mills. Table 3.6 gives the permissible limits of various pollutants in India, as prescribed by the Central Pollution Control Board (CPCB 1995). However, given the average effluent discharge of the wood-based, agro-based and waste paper mills summarised, these standards are not very often met. This has already lead to closure of numerous paper mills in India. Enforcement, however, is very difficult, given the limited budgets of the monitoring government agencies. Another problem is the fluctuation in the concentration of the effluent in time. Also, the timing of the actual discharge of effluent can differ from the timing of the monitoring, which prevents the paper mills from being accused of violating the emission standards.

Chlorine, traditionally used in the bleaching process of all kraft pulp mills, is the chemical principally responsible for the formation of chlorinated organic compounds. With respect to pulping, dioxin and furans are considered the most important chemicals, since they persist in the environment for many years and some forms are extremely toxic. In order to meet the problem of these pollutants, the problem should be addressed in the manufacturing process itself, since secondary treatment systems remove only about half of the chlorinated organic compounds produced. In the last years, major efforts have led to the reduction of approximately 80% of the absorbable organic halogens (AOX) which is the traditional measure for furans. The costs of this technological change have been substantial. Notably, the Indian paper industry with its, largely outdated equipment, did not demonstrate a comparable reduction of AOX levels. The dioxin "discovery" of the mid-1980s, in combination with increasing environmental awareness of consumers, forced the international paper industry to eliminate the use of chlorine in its production process. This technological drive towards cleaner production resulted in "totally chlorine free" and "elemental chlorine free" pulp and paper.

However, this tendency has not yet taken root in India (IIED 1995). Generally, it can be concluded that, although its environmental performance with regard to water pollution is improving over the years, the Indian paper industry is falling further behind compared to international competitors.

Table 3.6 Permissible limits of pollutants and effluent discharge

	Parameter	Unit	Permissible Limit
Large pulp and paper mills (Capacity more than 24000 TPA)			
a. Wastewater quantity	Effluent discharge	m^3/tonne	100
b. Wastewater quality	BOD	mg/litre	30
	COD	mg/litre	350
	TSS	mg/litre	100
	PH		6.5-8.5
c. Emissions	PM	mg/m^3	150
	H_2S	mg/m^3	10
Small/Medium pulp and paper mills (Capacity upto 24000 TPA)			
a. Wastewater Quantity			
- Agro-based mills	Effluent Discharge	m^3/tonne	150
- Waste paper mills	Effluent Discharge	m^3/tonne	50
b. Wastewater quality			
- Discharge into inland surface water	pH		5.5-9.0
	TSS	mg/litre	100
	BOD	mg/litre	30
- Disposal on land	pH		5.5-9.0
	TSS	mg/litre	100
	BOD	mg/litre	100
	SAR		30

Source: CPCB 1995.

3.8.3 Air pollution

Although air emissions are generally considered to be of relatively minor importance as compared to water pollutants, gaseous emissions by the Indian paper industry are certainly not minor. In particular, the large number of old mills in the Indian paper industry are causing severe air pollution. The main source of air pollution is the manufacture of chemical pulp. Common air pollutants are total reduced sulphur (TRS), oxides of nitrogen (NOx), oxides of sulphur (SOx) and chlorine gas. The main environmental effects are acid rain from the use of fossil fuel and ozone depletion caused by chloroform which is traditionally used in bleaching systems. In addition, various welfare effects are generated of which the "rotten egg smell", caused by hydrogen sulphite, is the most common. Unfortunately, little data is available on air emissions from the paper industry in India.

3.8.4 Solid waste

Solid waste has not been considered a very important environmental problem of the paper industry. One of the reasons is that solid waste from pulp and paper production is generally not classified as hazardous. However, with the general tendency of increasing disposal costs, the issue becomes more serious. Solid waste is generated in various stages of the production process, such as raw material handling, rejects from screening and centri-cleaners, primary and secondary sludge and coal and boiler ash from steam generation. The type and quantities of solid waste generated differ considerably across mill types.

For the production of one tonne of paper in agro-based mills, 210 kg of solid waste is generated when rice and wheat straw are used and 550 kg of solid waste when bagasse is used. In addition, 220 kg of primary and secondary sludge is produced, giving the waste water a solid load. The coal requirement in the digestors and the papermachines is 3.5 tonnes which eventually leads to 1.3 tonnes of coal or boiler ash. The total solid waste generation is estimated at around 2000 kg per tonne of output. Waste paper based mills are much more efficient in terms of solid waste. Only 46 kg of waste paper is lost in handling, and another 46 kg is in suspended solid form. Coal requirement is 1.5 tonne and 58 kg is lost as boiler ash. The total average solid waste generated by waste paper based mills is only 150 kg per tonne of output (CBP & CWP 1986).

Again, these figures are rather poor compared to the average international performance. While in the past, solid waste generation ranged up to 250 kg (dry equivalent) per tonne of output, nowadays very few mills discharge waste in such quantities. Some paper mills are even recorded as generating as little as 10 kg per tonne (IIED 1995). Also with regard to the quality of the sludge, Indian performance is worse. As a result of outdated equipment, fewer chemicals are recovered which partly end-up in the sludge. This problem is more severe in the case of small scale units in India as they do not adopt chemical recovery. Therefore, sludge can be highly toxic and contains various heavy metals such as zinc and polychlorinated biphenyl (PCB). Disposal of this sludge either on land or into water streams is detrimental to the environment.

3.9 Summary and conclusions

Rapid urbanisation, increasing literacy rates and general industrial growth are expected to create a growing demand for paper products. Various types of paper are produced by the paper industry in India using both conventional and non-conventional raw materials. Utilization of non-conventional raw materials (i.e. agro residues and waste paper) has been rising due to increasing depletion of forest based raw materials. The share of wood-pulp based paper has declined from 65 % in 1985 to 49 % in 1992, while the share of agro- pulp based paper increased from 22 % to 29 % during the same period. The sharpest rise has taken place in the share of waste paper production which has risen from 13 % to 22 % over the same period.

This rise in the share of waste paper as a primary input is due to the changing size and distribution of the Indian paper industry in favour of small paper mills which are the principal users of waste paper as an input. Government policy actively encouraged the formation of small mills by liberalising import of second hand machinery and fiscal concessions. Lower capital and energy requirements of the waste paper pulping process has also contributed favourably to waste paper usage. Stricter enforcement of emission standards has forced the small mills to switch from agro-residues to waste paper because of lower emission levels associated with waste paper usage.

In 1990 the combined share of small and medium mills was found to be 48 % in total capacity. They specialise in the production of industrial papers. Large mills are in general wood pulp based and are the major producers of cultural paper, mainly writing and printing paper. Large mills have been subjected to a variety of controls and regulations which has affected the structure and performance of the industry. In 1987 the price and distribution controls were repealed. An analysis of the market shares and concentration ratios of the paper industry over the period 1989 to 1992 brings out two important features: concentration ratios have been low and unstable, and Ballarpur Industries is by far the largest firm and is expected to remain so in the foreseeable future. An evaluation of entry barriers suggests that neither scale economies nor capital requirements are likely to pose a significant barrier to entry.

The profitability performance of medium size firms is found to be superior to small and large firms. The price decontrol in 1987 is found to have a positive influence on the industry profitability performance. Real prices of all types of paper (except newsprint) have also been falling in the post decontrol period. Large increases in the input prices (i.e. prices of chemicals, electricity, coal, wood pulp and imported waste paper) were observed in the 1990's. Given the technology of paper production, how firms in the industry respond to relative input price changes and adjust their input mix, appears to be an important question. This question is addressed in more detail in chapter 5.

The environmental profile of the Indian paper industry is not very positive. Energy consumption is higher than the international standards, due to interruptions in production, the poor quality of fuel and equipment, and the relatively low rate of waste paper utilization in the production. Even more important is the environmental impact of water pollution and consumption. Pollutant concentrations in waste water are generally higher than the international average and water recycling systems are only slowly making their entry in the Indian paper industry. Similar conclusions can be drawn for air emissions and solid waste. The Indian government recognises the significant pressure of the paper industry on the environment and intensifies the enforcement of environmental regulations. This has forced many paper mills to switch from agro-based raw materials to waste paper. The overall environmental implications of the change of the input furnish of the paper industry will be assessed in chapter 6.

In chapter 2, it was explained that the difference between the recovery rate and the utilization rate in a particular country is related to the net trade in paper and paperboard and waste paper. The utilization rate in India is much higher than the recovery rate. This implies that India is either a paper and paper board importer or an importer of waste paper. In fact, India's decreasing imports of paper and paperboard is compensated by the increase of import of waste paper. Although socio-economic effects of this development, such as employment in the Indian paper industry or the Indian balance of payments, appear to be positive at first sight, a more specific analysis is required to also include the up and downstream effects. In chapter 6, these backward linked socio-economic effects will be analysed in more detail.

Chapter 4.

WASTE PAPER RECOVERY IN MUMBAI[1]

Pieter van Beukering
Edwin Schoon
Ajit Mani

4.1 Introduction

International trade and local recovery of waste paper seem to be two separate issues, yet both activities are closely linked through the price of waste paper. This implies that changes in the recovery of waste paper in one country can have a significant impact on the recovery of waste paper in another country. A perfect example of this relationship was demonstrated in the late eighties and early nineties when the German government introduced various policy measures in order to increase the recovery of waste paper in Germany. From 1989 to 1993, the collection in Germany increased by almost 50%. Among other things, this sudden increase in supply led to negative prices for low grade waste paper on the international market (Hagen 1994). Many neighbouring countries encountered considerable problems in maintaining the local collection system intact. Subsidies had to be provided to waste paper collectors to prevent bankruptcy. Obviously, developing countries face more difficulties in meeting such fluctuations. Governments in the South do not have the budgetary space for unforeseen subsidies. The impact of price fluctuations can therefore be severe.

In this chapter, waste recovery in developing countries will be described. In order to address the question regarding the possible impact of international price fluctuations on the local recovery of waste paper, a case study will be presented on the recovery sector in Mumbai. Besides focusing on economic effects such as developments in value added and public costs, the social impact is considered in terms of employment and income distribution. Also, environmental effects are considered within the boundaries of the recovery sector. Note that the impacts of the actual recycling process are ignored in this chapter. Based on this assessment, conclusions can also be drawn on the feasibility of improving the recovery sector in Mumbai.

The paper is structured as follows. First, the general concept of waste recovery and waste management in developing countries is described in Section 4.2. A theoretical approach is developed to frame the problem. In Section 4.3, this issue is narrowed *down to waste paper in Mumbai. The sources of waste paper and the factors involved* in collecting the waste are described in Section 4.4. The waste paper trade sector is assessed in Section 4.5. A simulation model is developed in order to determine the overall economic, environmental and social impact for different scenarios of waste management (Section 4.6). Finally, conclusions are drawn in Section 4.7.

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[1] Mumbai is the pre-colonial name for Bombay and was re-introduced in 1996.

4.2 Solid waste management and recycling in developing countries

Developing countries have been recovering and using recyclable materials from their municipal solid waste for many decades. Moreover, recycling activities in the South are expanding rapidly (Savage and Diaz 1995). Two factors underlie this development. First, local industries have increasingly recognised the advantages of recycling such as lower energy consumption and emissions. Therefore they enhanced their demand for recyclable materials. Second, consumers and collectors have become more aware of the economic value of recyclable waste and gradually improved the separation of solid waste. This has led to an increase in the supply of secondary materials. In this section, the last factor will be discussed and analysed. As literature on this subject is rather scarce, most conclusions are based on a survey performed for the waste paper collection sector in Mumbai. First, an overview on recyclable waste collection in developing countries is presented.

4.2.1 State-of-the-art of SWM in developing countries

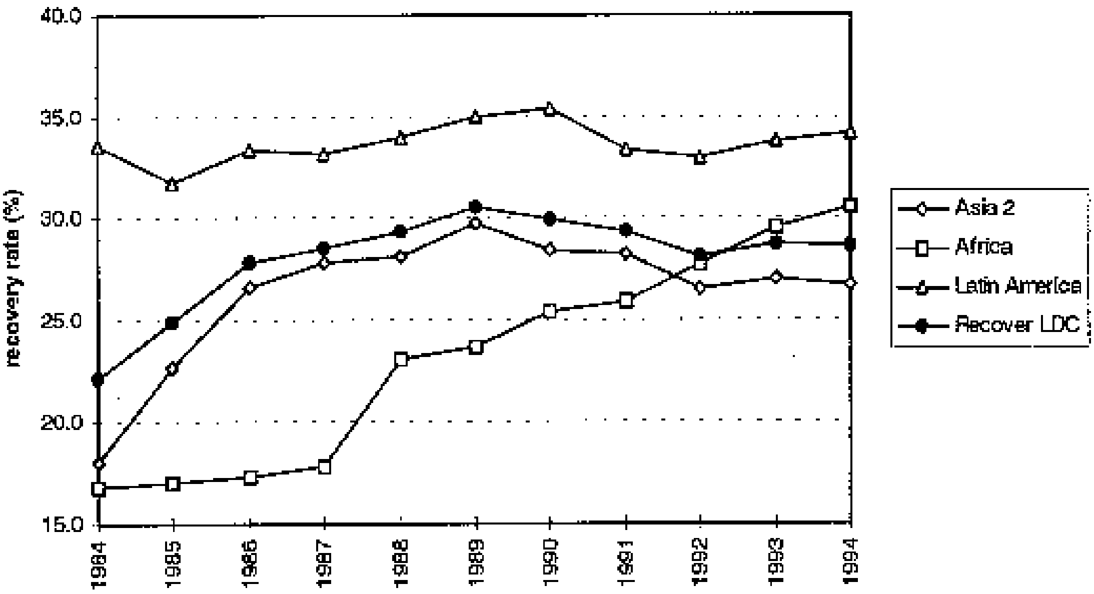
According to the World Bank (1995), the share of population living in cities in developing countries rapidly increased from 28% in 1970 to 38% in 1993. Projections for future developments show that this tendency will continue at an even faster rate. This urbanisation trend coincides with economic development, leading to higher income and consumption levels. As a result, municipal solid waste will become an even more urgent problem for many metropolises in the South. The well-known waste management hierarchy which stems from SWM in industrialised countries - waste prevention, reuse, recycle, energy recovery, disposal - is also in force in developing countries (Schall 1995). However, though the order of the options is similar to the industrialised world, the configuration of these options is different. For example, waste prevention is particularly relevant for countries with high consumption levels. Unnecessary packaging materials or wasteful consumer behaviour is generally less common in developing countries, and therefore the possibilities to reduce waste production at the origins are also less.

Also, disposal options in developing countries differ from the North. At present, up to 50% of municipal budgets are spent on solid waste management in developing countries. Still, waste officials are not able to manage this problem efficiently. Due to lack of funds, on an average only 50% is collected in developing cities (Cointreau 1991). But even when budgets are adequate, collection and safe disposal remains a problem. Overall, inappropriate solid waste management leads to a number of societal problems, such as increased risk for epidemics, air-pollution caused by illegal waste burning and pollution of groundwater. The limited resources for SWM by the municipalities in developing countries enhances the need for cost-effective options to manage urban solid waste.

Most developing cities are serviced by an informal sector which exists parallel with the formal waste collection authorities. This sector is mainly guided by market forces. The role of governments in recovering secondary materials is small. This informal sector is essential for the environment as well as the local economies in urban centres. First, by collecting waste materials the informal sector takes over a part of the burden of the municipalities. Second, since the waste collection is labour intensive and involves no special skills or transaction costs, it provides a livelihood to many new immigrants and marginalised people in big cities in developing countries. Estimates show that these activities account for an estimated 1-2% of the workforce in large cities (Cointreau 1989). Waas and Diop (1991) estimate that in Dakar around 200,000 people are employed by the informal recycling sector. Third, informal collection prevents environmental costs and reduces capacity problems at dumpsites.

It is difficult to quantify the total contribution of the informal sector to the urban waste management. The informal characteristic of this sector implies lack of official statistics on this economic activity. Quantification of informal recovery are therefore rather scarce and uncertain. For Mexico, waste pickers are estimated to remove 10% of the municipal waste (Bartone 1991). In Bangalore (India), the informal sector is claimed to prevent 15% of the municipal waste going to the dumpsite (Baud and Schenk 1994). In Karachi, the informal sector reduces municipal waste collection by 10% (Ali *et al.* 1993). For specific materials, such as waste paper, more specific estimates can be derived. In Figure 4.1, the slow increase of the recovery rate in developing countries is depicted. Especially the African and Asian region expanded the recovery in the last decade. Yet, the increase in the former continent can also be the result of decreased consumption levels.

Figure 4.1 Waste paper recovery rates in developing countries (1984-1994)[1]



Source: Pulp and Paper International (PPI) 1994

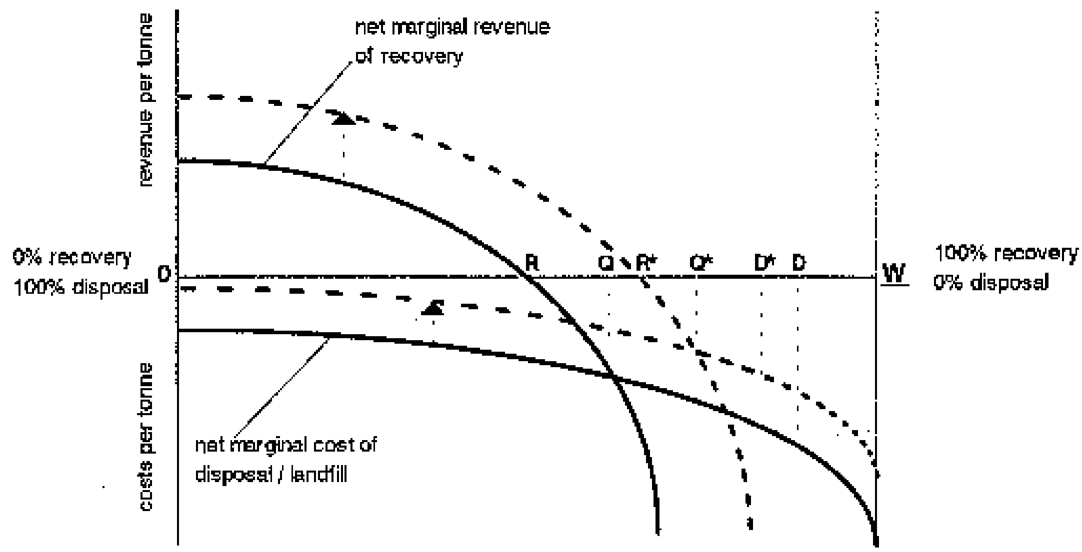
[1] The years 1993 and 1994 are projections based on the previous development.
[2] Japan and the Republic of Korea are excluded from "Asia"

4.3 Theoretical framework for waste management and recycling

Three features are typical in waste management in developing cities. First, the municipalities in developing countries have insufficient means to manage the growing burden of solid waste. Second, the informal sector plays an important role in recovering large quantities of solid waste at zero cost to the public. Third, despite the efforts of the formal and informal sectors significant quantities of waste remain uncollected. To illustrate the current waste management situation in developing cities, a simplified framework is presented in Figure 4.2. Prices for each type of recovered material are assumed to remain constant. From this economic framework, the optimal waste management (landfill and recovery) can be derived. On the vertical axis, direct costs and revenues of both options are depicted. The horizontal axis shows the quantities of the respectively recovered (recycled) waste and disposed (landfilled) waste. The total amount of generated waste **0W** remains constant.

The waste has three possible destinations: informal recovery for recycling, formal collection for landfilling, and in the worst case the waste will be left uncollected. These management options are expressed in the cost curves which depict the net marginal cost or benefits of each additional unit of waste for that particular management option. The net marginal cost curve for informal recovery starts above the horizontal axis because recycling initially generates net revenues. The marginal revenue decreases with increased collection because the remaining recyclable waste at the source becomes more scarce and the quality deteriorates. Relatively more effort is required to recover it. Recycling is cost-effective upto the quantity **R** is reached. Therefore, point R depicts the optimal quantity of recovered waste under free market conditions. Recovery of waste beyond R is not cost-effective. Recovery in developing countries will not exceed R because the informal sector is not compensated for the resulting additional costs.

Figure 4.2 Current and optimal recovery and disposal configuration



Source: based on Bertolini 1994

The net marginal cost curve of disposal/landfill should be read from the right to the left. Waste collection starts at W and will move gradually towards the left as long as the municipality budget holds. This curve starts below the horizontal axes because formal collection does not generate net benefits. Therefore, this curve never intersects with the horizontal axes. As opposed to the net marginal curve of informal recovery, an increase in formal waste collection decreases its net marginal costs. These economies of scale are illustrated by the more than proportional decline of the marginal cost line, starting at the right hand side. Because municipalities in developing countries generally have insufficient budgets to collect all the disposed waste, formal waste collection usually does not accomplish the desired quantity of WR. In Figure 4.2 this is indicated by the amount WD which is the actual formal collection and landfill. This leaves an amount of RD as uncollected waste. Yet at R, the marginal costs of recovery are still lower than the marginal cost of disposal. In this situation it is cheaper for the municipality to recover waste instead of collecting it for landfilling. At the intersection of both marginal cost curves **Q**, recycling is no longer preferred above landfilling. Beyond, Q disposing waste is cheaper than recovery. This leaves a quantity of Q<u>W</u> of waste to be disposed. A quantity of RD remains uncollected.

In industrialised countries where municipal budgets do not form a constraint, the most cost effective solution is to first increase the recovery for recycling purposes (from R to Q). Beyond Q, it is cheaper to collect the waste for disposal and thus follow the net marginal cost curve (DQ). In developing countries, two reasons exist which prevent the municipality from following this approach. First, municipal budgets are limited. Therefore, the waste management officials are constrained in the total waste collection they can perform. Second, their involvement with the informal recovery sector is absent. Therefore, the municipality does not have the proper infrastructure to exploit the cheaper option of recovering RQ for recycling.

What is the most efficient solution to solve the problem of uncollected waste in developing cities, given the limited budget of municipalities and the limited involvement of governments with recycling? In the above theoretical framework, two options prevail. First, the waste collection of the municipality can be improved by increasing the efficiency of the solid waste management. Official waste collection systems are often inefficient. Generally, second-hand vehicles are operated which are extremely polluting and not suitable for local conditions. As a result, maintenance costs are high (Pearce and Turner 1994). Improvement of the waste management will allow more waste to be collected for a similar SWM budget (shift D to D^+). This progress is depicted in Figure 4.2 by a shift of the net marginal costs curve to the right.

The second option to reduce the uncollected solid waste is to encourage the recovery of recyclable waste by the informal sector. This can be achieved through reduction or elimination of sales tax on local waste trade or through the promotion of waste separation at the source. Another option which is often considered is the replacement of the informal sector by a Western style recovery system. Whether this alternative is feasible will be discussed in the coming sections. An improvement of the informal collection sector is depicted in Figure 4.2 by a shift of the net marginal revenue curve to the right. This implies that the amount of recyclable waste collected cost-effectively will increase from R to R^*. In the new situation, the uncollected solid waste has decreased from RD to R^*D^*.

4.4 The waste paper collection sector in India

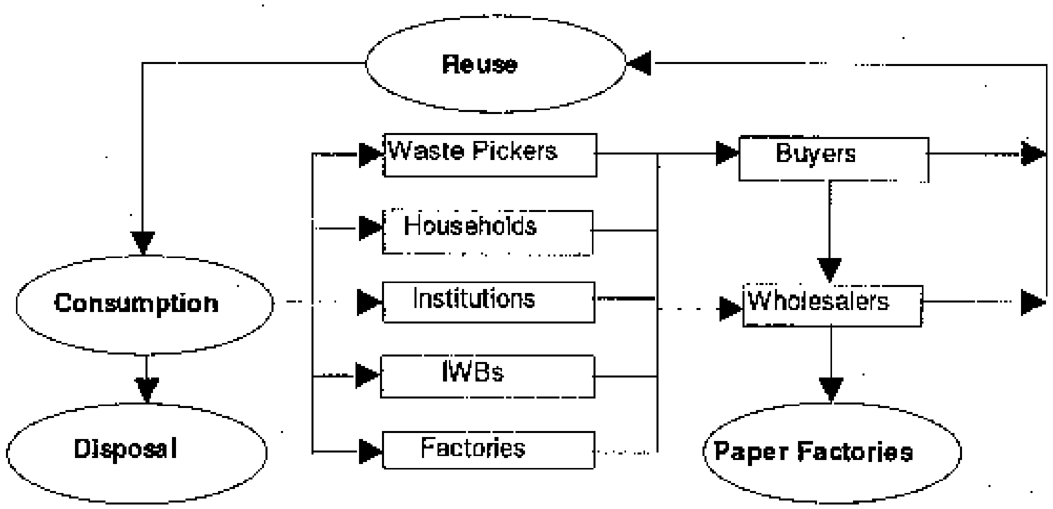
4.4.1 General structure

In order to determine the economic, social and environmental impacts of different policies directed towards the local waste paper collection in India, it is necessary to understand the complex system of entrepreneurs and processes which are linked to this sector. Ignoring these complexities would particularly lead to an underestimation of the social dimensions of the paper chain, because it is mainly the underprivileged who play an important role in this sector. The boundaries which will be considered in this partial life-cycle run from paper consumption to the disposal or recovery of paper products. Impacts from the actual utilisation of local waste paper are excluded. These upstream effects are considered in chapter 6. The various routes of paper in the recovery sector are depicted by the flow-diagram in figure 4.3.

Processes

Unlike the processes which take place before consumption, the processes in this phase are extremely labour intensive and involve only a limited input of capital. The following processes will be considered. First, the *consumption* process is of major importance. Most studies on the paper cycle only look at the consumption of paper products which are either supplied by local manufacturers or by foreign producers. The fact that a part of the consumption also involves re-use of waste paper without reprocessing taking place, is generally ignored. Yet, particularly in developing countries, re-use is an important alternative destination for waste paper and thereby may have a negative impact on the supply of secondary fibre to the recycling industry. Therefore, *re-use* is included in this study. This has two implications. First, the total level of consumption in this analysis will be higher than the formal level of consumption. The actual consumption will therefore be extended by a certain amount of re-used waste paper. Second, as re-use has a negative effect on the quality of the waste paper, it is assumed that paper which is re-used can no longer be available for recycling. This implies that the quantity of unrecoverable waste paper for disposal will increase if more waste paper is re-used.

Figure 4.3 Flow-diagram of the local paper consumption and post-consumer destinations of waste paper



Note: IWBs stand for Itinerant Waste Buyers (see below)

After consumption, a part of the paper diverts from the cycle through either long term *storage* such as libraries, or through structural *losses* such as sewage. Waste paper can also be *burned* in order to reduce the disposal burden. The remaining paper is either *landfilled* at the dumpsite or it is *recovered* and supplied to the trade sector through different entrepreneurs. In case of landfilling, the waste paper can still be recovered by entrepreneurs who operate at the dumpsites. Eventually, the trade sector will supply the waste to the paper industry or offer part of it for re-use to the consumers.

Entrepreneurs

The entrepreneurs who operate in this field can be broadly categorised into two groups: the formal and the informal sector. Generally, the Waste Management Departments of the Municipal Corporations in India are the only formal stakeholders in the post-consumption waste paper chain. The municipality is responsible for the collection, removal and disposal of garbage and sweepings from public roads, streets, foot-paths and lanes, and maintenance of dumping grounds (Hadker 1995). Often, in developing countries, dumping or incineration is performed in an uncontrolled manner, resulting in high municipal costs. Recycling is rarely considered by the formal sector. The informal sector, which according to the International Labour Organisation (ILO) refers to those employers classified as own-account workers, unpaid family workers and those "not classifiable by status", collects and trades mostly unregistered waste materials (World Bank 1995). Various entrepreneurs play a role in the local supply of waste paper.

The main source of waste paper are the *households*. They save their own waste paper which is either sold to the buyer or to the Itinerant Waste Buyer (IWB). As this mainly involves newspapers and magazines, the households are also the main source for re-use. In addition *institutions* and *factories* participate in the informal paper cycle. This group includes government departments, private companies and shops. Office boys or caretakers gather the waste paper which is generated in the offices, and sell it off to IWBs or buyers. The collection of waste paper is performed by either *waste pickers* or *IWBs*. The waste pickers, who are mostly unskilled migrants, roam on the streets and dumpsites to collect any type of material which they can sell to the buyer. The *IWB* is also mobile, but instead of picking waste from bins or dumpsites, he goes from door to door by bicycle to buy the waste from households or shops. Since his material has not yet been mixed with disposable waste, the quality is much higher than the waste paper gathered by the waste pickers (Ali *et al.* 1993), which implies that the IWB is a major supplier of re-usable paper.

Finally, the waste enters the trade sector, which despite the fixed location can still be considered an informal activity because the traded materials are mainly unregistered and the labourers sorting out the waste belong to the non-wage employment. The *buyers'* main role in the paper cycle is to purchase from the above sources, sort out the waste, bundle it and sell it off to the wholesaler. The role of the *wholesaler* is to accumulate the purchased material until the quantity is sufficient for transportation to the recycling plant. The main difference between the wholesaler and the buyer is that the former is specialised in one specific type of material, whereas the buyer generally buys any type of waste which is offered. Also, the quantities dealt with by the wholesalers are much larger than the buyers trade volumes.

4.5 A case study on the waste collection sector of Mumbai

The collection of waste paper in India mainly takes place in urban centres for obvious reasons. The amount of waste generated increases with increasing incomes and increasing population. Also the "throw-away" consumer behaviour is more manifest in cities. In addition, collection of waste is easier in cities as the population density is higher. Yet, this relationship does not always hold. Traffic jams and high rise buildings can hamper the recovery and collection of waste. Also booming real estate prices makes it more difficult for waste traders to remain in the city areas. In this case study, Mumbai was selected because it gives a good representation of other megacities in developing countries. Since reliable information on the local waste recovery in developing countries is lacking, several surveys were conducted in Mumbai. A summary of the most important findings of these three surveys is given in the following sections. Information on the other stakeholders in the waste paper collection cycle are retrieved from literature or other surveys. The main objective of the surveys is to determine the relative contribution of the various entrepreneurs in the waste paper collection sector, and to analyse the performance of these actors so that suggestions for improvement of the waste management in developing cities can be made. These data will be combined in the simulation model in Section 4.6.

4.5.1 The waste picker

Waste pickers contribute to solid waste management and to the supply to the recycling industry by collecting, sorting and selling recyclable waste materials to buyers (Huisman 1994). The individuals operating as waste pickers originate from various groups, such as run-away children, migrated women, or unemployed labourers. Research on waste pickers is rather scarce. In 1988, Gilhuis emphasised the role of waste pickers in Curitiba (Brazil). For Bogota (Colombia) it was estimated that 30,000-50,000 people earn from collecting recyclable waste (Hardoy *et al.* 1992). Huisman (1994) focused particularly on the position of female waste pickers in Bangalore (India). Furedy (1990, 1994) contributes by giving an overview of the social context of waste pickers in various Asian cities. The general conclusion of these studies is that waste pickers play a significant role in the waste management in developing cities.

A survey among waste pickers was conducted to quantify their contribution. In other words, how much of the supply of waste to the recycling industry depends on waste pickers' activities and how much waste is prevented from landfilling? In order to represent the variety in the working area, 60 waste pickers were interviewed casually[2], in four types of areas: a dump site, a residential area, an industrial area, and a commercial area. Additionally, 7 group discussions[3] were held to enable the respondents to talk more freely about their activities and the social conditions. The outcome of these surveys will be used in the simulation model which is explained in the coming sections. In addition, the possibilities to improve their performance are considered. For this reason, a qualitative assessment is made.

Of the total number of 60 waste pickers interviewed, 23 were male and 37 were female. Since respondents were selected at random, we can infer that the waste picking workforce is not equally divided between males and females. Waste picking is a transitory occupation requiring no skill and is often resorted to by new immigrants to the city. These characteristics account for the bias in favour of females. Huisman (1994) confirms this finding.

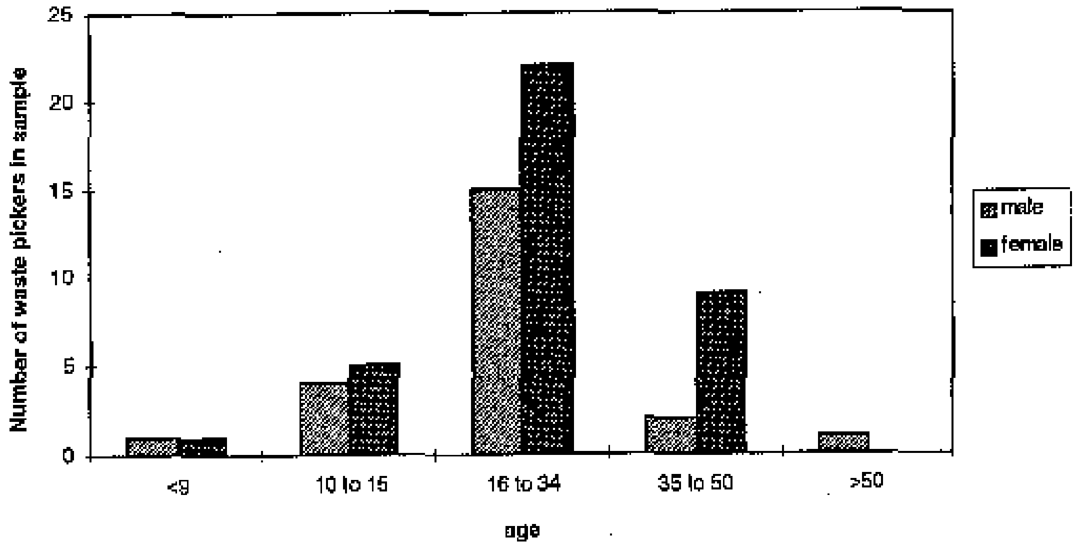
The frequency distribution in figure 4.4 shows that 60% of the respondents are 25 years old or younger. Of this young workforce almost 17% of the sample are children

[2] Casual selection implies that the interviewer operates in a specific area and randomly selects recognised waste pickers for an interview.

[3] The group discussions were held among waste pickers who were already interviewed and waste pickers who joined their friends.

of 15 years or less. The drop-out rate from the workforce particularly for males is pronounced after the age of 35. Again, this outcome coincides with Huisman's study (1994) as well as NEERI (1995). An explanation for this phenomenon is that men find waste picking too inferior. Another reason could be that, although both boys and girls enter the trade at an early age, boys "graduate" into other occupations, while women tend to stay on. Women perceive the advantages of bringing their children along with them and the freedom to decide upon their own hours of work.

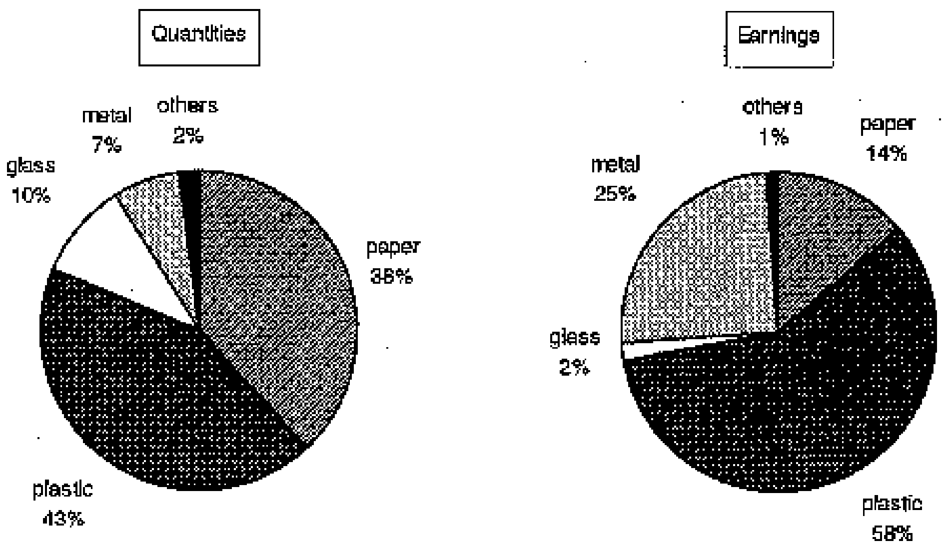
Figure 4.4 Number of male & female waste pickers according to sex and age



Practically all the respondents were migrants. Almost 52% originated from Maharashstra State, of which Mumbai is the capital. 38% of the interviewed waste pickers came from Tamil Nadu. Half of the respondents were originally from rural areas, while only 7% came from other large cities. The illiteracy rate among the respondents was 75%. Only 10 waste pickers had had some kind of formal schooling, between classes 4 and 9. Clearly, waste picking is a transitory occupation of new migrants who have little chance to find other occupations. Another important finding is the dominance of Hindus in waste picking. Only one Muslim and one Buddhist worker were registered in the survey. In the buyers' and the wholesalers' surveys, Muslims were found to be much more present in the sample. This indicates that it is not necessarily the prescription of the Islamic religion which prevents Muslims to work with waste. A more likely explanation could be the stronger family back-up of the underprivileged in the Muslim community, which makes resorting to waste picking unnecessary. Also the reluctance of Muslim women to go around in public places might be an explanation.

The social profile of the respondents is diverse. However, some patterns in social conditions can be recognised. A large majority of the waste pickers live with their families and contribute to household income. It was observed that in waste picking families, young children accompanied their mothers from an early age. Only the male workers complained about police harassment. This particular vulnerability can be an additional explanation of the minority of older male waste pickers. Common forms of harassment are extortion, verbal and physical abuse, false accusation in theft cases which occasionally leads to imprisonment. The female waste pickers did not complain of any harassment by the police. Although they did not confess to taking drugs, group discussions showed that a majority of the older male waste pickers and a few female waste pickers were addicted to drugs and alcohol. The women waste pickers complained about their husbands being addicted to alcohol. The common health hazards that waste pickers face are directly related to the unhealthy conditions in which they work and the unhygienic and sometimes hazardous materials they handle. Common ailments include viral infections, respiratory disorders, and skin infections. Cuts and wounds due to sharp objects in the waste handled are common.

Figure 4.5 Compositions of quantity of waste and earnings by waste pickers



All the respondents operated regularly in a particular territory. Trespassing into territories of others rarely occurs. A new arrival relies on a "senior" waste picker to whom he or she is attached for some time before operating individually. All the waste pickers said they sort the materials before selling them. The sorting usually takes place near the buyers shop, just before the transaction. The total average quantity of waste materials collected by the waste pickers per day is almost 13 kgs. The average composition of this bulk is depicted in Figure 4.5. Clearly, paper and plastics form the major materials with respectively 38% and 43% share by weight. The category "others" mainly consists of wood and thermocol. The collected metals are tin, iron and aluminium. Within the paper category, brown kraft paper and duplex account for more than 70%. This is likely as the more expensive paper types are not disposed in waste bins. It should be noted that the seasonal variation in waste paper collection by waste pickers is larger than for plastics because of the impact of the monsoons.

The daily income of the waste picker in Mumbai comes up to Rs. 37. However, if the reported quantities are exposed to prevailing market prices of waste, their average income should be higher (Rs. 57). This can be explained as either an underestimation of the respondents or as a general tendency of the waste buyers to pay less than the market prices. It was also found that male waste pickers (Rs.47) are generally earning more than female waste pickers (Rs.28). Finally it should be noted that waste pickers also gather materials which are not sold, but instead are used for personal use such as firewood. This category was not included in the earnings assessment. Figure 4.5 also depicts the average contribution of the collected materials by waste pickers in terms of earnings. Whereas paper is important in terms of volume, the earnings derived from paper are not very significant. Because of the generally lower price of waste paper and low quality of the waste paper collected from the bins, paper only contributes 14% to the income of the waste picker. Plastic on the other hand contributes 58% of the total income. Typically, metals which only account for 7% of the collected materials in terms of volume, generate 25% of the income. This explains the habit of waste pickers to burn waste at the dumpsites to recover metals from the ashes.

Various correlation tests were performed in order to find variables which determine the income of the waste picker. In view of the unskilled nature of the work, it was expected that there would be a correlation between hours of work and earnings. However, the results of the test rejected this notion. Also the correlation between age and earnings was negligible. Even the area of operation does not have an impact on the income levels. This suggests that waste picking is an activity which requires no particular skills and which is considered as a survival strategy: waste pickers work until enough income is generated to buy the basic commodities. This is supported by the fact that only 7% of the waste pickers save an appreciable amount of their incomes.

Almost 72% of the respondents reported seasonal variation in quantity as well as quality of waste collected. During the monsoons less waste is collected, which also is of a lower quality. Because the quality effect dominates the quantity effect - traders anticipate this slack period by stocking material - lower prices are apparent during the monsoons. The respondents were also asked how they reacted to price changes. In the case of increased prices of waste materials, only one third of the waste pickers behave predictably by maximising income. Most of the remaining waste pickers are not price-sensitive and collected uniform quantities. Only one respondent claimed to collect less with higher prices. More than 71% of the waste pickers had regular transactions with one buyer while 29% of the waste pickers sold materials to 2-3 buyers. This is a strong indication that there exists a large dependency on a particular buyer. The buyer attempts to enlarge his relatively small margin by keeping the prices as low as possible. In times of inflation, poor weather and competition the waste pickers have to suffer the consequences of the decline in their income. The buyer binds them for longer periods of time through loans and other facilities.

The male respondents particularly considered waste picking as a temporary occupation. They prefer to switch over to other manual labour such as construction work or street vending, if opportunities arise. The majority of the female workers preferred waste picking because of the independent nature of the work. Also they claimed that waste picking was more rewarding. Coolies and construction workers earn respectively Rs.20 and Rs.25 per day (Huisman 1994). This difference in attitude between males and females is slightly supported by the number of years that the respondents already had worked in waste picking. While males have an average experience of 7 years, the experience of females goes up to 9 years.

Before the contribution of waste pickers to the SWM in Mumbai and the supply to the paper cycle in India can be analysed by integrating the findings in the material flow model, several coefficients need to be defined. First, it is required to know how many waste pickers are required to collect a specific quantity of waste paper. According to the survey, one waste picker collects approximately 1,400 kgs of waste paper per year if the negative impact of the monsoon is taken into account. This means that for the supply of 1,000 tonnes of waste paper derived from the streetbins and the dumpsite, 714 waste pickers need to work for one year. The value added of this activity is completely determined by the weighted average of prices of the waste paper which is supplied by the waste picker. Because of the low quality of this waste paper, the average price is only Rs.1,610 per tonne. The contribution to the SWM in Mumbai goes beyond the collection of waste paper. Also plastics, metals and other recyclable waste need to be taken into account in this respect. The findings show that a waste picker collects approximately 4,000 kgs of waste per annum. It is assumed that the major share of this waste is collected from streetbins.

An aspect of special social importance is the number of children working in this type of activity. Child labour is a complex issue. Often, poor households have no choice but to send their children to work. Also, children who work in waste picking often have no families. The survey revealed that it is often boys who survive without families. Most girls accompanied their mothers and thereby supported the family income. Overall, 18% of the respondents were 15 years of age or younger. A final estimation, required for the model is the number of waste pickers operating in Mumbai. No official figures on the total numbers are known. Attempts to estimate numbers were made in Bangalore (25,000 waste pickers on a population of 4.5 million) (Huisman 1994), and in Karachi (20,000 waste pickers on a polupation of 9 million) (Ali *et al.* 1993). This implies a ratio of one waste picker to between 200 and 450 citizens. Based on this ratio, Mumbai would have about 25,000 to 50,000 waste pickers. However, the reliability of such an extrapolation is limited. Based on the surveys, it could be estimated that Mumbai employs around 35,000 waste pickers. In terms of volume, 38% (13,300 waste pickers) of their efforts is concentrated on waste paper.

4.5.2 Households, factories and institutions

Being the consumer of newly produced and re-usable paper and the only source of local waste paper, households, factories and institutions perform an equal role in the paper cycle in Mumbai. Therefore, these stakeholders will be discussed simultaneously. The official per capita consumption of paper in India is 4 kg per year (Rao 1995). To get a sound notion of the volume of waste paper flow in Mumbai, this official figure must be adjusted. First, it does not give a realistic representation of the consumption in Mumbai because it is the average per capita consumption of paper for India. The rural population which still accounts for almost three quarters of the population, is predominantly illiterate (World Development Report 1995). Second, the amount of re-used paper is ignored in this estimate because the trade of waste paper for re-use is not registered. Finally, data on volume and composition of the waste in Mumbai demonstrates that the per capita disposal of paper is at least 13 kgs per year (Hadker 1995). This figure excludes the waste paper which is recovered for the purpose of re-use. On the basis of these facts, it is estimated that the average consumption of newly produced paper in Mumbai is 18 kgs. Also, it is assumed that per capita re-use of waste paper for each resident of Mumbai is approximately 2 kg. The total "informal" per capita consumption is therefore determined at 20 kg per year.

The post-consumption stage of paper in households and institutions can be divided into three categories. The first category is the paper that is diverted from the paper cycle for other reasons than disposal, such as sanitary paper and long term storage.

Obviously, sanitary paper consumption is more important in the North than in the South. Therefore, sanitary losses are ignored in Mumbai. Storage, on the other hand, is an important leak in the paper cycle. Given the conservative attitude towards disposing of books, magazines and reports, this ratio is significant in India. The second category includes the waste paper which is directly or indirectly supplied to the waste trade sector by households and institutions. From the buyers, survey it was estimated that the buyer purchased approximately 50% of the traded materials from households, institutions, and factories. The IWB is fully dependent on households and institutions. The third category is the waste paper which, together with the other waste, is disposed of in the street bins. Before this waste eventually ends up at the dumpsite, waste pickers will select out various valuable materials. This reduces the volume and changes the composition of the waste. Eventually 1.67 million tonnes of institutional and household waste paper were landfilled by the municipality in Mumbai in 1992-93 (Hadker 1995). Given the average per capita waste generation of 0.5 kg per day which aggregates to 1.96 million tonnes for Mumbai, and an approximation of 35,000 waste pickers in Mumbai, it can be assumed that 8% of the post-consumer waste is recovered by waste pickers and 7% of the post-consumption waste is burned or remains uncollected. Although this figure is rather uncertain, more accurate estimates could not be derived from the available data.

Finally, the question remains of how increased seperation of household waste can be achieved. There have been a number of studies by behavioural psychologists to examine the motivation of participants in recycling schemes and the effects of different kinds of inducement on the rate of participation. Urban citizens in the US were found to participate mainly for personal satisfaction associated with environmentally responsible behaviour. Yet, financial incentives such as direct charges for waste management services were also found to be necessary to motivate the less environmentally motivated citizens (Gandy 1994). Given cultural and economic dissimilarities, differences in motivation of citizens in developing and industrialized countries seem to be rational. A survey conducted among households in Bangalore revealed that the reasons for separating and selling waste were not purely economic (Furedy 1994). Most households replied that it was a tradition or habit. Nevertheless, 76% of the respondents also mentioned that "waste trading was important to their household, since the money they earned from selling the materials was useful". It should be taken into account that it is generally not the head of the household who takes care of the waste but the servant. For this group, the economic importance is much larger than for the middle or higher class families who consume the paper. The same can be said for office-boys and caretakers working for institutions. One can conclude that although it is difficult to quantify, waste paper supply done by households and institutions forms a significant contribution to the paper cycle. Although waste separation at the source is a tradition in most families and offices, efficiency can still be improved through awareness campaigns. It should be realised, however, that overall economic growth may also have counteractive effects on waste recovery. The danger exists that growing urbanisation will force the buyers to move from the residential centres to the industrial suburbs. As distances increase, the motivation of the households and institutions to separate and sell the waste diminishes. This trend may have a negative impact on the recovery rate (Furedy 1990).

4.5.3 IWBs

IWBs form an important part of the waste recycling system in Indian cities. They go around the city on bicycles or even on foot buying recyclable waste from houses, institutions, offices and other sources. The collected recyclable waste mainly consisting of paper, plastic, glass bottles, and metal scrap, is purchased from households and institutions and sold to buyers. The IWBs are important for the paper cycle as they obtain waste at source before it is mixed, damaged or contaminated. Because the IWBs cover a different segment of the waste recovery sector, they are not in direct competition with waste pickers (Ali *et al.* 1996). Most of them are independent operators, while some are employees of the buyers on whom they are dependent for financial assistance. The IWB collects about 40 kgs of recyclable waste per day which generates a daily income of Rs. 50-60 (Furedy 1994). Although the IWBs are common in most Indian cities, their present existence in Mumbai is minimal. Whereas their contribution to the supply of waste paper in Bangalore accounted for 19% (Beukering 1994), the field survey indicated a contribution of less than 4% by the IWBs in the Mumbai waste paper supply. This can be explained by the fact that due to the high rise housing conditions in Mumbai, it may be very difficult for the IWBs to access the residential and commercial areas and may be difficult for door-to-door collection. Also the heavy traffic impedes the performance of the IWBs.

4.5.4 The municipality

The Solid Waste Management (SWM) in Mumbai is undertaken by the Municipal Corporation of Greater Mumbai (MCGB). The annual growth of 6.2% in waste generation in Mumbai is almost four times as large as the population growth of 1.6%. Because of this exponential increase in solid waste, the total budget spent on SWM is simultaneously growing. At present 7% of the MCGB budget is spent on SWM (Hadker 1995).

The solid waste department of MCGB employs 26,239 people. This implies that MCGB requires more than 9 employees to process 1,000 tonnes in a year. The total wage bill is around Rs. 992 million. Thus only for labour costs, SWM costs Rs. 348 per tonne of garbage. Also the transport is costly. Assuming that about 780 trucks operate each day, covering a distance of 100 kms, the total daily consumption of diesel exceeds 2,600 litres. This alone costs around Rs. 93 million per year. The overall budget of the SWM department in Mumbai was Rs. 1,273 million in 1992-93, which means that the total costs of managing one tonne of garbage is Rs. 447. Budgets of solid waste departments in developing cities rarely reflect full costs (Cointreau, 1996). One can consider this estimate to be slightly undervalued as the 170 hectares of land used for dumpsites in Mumbai, could be priced at Rs. 1.5 billion (Hadker 1995). These opportunity costs are ignored. Also indirect costs such as related staff in other departments are not taken into account. As opposed to the entrepreneurs in the informal sector, the economic potential of solid waste is rarely exploited by municipalities. Obviously, the most valuable materials have already been harvested before it reaches the dumpsite. Attempts in India to convert the solid waste into compost have not been very successful until today. Too often "Western technologies" are applied which are not suitable for Indian conditions (Baud & Schenk 1994). Although, experiments are conducted to develop decentralised composting and energy recovery of solid waste, these new methods have not been applied on a large scale.

The volume and the composition of the waste changes during the process of collection and disposal. Waste pickers scour the street bins to extract valuable material. Table 4.1 demonstrates how much of each material is recovered from the bins in Mumbai and how the composition alters accordingly. This change in volume and composition is an important element in the evaluation of the environmental impact, but also to verify the contribution of waste pickers to the solid waste management system. According to the table, it can be concluded that waste pickers play an important role in further reduction of the post-consumption waste.

Table 4.1 Waste volume and composition for different stages in Mumbai 1993 (in Kilo Tonnes, KT)

Material	Disposed (bin)		Recovered		Burn/Uncollected		Collected MCGB	
	in KT	%	in KT	%	in KT	%	in KT	%
Organics	1136	58	3	2	3	2	1130	68
Dust	292	15	0	0	0	0	292	18
Paper	197	10	61	38	51	38	85	5
Plastic	210	11	69	43	57	43	83	5
Glass	58	3	11	7	10	7	38	2
Metal	41	2	16	10	13	10	12	1
Others	27	1	0	0	0	0	27	2
Total	1961	100	160	100	134	100	1667	100

Source: compiled from Ali et al. 1993, NEERI 1994 and Hadker 1995

The waste which is eventually left will be either landfilled or burned. Waste burning is carried out both by the formal and informal sector. The main reason for the municipality to burn waste is to reduce the volume. This is particularly done for the uncollected waste. Sometimes waste burning is also performed by waste pickers in order to select the metals which are left in the ashes. Obviously, this activity is very damaging to the environment. An air-pollution study in Manila indicated that refuse burning was the second major cause of health damage through air pollution (Larssen *et al.* 1996). Energy recovery does occur at a household level. Sometimes, note books and magazines are used to heat traditional boilers. With continuous uncontrolled waste dumping and landfilling, the quality of the land deteriorates. As a result, underground water will get polluted through leaching of hazardous substances (Hadker 1995).

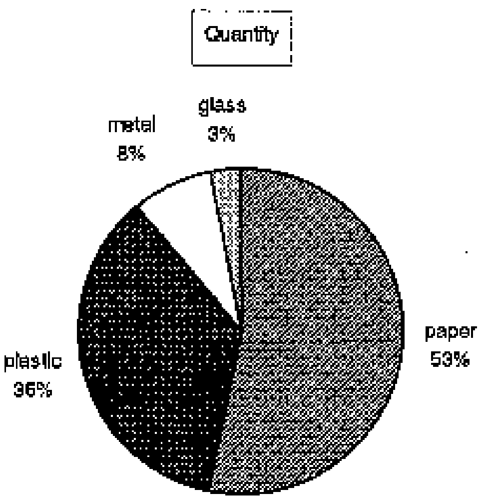
4.5.5 The buyers

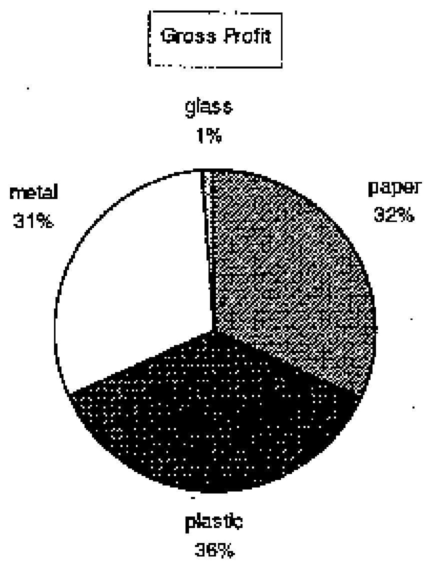
The buyer differs from his suppliers as he operates from a fixed location. Instead of trading one particular material, like the wholesaler does, any recyclable material is usually traded. Their knowledge of materials and the related prices is considerable. Without this experience the buyer would not be able to operate profitably since the margin between buying and selling price is generally low. In order to understand the profile of the buyer a survey was performed across 37 traders. As with the previous sections, the profile, the performance and the coefficients for the model are described.

The majority of the interviewed buyers were the owners of a complex of operation. 40 % of the respondents operate in a rented place. The relative representation of the various religions among the buyers differs from the composition derived from the waste pickers survey. The composition showing 65% Hindus, 19% Muslims and 13,5% Jains is more in line with the average distribution of the Indian population. The buyers have a better educational background than the waste pickers. Of the 73% of the buyers that had some sort of education, 63% were educated upto the primary level, 26% up to the secondary level while 7% were educated up to undergraduate level. Half of the respondents got into the waste trading business because it was already a family activity. Compared to the wholesalers, the entrepreneurs working as buyers represented a relatively recent group in the Indian paper cycle. 35% of the units started business after 1985 and 27% of the units were established between 1976 and 1985. The rest of the units were set up before 1976. The most important suppliers of waste to the buyers are waste pickers (47%) and households (42%). Smaller amounts are supplied by itinerant waste buyers (4%), factories (4%) and institutions (3%). An essential difference between buyers and wholesalers is their locational preference. While most wholesalers are situated in commercial or industrial areas, buyers prefer (68%) residential areas probably for reasons of minimising the distance to their suppliers, while 13 units are located randomly. The reasons given by the respondents for a certain location are proximity to residence, suppliers and customers as well as good facilities and no interference from the government. The scale of the operation area is relatively small, consisting of 230 square feet (SF) on an average with a dispersion between 50 and 1200 SF. This feature makes clear that the average buyer does not have much space to keep stocks. The average stock kept by a buyer is 1.34 tonnes per week. The majority of the buyers work 9 to 12 hours a day and operate 6 days a week.

The average buyer trades 39 tonnes of recyclable waste every month, with a slack period during the monsoons between June and September. The waste traded mainly consists of paper, plastic, metal and glass. The composition in volume and value terms is depicted in Figure 4.6. Although waste paper is the most notable commodity in terms of volume (53%), in value terms plastic is more important. The seasonal impact is taken into account, as these are annual averages.

Figure 4.6 Composition of the quantity and gross profits of the buyer





The average total turnover of a buyer is about Rs. 100.000 per month. For waste paper this results in an average turnover of Rs.32,000 per month. For paper, plastic and metal the gross profit per tonne is respectively Rs.1,390, Rs.1,767 and Rs.6.684. The average gross profit is Rs.22,500 per month of which is Rs.7,290 is gross paper profit.

In order to determine the net profits, other costs are estimated. For employment costs, it was found that the average buyer unit employs 1.2 workers. This figure excludes the owner. The average wage bill of a buyer unit, with an average wage of Rs.775 per month per employee, is Rs.900 per month. The average electricity bill and water bill only account for Rs.167 and Rs.27 per month respectively. Some entrepreneurs also indicated that they paid a certain amount of "hafta". These are informal costs paid to the authorities in order to get permission to maintain a business. Only 5% of the respondents paid taxes. This cumulates to a limited amount of variable cost of about Rs.1,100 per month (excluding tax and hafta). Thus variable costs seem not to be very important for the performance of the buye. Price fluctuation of recyclable waste, on the other hand, has a crucial impact on the buyer's performance. It should be realised, however, that the cost of the property is not taken into account. Given the high land value in Mumbai, this might have a considerable impact. Despite the relatively high gross profit rates the competition between buyers was found to be fierce. 86% of the buyers experienced competition from other buyers as a major threat for their performance. The majority of the buyer units (62%) were situated in areas with high concentration of buyer units. As a result, several buyers (18%) tended to consult other traders in order to fix prices and negotiate on territories.

For the model of the collection sector in Mumbai several parameters need to be determined. To make a clear assessment of the total impact of the buyers of waste in Mumbai, it is crucial to know the number of buyers operating in Mumbai. Based on the average quantity of waste paper traded by a buyer in the paper cycle and the total volume of waste paper trade, it was estimated that approximately 360 buyers operate in Mumbai. It is assumed that buyers themselves do not supply to factories, but to wholesalers only.

4.5.6 The wholesalers

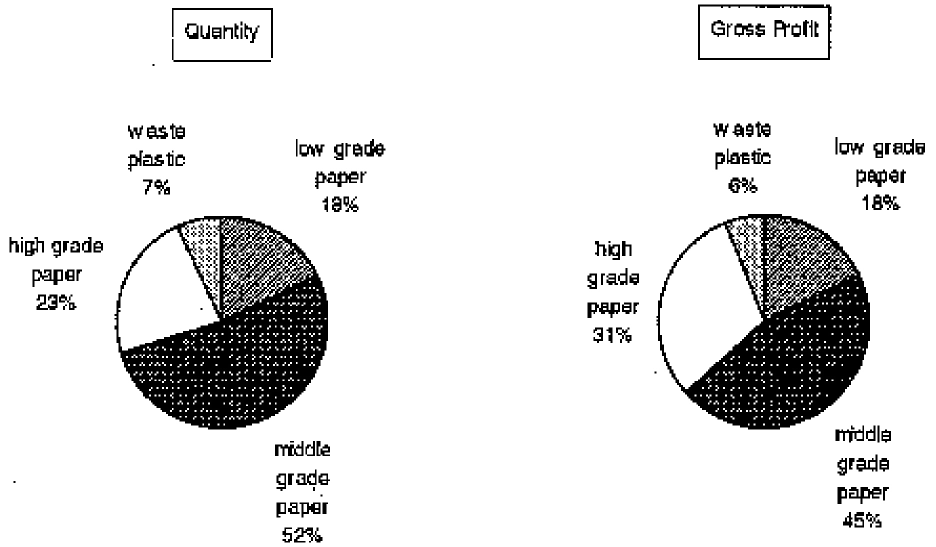
Wholesalers distinguish themselves by trading one type of waste, operating on a larger scale than buyers, and supplying directly to paper mills. This section is based on data collected during a survey among 37 waste paper wholesalers. The majority of the respondents owned the company and the place of operation, while 35% operated in a rented place. The wholesalers' group contained a relatively high representation of Muslims: 51 % Hindu, 43% Muslim and 3% Jain. The educational background of the wholesalers was generally higher than that of the buyers with 35 % primary level, 27 % secondary level , 14% undergraduate level and 3% graduates. The remaining 19% were exposed to some sort of informal education. More than half of the respondents entered into this trade because the trade was traditionally practised by the family, while 32% claimed to have entered the waste trade for economic reasons. 11% of the wholesalers were operating as buyers before and expanded their business. The majority of the companies were established before 1985 (92%) of which 26% were established even before 1965. There were not many new entries in recent times.

The most important suppliers of waste to the wholesalers are buyers (39%), waste pickers (20%), factories (11%), institutions (23%) and IWBs (5%) and households (2%). The location of the companies is in most cases (41%) a commercial area, while industrial areas (24%), residential areas (24%) and mixed areas (11%) prove to be less popular to wholesalers. The reasons mentioned by the respondents for these locations are the short distances to customers and suppliers, living in the area themselves and the existence of good facilities in the neighbourhood. Most of the wholesalers (78%)

are located in an area where other wholesalers are active, including those specialised in plastics, glass and metals. The surface of the operating area varies from 50 to 400 square metres, of which most wholesalers (62%) have a surface of less than 100 square metres.

The average wholesaler has a monthly turnover of Rs.767,737. The monthly amount of waste traded by an average wholesaler is 382 tonnes, making the scale of a wholesaler unit much larger than the average buyer unit. The same counts for the gross profit which totals Rs.170,076 a month, being 22% of average turnover. In Figure 4.7 the composition of the average waste paper that the wholesalers trade, is depicted. Most wholesalers do some limited waste plastic trading at the side. The middle grade waste paper constitutes the major commodity for the wholesaler. This paper generally originates directly and indirectly from households and institutions. The high grade paper mainly comprises white cuttings which are supplied by factories or printers. As can be seen in the gross profit distribution, the last category provides larger profit margins. For example, the gross profit on white cuttings is Rs.3,025 per tonne while newspaper only generates a profit of Rs.850 per tonne for the wholesaler.

Figure 4.7 Composition of quantity/earnings of the waste paper wholesaler[1]



[1] - *low grade waste paper includes kraft paper, mixed waste paper and corrugated paper;*
- *middle grade waste paper includes note books, , magazines and newspaper;*
- *high grade waste paper includes white cuttings, shareforms, and office records.*

Similar to the buyers, the majority of the wholesalers claim to experience a 'slack' period between June and September, when the monsoons influence business. The majority of the units (65%) are open 7 days a week, while the rest are active 5 or 6 days. In 3% of the units they work up to 8 hours a day , 68% works 9 to 12 hours and 19 % have an even longer working day. All these wholesale activities provide work for an average 7 employees per unit. The average salary of the employees in a wholesaler unit is approximately Rs.1,235 per month. This is higher than the wages in the buyers' units. The workers are paid on a monthly basis. Again this implies a more stable employer-employee relation than for the buyers. On an average, the wage and electricity bill are respectively Rs.11,531 and Rs.386.

As opposed to the buyers, 86% of the wholesalers claim to pay taxes which include sales tax and income tax. The percentage of sales tax varies from 4% to 6%, depending on the quantity traded which would result in an average payment of Rs.52,885 per month. Hafta is also a common phenomenon in the wholesalers' trade. This group is generally well organised. More than 50% of the respondents had contracts with their suppliers in order to prevent fluctuations. Unfortunately the survey did not provide enough information to calculate the costs of transportation. The expectation is that transportation costs would cause a reduction in the profit margin of a few percentage points. The overall calculation (excluding transportation costs) leads to a net monthly profit of Rs.104,931, which corresponds with a profit margin of 14% on an average.

In contrast to the buyers, competition is not mentioned as a trade constraint. Instead, power cuts, governmental interference and communication problems were mentioned as trade constraints by the wholesalers. 16% of the wholesalers reported to have frequent contact with competitors for territory and price fixing. This suggests that there exists oligopolistic power among certain wholesalers. The total number of wholesalers can be estimated by dividing the total volume of waste paper traded by the average trade of a waste paper wholesaler. According to this approach Mumbai appears to have around 67 waste paper wholesalers. This indicates a ratio of 7 buyers for every wholesaler. Estimates in Bangalore, revealed a higher ratio (1:10) (Furedy 1994).

4.6 The simulation model for the waste paper supply in Mumbai

To structure the waste paper flow of Mumbai, a *simulation model* is developed. The main purpose of the model is to asses the current situation for economic, social and environmental characteristics and to analyse the impacts from changed circumstances or policy measures. Three main scenarios are presented: a baseline scenario, a scenario with the introduction of a Western recycling system, and a scenario in which the current informal system is improved. These scenarios are elaborated in the following sections. Crucial to the success of a particular management option is the willingness of the Mumbai public to separate their waste. Because this information is not available, a range (5) of exogenously determined public responses are simulated. Based on this exercise, it is possible to identify the optimal management under varying responses from the public. Including the baseline, 11 scenarios are assessed.

The time span of the analysis runs from 1993 to 2010. This period is of sufficient length to demonstrate the short and mid term effects of certain policy measures. Extension of the time horizon is inappropriate because society will change so drastically that the underlying assumptions are no longer remain valid. The results of the analysis will first be presented for each individual year. Given the uncertainties regarding the data on the informal recovery sector and the performance of the formal waste management, the reliability of the model is limited. Relative price changes or technological developments are not taken into account. Therefore, the outcomes of this model should be solely interpreted as an illustration of the possible effects of policies. Finally, the outputs of the simulation model will be evaluated by the application of a *multicriteria framework*. No attempt is made to internalise intangible effects. Economic valuation of these effects lies beyond the scope of this study.

4.6.1 The model

A graphic representation of the model and its boundaries is given in Figure 4.3. Note that the industrial recycling process of waste paper is ignored in this model. The evaluation criteria of the simulation model respectively represent employment (y_e), environmental impact (y_i), income inequality (y_p) and public costs (y_y) within the waste paper cycle. These criteria are driven by the physical allocation of waste paper after consumption. The configuration of this allocation is specified by:

$$y_n = f_n(x) = f_n(x_s, x_b, x_l, x_u, x_i, x_w),\ n = e, i, p, y$$

The variable x is the vector of six types of physial allocations of waste paper: storage (x_s), burning (x_b), landfilling (x_l), re-use (x_u), informal recycling (x_i) and Western recycling (x_w). In the simulation the waste paper allocations are constrained within:

$$A = \{x_s, x_b, x_l, x_u, x_i, x_w\}$$

where

$$\forall x \in A, x \in S = \{\ 0 \leq x \leq X;\ x_s + x_b + x_l + x_u + x_i + x_w = X\ \}$$

A represents the constraint set for the number of scenarios which are simulated. S represents the constraint set of the waste paper cycle. These constraint sets are described in the coming sections. A specification of the model is presented in appendix 1. The four evaluation criteria give general understanding of the economic, social and environmental aspects of the waste paper recovery cycle.

Total employment: Employment is expressed in labour-years. The allocation of waste paper determines the composition of the actors involved in the waste paper recovery cycle. Actors such as households, institutions, factories, waste pickers, IWBs, buyers, wholesalers, municipal disposal workers, and municipal recyclers. The actors households, institutions and factories are excluded from the workforce because collection of waste paper forms a negligible part of their productive time. Because the model is limited to the waste paper cycle, the employees of the waste management department of the Mumbai municipality (MCGB) are included only for the amount of waste paper which they collect. Similarly, waste pickers, buyers and wholesalers are included in the employment calculation for the part of their time they spend on the collection of waste paper. It should be kept in mind that the total group of people that depends on waste collection is much larger than the employment figure calculated in the model because the other waste flows are ignored. Formally the "employment" criteria is:

$$y_e = \sum_a e_{a,t} \qquad (1)$$

where $e_{a,t}$ denotes the number of persons employed in a certain type of work a in period t. A detailed description of the employment function is given in appendix 1.

Evironmental impact: The environmental impact of the recovery sector derives from transport of collected or disposed waste paper, burning of waste paper and the landfilling of solid waste. Note that burning is different from incineration: it is only practised to reduce volume. No energy is recovered. As mentioned, the indirect effects of waste paper recovery such as savings on industrial energy and preventing deforestation, are excluded. To calculate the environmental impact, environmental indices are calculated on the basis of the methodology presented in Weaver *et al.*

(1995) (see appendix 2). First, the emissions generated by the processes in the waste paper recovery cycle are translated into six environmental problems (global warming, human toxicity, ecological toxicity, photochemical oxidation, acidification, nutrification and solid waste). Next, assuming equal importance of the six environmental problems, environmental indices are designed for each process. These indices on a per unit basis are presented in table 2. Consequently, for each scenario in the waste paper cycle an environmental score is generated. Formally, the environmental criteria is:

$$y_i = \sum_j i_{j,t} \qquad (2)$$

where $i_{j,t}$ denotes the environmental impact of a process j in period t. A detailed description of the environmental function is given in appendix 1.

Table 4.2 Environmental indices for the processes in the waste paper recovery sector in Mumbai

	Unit	Eco-index
Transport by truck	per kg/km	0.0285
Waste paper burning	per kg	10.7270
Landfilling	per kg	7.6930

Source: Based on Virtanen and Nilsson 1993

Income inequality: In order to use the variable income distribution as a social indicator, the Gini-concentration ratio is calculated which is a numerical measure of overall income inequality (see appendix 5) (Gillis *et al.* 1987). The theoretical range of the Gini ratio is from zero (perfect equality) to one (perfect inequality). The group which is considered in this context excludes households and institutions. Included in the calculation of the Gini ratio is the group of people that lose their job. Formally the "income distribution" criteria is:

$$y_p = f(\gamma_t) \qquad (3)$$

where γ denotes the Gini-coefficient of a certain allocation of waste paper in period t. A detailed description of the income inequality function is given in appendix 1.

Public costs: Public costs of MCGB for the collection of waste paper and landfill materials includes the wages of the civil servants, the costs of petrol and depreciation costs of the SWM equipment. In the case of the introduction of a Western waste paper collection system, the costs will increase with the amount of collected materials by the municipality. Public costs are further specified in the coming section. Formally, the "public costs" criteria is:

$$y_y = \sum_j c_{j,t} \qquad (4)$$

where c_j denotes the public costs of a certain policy option j in period t. A detailed description of the public cost function is given in appendix 1.

4.6.2 Constraints

Consumption: Consumption is considered to grow with income and population. As explained in section 4.2, paper and paperboard consumption in Mumbai is considered to be 20.4 kg per capita in the first period. The annual combined growth rate of population and income is estimated to be 5.91% (NEERI 1994). It is assumed that the sum of the post-consumption allocations (Σx_j) in period t is equal to the total consumption in Mumbai over the period in Mumbai. The definition function of the growth path of the total consumption and the sum of the post-consumption is:

$$X_t = 20.4 \cdot (1.0591)^t \tag{5}$$

where X_t denotes the total consumption of paper in Mumbai in period t.

Recovery: For reasons of long term storage, sanitary loss and technical limitations, the maximum recovery rate is 90% of the total consumption (Virtanen & Nilsson 1993).

$$(x_{u,t} + x_{r,t} + x_{w,t}) < 0.9\ X_t \tag{6}$$

where $x_{u,t}$ denotes waste paper recovery for re-use, $x_{r,t}$ denotes informal waste paper recovery for recycling, and $x_{w,t}$ denotes formal recovery for recycling in period t.

Reuse: With growing income, reuse of waste paper declines. Quality demands of society increase so that, for instance, newspapers are no longer considered hygienic packaging material. Therefore, the share of waste paper which is diverted for reuse is assumed to halve over the period from 1993 to 2010. This implies that the total volume of re-used waste paper ($x_{u,t}$) will grow proportionately less (1.67%) than the volume of paper consumption (5.91%) each year. This is denoted as:

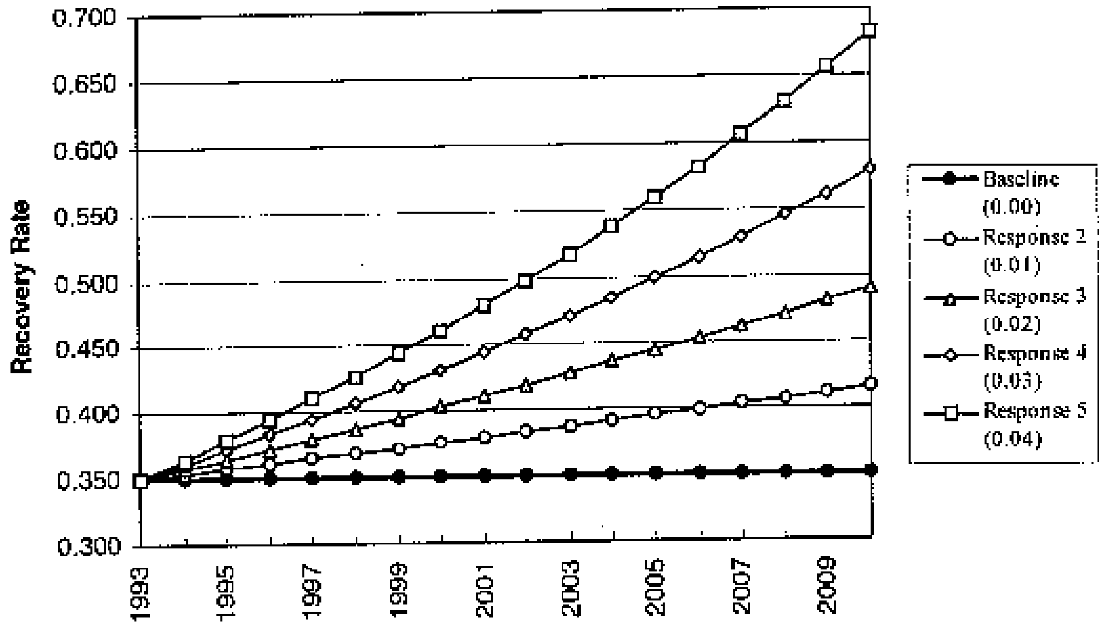
$$x_{u,t} = x_{u,t-1} * 1.0167 \tag{7}$$

Responsiveness: A key feature in the analysis of the management alternatives is the effectiveness of a particular policy measure. Because the encouragement to consumers to separate the waste is an important instrument, success largely depends on the societal response to recycling campaigns. A case study in Hong Kong demonstrated that despite a generally positive attitude in terms of willingness to improve recycling behaviour, in practise the success of a recycling campaign cannot be guaranteed (Chung and Poon 1994). Therefore, five different levels of responsiveness are exogenously defined to simulate the different degrees of success of the recycling campaigns. Responsiveness modifies the growth rate of the total waste paper recovery.

$$R_{R,t} = R_{R,t-1} \cdot (1 + \alpha) \tag{8}$$

where $R_{R,t}$ denotes the overall recovery rate, which is the sum of the reuse rate ($r_{u,t}$), the informal recycling rate ($r_{r,t}$) and the formal recycling rate ($r_{w,t}$) in period t. The α represents the response of society. A responsiveness parameter of α=0.05 implies that a particular management effort would lead to an annual growth of the recovery rate of 5%. Figure 4.8 depicts the impact of the different degrees of responsiveness of the public to policy measures on the overall recovery rate.

Figure 4.8 Recovery rate developments with varying responses (1993-2010)



Policy measures and public costs: Ignoring the economies of scale, the standard municipal costs on labour, capital and fuel for collection of solid waste, are considered constant at Rs.998 per tonne (NEERI 1994). A Western waste paper collection system requires a significant starting investment, such as distributing waste paper containers and setting up a special department for co-ordinating these activities. Therefore, an annual fixed costs component of Rs.146 million is assumed with an additional cost component of Rs.1,079 per tonne. The net costs will decrease with increasing success of the policy because the collected materials generate revenues as these are sold at market prices. It is assumed that for the first two years, government agencies are encouraged to comply with the new system. As a result the collected paper by the new system autonomously increases in the first two years to 10% of the total waste paper consumption. After this, the "Western" recovery rate will grow depending on the responsiveness of the public. The annual fixed costs of the informal policy which mainly encompass an intensive media campaign focused at consumers is Rs.20 million. Because the benefits of this policy will accrue to the informal sector, no direct income is generated for the public sector. Yet, the avoided costs for collecting disposed waste can create an indirect reduction of the overall public costs. In a situation where the response of the public is absent, the public costs will increase with the budget spent on the public campaign. Sales tax payments of the waste paper traders are ignored as available data are unreliable.

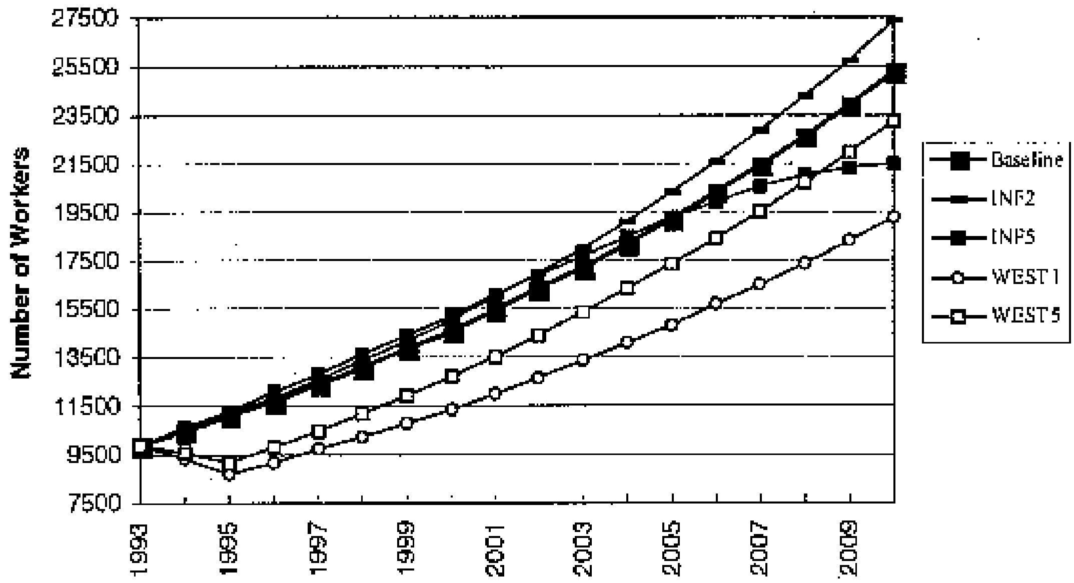
4.6.3 Simulation results

The simulation model primarily has an illustrative purpose. The coefficients in the model have been calculated from the field survey and therefore represent sample averages. Other coefficients are derived from literature or expert opinions and thus do not necessarily reflect population averages. Yet as the field samples are drawn randomly and the applied literature is reliable, no systematic errors are expected. Therefore, it can be assumed that the model sufficiently meets the purpose of demonstrating the possible effects that derive from policies aimed at increasing the recovery of waste paper in Mumbai. These economic, social and environmental effects are discussed seperately. The outcomes are presented graphically. For reasons of convenience, only those development paths are depicted which generate a maximum or a minimum result. Unless presented otherwise, the baseline coincides with the "informal policy without public response" path (INF 1).

Employment

Figure 4.9 depicts the outcomes of total employment in the local waste paper collection cycle in Mumbai. One should realise that the employment for the overall waste collection is much larger. Not surprisingly, each development path eventually leads to higher levels of employment. This is the logical result of increasing levels of waste generation in Mumbai. More people will get involved in the recovery or landfilling of waste paper. Two interesting features prevail. First, in the Western scenario the level of employment drops immediately after the introduction of the new collection system. This is caused by the autonomous increase in waste paper supply by government agencies to the formal collection system which otherwise would have created employment in the informal sector. Especially in the beginning, the labour intensity in the informal sector is higher than in the formal collection sector. In other words, in the short term crowding out of the informal sector will occur which will significantly reduce employment.

Figure 4.9 Total employment in the waste paper collection cycle (1993-2010)

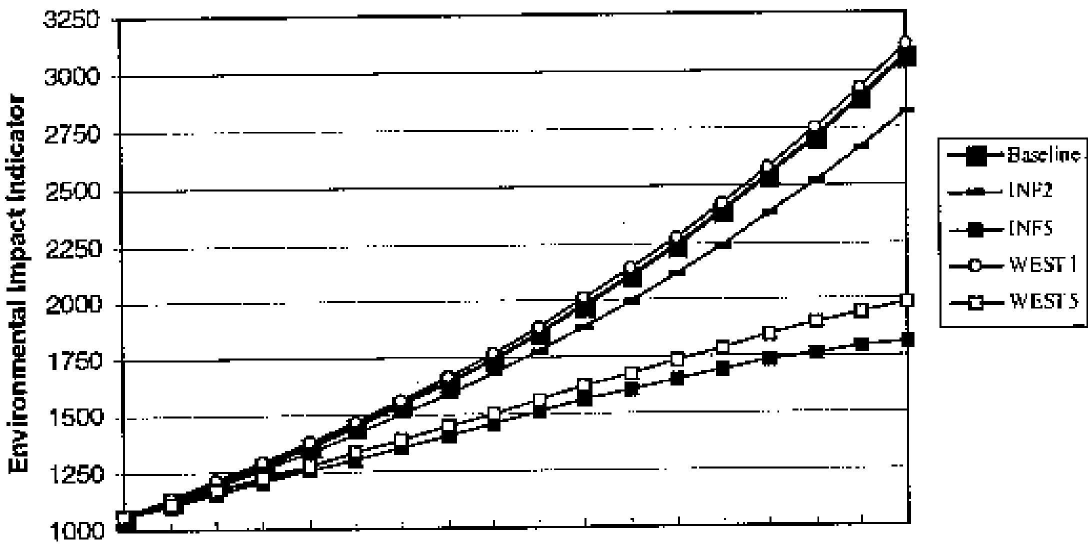


Second, it can be seen that in the long term it is not clear which policy option creates more employment. In the short run, the informal sector benefits most in terms of employment. More buyers and wholesalers which in turn employ labourers, can operate at the waste paper market. On the longer term, however, this effect is offset by the fact that waste pickers and disposal workers will find less waste to collect because households and institutions start to separate their waste instead of disposing it. This effect can clearly be seen the curve of the informal policy with maximum public response in Figure 4.9. The relative employment will eventually decline because higher levels of separation result in less employment for the waste pickers and disposal workers. Efficiency improvement reduces employment in the collection sector. Therefore, employment is at its maximum in the scenario with informal policy measures and low public response. In appendix 4, the changes in the configuration of employment of respectively the baseline scenario, the informal scenario and Western scenario with maximum public response, are presented for the period 1993-2010.

Environment

Figure 4.10 presents the environmental effects of the various scenarios in the paper collection cycle. Clearly, environmental quality decreases in time because more consumption leads to higher level of waste generation. In turn the waste is collected and landfilled, which has additional negative environmental implications. This is demonstrated by the upward slopes of the development path, indicating increasing environmental impact in time. For the environment, the baseline scenario is almost the worst development path. In other words, a recovery policy is required to prevent environmental damage. Only in the case of a Western collection system and no response of the public does the environment deteriorate more than without policy measures. This is the result of the autonomous supply of waste paper by governmental agencies to formal recyclers which have a more fuel-intensive collection practice than the informal sector.

Figure 4.10 Environmental quality in the waste paper collection cycle with varying public responses (1993-2010)



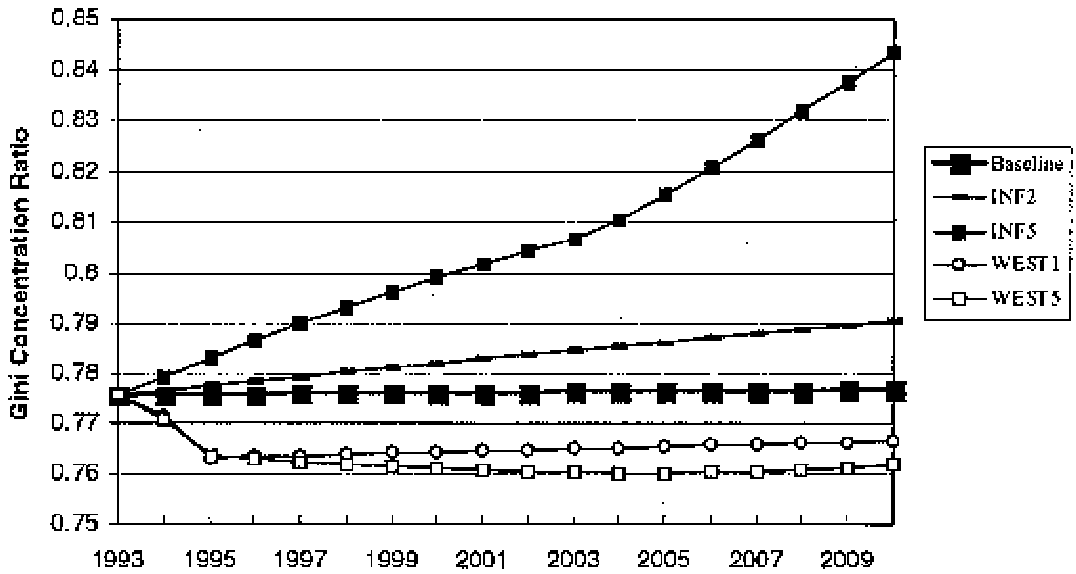
All the other scenarios are more desirable than the baseline scenario. In absolute figure, landfilling is considered the major environmental effect in the cycle (see appendix 3). The public response therefore plays an important role: the more paper is diverted from landfilling the better. On a per unit basis, waste paper burning is the worst practise in cycle (see table 4.2). Note, however, that in this study waste paper burning is assumed to remain constant over time at a rate of 10% of the total waste paper generation. Interactions between policy measures and burning are thus ignored. Yet, even at this low rate, waste paper burning contributes significantly to environmental damage. Also transportation activities cause problems. Particularly in Western scenarios, damage from transport is important. In appendix 3, the changes in the configuration of causes of environmental problems for the period 1993-2010 are depicted for respectively the baseline scenario, the informal scenario and Western scenario, with maximum public response.

Income inequality

Figure 4.11 depicts the developments in income distribution in the waste paper collection cycle with varying public responses for the period 1993 till 2010. The foregone income by the waste pickers who lose their jobs as a result of a particular policy are taken into account. Also the income of the formal recovery worker who enters the sector in a Western collection system is included in the analysis. The most unequal income distribution is noted by the value 0.843 and the most equal distribution has a value of 0.760.

The informal policy scenarios are characterised by increasing inequality of income distribution. This is the caused by the relatively decreasing employment of the waste pickers while the wealthy traders become more important. For the Western policy, income distribution moves in the opposite direction. The sudden decrease of these distribution curves is typical. This marks the entry of the formal collection workers in the labour market. Compared to the waste pickers, these workers are relatively well paid. Therefore the development path of the Western policy lies below the baseline scenario which indicates less income inequality. In appendix 5, an explanation is given for the Gini concentration ratio.

Figure 4.11 Income inequality in the waste paper collection sector with varying public responses (1993-2010)

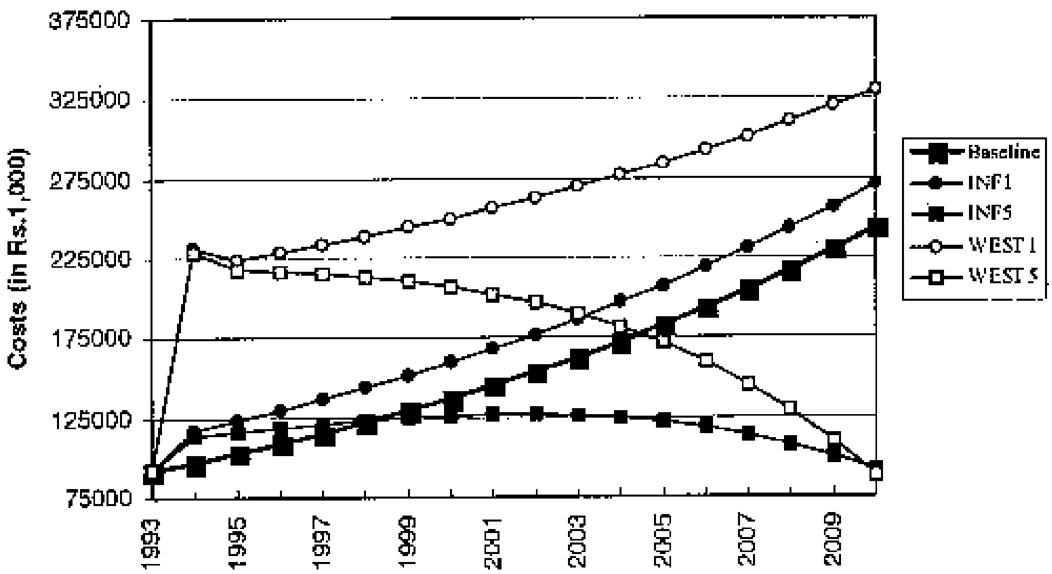


Public costs

Figure 4.12 depicts the developments in public costs in the waste paper collection cycle with varying public responses for the period 1993 till 2010. The scenario with the least public costs is indicated by a score of Rs.7.6 million and the most costly situation implies public costs of Rs.32.6 million in 2010. The baseline scenario curve indicates that without policy, public costs will increase continuously in the future. These costs are caused by greater waste collection and landfilling efforts. Yet, a few scenarios lead to higher public costs than the baseline development. These cases are characterised by low public response. Although efforts are made to reduce the amount of disposed waste, no significant reduction is felt in terms of landfilling. Nor does the Western collection system generate sufficient income from collected waste paper.

Another striking feature in Figure 4.12 is the sudden increase of the public costs with the introduction of a Western collection system in 1993/94. Obviously, the initial investment is much higher than for the informal policy where efforts are mainly focused at the encouragement of separation through campaign. A complex and voluminous infrastructure must be set up and maintained. The formal policy can therefore only be successful under conditions of maximum public response. This is illustrated by the curve "West 5" which reaches a public cost level of Rs.7.6 million in the year 2010. One should realise however that the informal policy reaches its break even point in a much earlier stage, under the condition of a public response parameter (α) exceeding zero. Thus, the net present value of the informal policy is higher than that for the formal policy, despite the fact that with maximum response the formal policy scores better in 2010. Especially if the model accounts for the potential tax payments by the informal sector, this policy turns out to be much more favourable than a Western collection system. To illustrate how these results can be interpreted from a policy perspective, an evaluation model is presented.

Figure 4.12 Public costs in the waste paper collection sector with varying public responses (1993-2010)



The evaluation model

The main purpose of the evaluation model is to select one alternative on the basis of its overall value score. This "weighed additive value function approach" involves several steps (Keeney 1992). First, the separate evaluation criteria need to be aggregated over time. Second, value functions are applied which associate a value between 0 and 1 with each criteria score in the range. The 0 and 1 values represent respectively the worst and best situations considered. This normalisation step facilitates comparison between the different discounted evaluation criteria. Finally, hypothetical weights are attached to combine the separate evaluation values into a single score. The outcome of this analysis is depicted in table 4.3, and an explanation of this table is given below.

Table 4.3 Discounted scores of the separate and combined criteria

	Public Costs	Total Employment	Environmental effect	Income distribution	Average value*	Overal rank
Baseline	0.82	0.83	0.06	0.68	0.599	6
INF1	0.66	0.83	0.06	0.68	0.557	7
INF2	0.73	1.00	0.26	0.52	0.627	5
INF3	0.81	0.90	0.48	0.34	0.632	4
INF4	0.90	0.85	0.72	0.16	0.659	3
INF5	1.00	0.78	1.00	0.00	0.694	1
WEST1	0.00	0.05	0.00	0.92	0.243	11
WEST2	0.07	0.00	0.08	0.95	0.275	10
WEST3	0.22	0.23	0.39	0.99	0.457	9
WEST4	0.31	0.35	0.60	0.98	0.560	8
WEST5	0.45	0.45	0.86	1.00	0.688	2

* *Equal weighs for criteria*

For the aggregation of the evaluation criteria over time, different approaches are followed, ranging from discounting to simple summation. Because of its monetary nature it is legitimate to discount the public costs over the period 1993-2010. Using a 10% discount rate (Hadker *et al.* 1995), the lowest present value is reported for the scenario "Inf 5". In this scenario, the additional public investments for increasing recovery are limited while at the same time the avoided costs for the municipality are at its maximum as a result of the high recovery of waste by the public. Sensitivity analysis shows that the "public cost" ranking order is not very receptive for the discount rate selected. Only with a discount rate smaller than 2% "West 5" dominates the result of "Inf 1", because the former scenario generates significant revenues in the future. The conclusion for public costs criteria is therefore that the introduction of Western recycling system is by no means a costs saving solution. With the informal recovery policy, public cost reduction will already be achieved if the societal response leads to an annual recovery rate growth (α) of more than 1%. Such conditions are not ambiguous in most large cities in India.

For employment, the employment levels over the period are aggregated. Two conclusions can be drawn from the ranking. First, it is clear that the Western policy generates much less employment than the informal policy. This is mainly caused by crowding out of the informal sector. Yet, if the response of the public is positive the formal employment will gradually increase because the labour intensity of Western recovery is higher than landfilling. As a result, in scenario "West 5" the level of employment eventually exceeds the level of scenario "Inf 5". For the informal policy, an adverse relation between employment and response exists. The more successful the recycling campaign, the less employment is generated. More and more waste pickers will lose their employment as households start separating their waste and sell it directly to the informal traders. Recyclable materials become harder to find in the municipal waste. Typically, scenarios "Inf 2, 3 and 4" score better averages than the baseline because the extra employment gained in waste trade exceeds the employment lost in landfilling and waste picking.

Environmental impact is ranked based on annual averages. The relation between response and environmental impact is very strong. Regardless of the type of policy, higher public response leads to lower environmental impact. Therefore, formal and informal policies score alternately in the environmental impact criteria. The best score is registered for the informal policy because this scenario is less transport intensive than the Western policy.

Income distribution is ranked on annual averages. As in the case of employment analysis, the response rate has an adverse impact on income distribution for respectively the formal and the informal policy. For the latter policy, a high response leads to higher income inequality because the income of the relatively wealthy traders will increase additionally. Note that the waste pickers become unemployed as a result of a successful campaign. The Western recycling policy generates more formal employment if the response is high, while at the same time the informal traders are by-passed. Therefore, scenario "West 5" scores best for income distribution.

In order to determine which scenario or policy alternative has the best overall score, the objectives of the involved decision maker are specified by attaching weights to each of the separate evaluation criteria (Beinaut 1996). These weights represent the relative importance of one criteria compared to the other. By incorporating weights, the utility function can be written as:

$$U(Y) = w_e U(Y_e) + w_i U(Y_i) + w_p U(Y_p) + w_y U(Y_y)$$

where weights are indicated by w_x, x = e, i, p, y, and are normalised to add up to 1. Generally, weights can be determined from opinion polls and or expert judgements. This is beyond the scope of this project. Therefore, for illustrative purposes, a combined score based on equal weights of the various evaluation criteria is composed. The results are presented in the last two columns of table 4.3. Obviously, this illustration provides an inappropriate representation of the preferences of policy makers from metropolises in India. In most cases, public costs will be a more binding criteria than for example income distribution. Also employment may probably be considered more important than the environmental impact of the different scenarios. A survey among policy makers who decide on waste management could reveal the correct weights. Nevertheless, the column "overall ranking" is helpful in demonstrating that there is not one particular policy which dominates the others. "West 5" owes its second rank to its beneficial income distribution and the environmental characteristics. However, in general, the informal policy option scores better. Therefore, policy makers in developing cities should be reluctant to introduce a Western collection system unless they are sure about a significant positive response of the public. The change that the public in developing countries is anxious to voluntarily separate their waste without financial compensation is probably small. Therefore, it seems better to do nothing (baseline) than to initiate a Western recovery system. Promoting informal recovery does seem to be a cost-effective policy in most cases. Unfortunately, this is rarely performed in developing cities.

4.7 Conclusions

With growing urbanisation and increasing per capita consumption, waste is becoming an urgent societal problem in many developing cities. Given the composition of the disposed waste, the solution to this issue will mainly lie in the choice between recycling and landfilling. So far, efforts for improvement in developing countries have mainly been focused at the last management option. However, as is theoretically illustrated in sections 4.2, the potential for solving the waste problem through enhancing recovery activities certainly deserves more attention. The local governments can play an important role in this process by initiating appropriate recovery policies. In this paper, the question is addressed whether this enhancement should follow the Western approach of recycling development or whether an alternative "informal" policy would be more appropriate. For this purpose a case study was performed on the waste paper collection in Mumbai, taking into account both the formal and informal sector. Indirectly, this analysis can also be applied to the problem of crowding out the informal sector by simulating an increase in the imports of waste paper. In this section, conclusions are drawn with regard to the economic, social and environmental dimensions of these questions.

Recovery of recyclable waste in Mumbai is an activity which at present is mainly performed by the informal sector. Government agencies are practically absent in this respect. The largest group in the informal sector are the waste pickers. Partly as a result of increased attention of the media, this group is generally seen as the figure-head of recycling in developing countries. Therefore, one would think that what is good for the waste picker is also good for the recycling sector. This notion is not completely true. Waste pickers are dependent on the recyclable waste which is discarded by households and institutions. Policies aimed at improving waste recovery at the source will therefore have a negative impact on the activities by waste pickers. This dependency implies a trade-off between social costs on the one hand and economic and environmental gains at the other. Waste pickers are dependent on inefficiencies of society. Yet social advantages also accrue with improved recovery of waste. The increased unemployment among waste pickers can be compensated for by the growth in labour demand by the expanding waste trading network and recycling industries. Another social advantage is that waste pickers do not have to perform unhealthy work which has a low status, although obviously having no job is a worse alternative. An important lesson from this distinctive relationship is that NGO's and policy makers should not restrict their view to the well-being and functioning of the waste pickers, but expand their present perspective.

Another important group are the generators of recyclable waste, such as the households, the institutions and factories. The sooner the separation of recyclable materials from the main waste stream occurs, the better it is. This will prevent unnecessary contamination and damaging of valuable secondary resources. Also, in the case of separation at the source, social benefits can be achieved as it are often the poorer servants and caretakers which gain from this process. Obviously environment is the better off because the process of *entropy* of resources is diminished, and less waste is landfilled or burned. In fact, source separation also facilitates a higher degree of re-use, which is certainly placed high at the waste management hierarchy, and helps to upgrade the low quality of waste paper for the paper industry. The main question is how separation at the source should be promoted and how the public will respond to such policies.

A link in the informal recovery sector which receives only limited attention are the buyers and the wholesalers of recyclable waste. This trade network forms a solid foundation for the improvement of the recovery rate. Replacement of this informal network with a Western collection system may have devastating effects. Fortunately, examples of such inconsiderate government interventions are rather scarce. Still, some municipalities in developing cities seriously consider the incorporation of expensive source separation systems. Given the current levels of poverty, such Western systems which depend heavily on "consumer volunteerism" are bound to fail. Nevertheless, the municipal attitudes towards the informal recycling are discouraging. "The municipal officers support the concept of recycling, but their plans are at the level of installing composting plants and generating energy from waste" (Ali *et al.* 1993).

The simulation and evaluation models which were developed for the waste paper collection sector in Mumbai enabled the analysis and evaluation of the introduction of two types of policies: a Western collection system and an "informal" policy scenario. Also an explanation is provided for the development path without policy intervention. The wide range of responsiveness of the public to the policies illustrates the importance of this parameter which is generally not taken into account sufficiently in waste management policy decisions. In most scenarios, the "informal" policy of encouraging the public to separate their waste and market it personally to the informal network, appears to be the better option. The Western collection system can only be successful if *voluntarism* is appreciable in developing cities. Given the relatively high level of poverty in most urban areas, it can be expected that consumers prefer to sell their waste to the informal network instead of supplying it free to the formal collectors. Other policy options such as securing waste prices, or subsidising the informal sector were not analysed because of the impossibility to enforce such policies in an unregistered sector.

Finally, the question of what the effects are on the informal waste collection sector if the import of recyclable waste increases is addressed. The disadvantage of a market driven sector is the vulnerability to price fluctuations. Most local waste traders have sufficient margins in their trade to survive a recession. The most vulnerable group in the informal sector is the waste picker and the IWB who operate at subsistence level. Given the importance of these actors in the current system, a decrease in the price of waste might lead to significant damage in the recovery rate of recyclable waste. Not only can this result in a shortage of raw materials for the recycling industry, it also increases the solid waste burden in developing cities. This is another argument to improve the current system and reduce its vulnerability to price fluctuations. Encouraging consumers to sell their waste directly to the informal waste sector is a way of achieving this. Consumers will not be as sensitive to price fluctuations as waste pickers because their total livelihood does not depend on it. This question is addressed in the following chapter.

This chapter focused predominantly on policies which directly address recovery of recyclable waste in developing countries. It is concluded that local governments can improve this process provided their policies build on the existing trade-networks and take into account the prevailing market forces. Only then can recovery rates increase which subsequently reduce landfill costs. Yet, besides policies which directly focus on the supply of recyclable waste, indirect policies stimulating local demand for secondary materials can be regarded as important tools. These demand policies, such as providing financial incentives to industries to use more recyclables or designing government procurement specification to allow recyclable content, and can have similar positive effects on recovery rates as direct supply-oriented policies.

Appendix 1

SET OF EQUATIONS

I. The Basic Model

$X_t = \sum_j x_{j,t}$ $j = s, b, l, u, w, r$

$X_t = X_{t-1}\,(1 + \mu)$ $X_1 = 204{,}000;\ \mu = 0.0591$

$r_{j,t} = x_{j,t} / X_t$

$r_{s,t} + r_{b,t} + r_{l,t} = R_{L,t}$

$r_{u,t} + r_{r,t} + r_{w,t} = R_{R,t}$ determines $r_{r,t}$

$R_{L,t} + R_{R,t} = 1$

$R_{R,t} = R_{R,t-1}\,(1 + \alpha)$ $R_{R,1} = 0.35$; for α see below

$r_{s,t} = 0.1$

$r_{b,t} = 0.1$

$r_{u,t} = r_{u,t-1}\,(1 + \tau)$ $r_{u,t} = 0.10;\ \tau = -0.04$

$r_{w,t} = r_{w,t}\,(1 + \alpha)$ for $t > 2$, $r_{w,1} = 0.05;\ r_{w,2} = 0.10$

II. Employment

$E_t = E_{f,t} + E_{inf,t}$

$E_{f,t} = e_{l,t} + e_{w,t}$

$E_{inf,t} = e_{wp,t} + e_{iwb,t} + e_{be,t} + e_{we,t} + e_{bu,t} + e_{wh,t}$

$e_{a,t} = q_{a,t} / \varepsilon_a$ $a = l, w, wp, iwb, bu, wh$

$e_{e,t} = 1.2\ e_{bu,t} + 7.3\ e_{wh,t}$ $e = be, we$

$q_{l,t} = x_{l,t}$

$q_{w,t} = x_{w,t}$

$q_{wp,t} = s^z_{wp,t}\,(x_{u,t} + x_{r,t})$ $s^z_{wp,1} = 0.41$

$q_{iwb,t} = s^z_{iwb,t}\,(x_{u,t} + x_{r,t})$ $s^z_{iwb,1} = 0.03$

$q_{rest,t} = s^z_{rest,t}\,(x_{u,t} + x_{r,t})$ $s^z_{rest,1} = 0.56$

$q_{bu,t} = s^x_{bu,t}\,(q_{wp,t} + q_{iwb,t} + q_{rest,t})$ $s^x_{bu,1} = 0.24$

$q_{wh,t} = s^x_{wh,t}\,(q_{wp,t} + q_{iwb,t} + q_{rest,t})$ $s^x_{wh,1} = 0.76$

$s^z_{wp,t} + s^z_{iwb,t} + s^z_{rest,t} = 1$

$s^x_{bu,t} + s^x_{wh,t} = 1$

$s^i_{a,t} = s^i_{a,t-1}\,(1 + \eta_a)$ a = l,w,wp,iwb,bu,wh,rest; for η_a see below

III. Environment

$I_t = i_{b,t} + i_{l,t} + i_{tr,t}$

$i_{b,t} = \phi_b \cdot x_{b,t}$

$i_{l,t} = \phi_l \cdot x_{l,t}$

$i_{tr,t} = \phi_t\,(x_{u,t} \cdot d_{u,t} + x_{r,t} \cdot d_{r,t} + x_{w,t} \cdot d_{w,t} + x_{l,t} \cdot d_{l,t})$ $d_{u,1}=15;\ d_{r,1}= 50;\ d_{w,1}= 75;\ d_{l,1}=20$

$d_{j,t} = d_{j,t-1}(1 + \beta)$ $j = u,r,w,l;\ \beta = 0.021$

IV. Public Costs

$C_t = c_{l,t} + c_{inf,t} + c_{f,t}$

$c_{l,t} = 998\ x_{l,t}$

$c_{inf,t} = c_{inf,t-1}(1 + \Omega)$ $c_{inf,1} = 20{,}000;\ \Omega = 0.02$

$c_{f,t} = 145{,}669 - 1080\ x_{w,t}$

V. Income Distribution

$\gamma_t = \int A / \int(A+B)$ for A and B see below

$\int A = \int(A+B) - \int B$

$\int B = \sum_{a=1}^{9} e_{a,t} \{ \sum_{b=1}^{a-1} y_{b,t} + 0.5 \cdot y_{a,t} \}$ a = eu,wp,iwb,we,l,w,bu,wu

b = eu,wp,iwb,we,l,w,bu,wu

$\int(A+B) = 0.5 \cdot \{ \sum_{a=1}^{9} e_{a,t} \cdot \sum_{a=1}^{9} y_{a,t} \}$ a = eu,wp,iwb,we,l,w,bu,wu

$y_{a,t} = e_{a,t} \cdot w_a$ a = eu,wp,iwb,we,l,w,bu,wu

Table 4.4 Parameters values for different scenarios

	Base-line	Informal Policy					Formal Policy				
		Inf1	Inf2	Inf3	Inf4	Inf5	West1	West2	West3	West4	West5
α*	0.00	0.00	0.01	0.02	0.03	0.04	0.00	0.01	0.02	0.03	0.04
η_{wp}**	0.00000	0.00000	-0.00140	-0.02190	-0.03760	0.05270	-0.00750	-0.00750	-0.00750	-0.00750	-0.00750
η_{iwb}**	0.00000	0.00000	0.01000	0.01750	0.02500	0.03000	0.00000	0.00000	0.00000	0.00000	0.00000
η_{rest}**	0.00000	0.00000	0.01000	0.01750	0.02500	0.03000	0.00500	0.00500	0.00500	0.00500	0.00500
η_{bu}**	-0.00580	-0.00580	0.00000	0.00530	0.01020	0.01470	-0.01230	-0.01960	-0.02790	-0.03770	-0.04950
η_{wh}**	0.00173	0.00173	0.00000	-0.00178	-0.00359	-0.00546	0.00343	0.00510	0.00673	0.00833	0.00991

* α is the annual growth rate of the overall recovery rate

** η_a is the annual growth rate of the share of actor a in the supply or trade of waste paper

SYMBOL DEFINITIONS

Meaning of Variables

X_t		total paper consumption
$R_{j,t}$	j = R,L	process categories
$r_{j,t}$	j=s,b,l,u,w,r	process rates
$x_{j,t}$	j=s,b,l,u,w,r	process quantities
E_t		total employment
$E_{j,t}$	j=inf,f	employment per worker group
$e_{a,t}$	a=l,w,wp,iwb,be,we,bu,wh	employment per sub-worker group
$q_{a,t}$	a=l,w,wp,iwb,be,we,bu,wh	quantity of waste paper per sub-worker group
ε_a	a=l,w,wp,iwb,be,we,bu,wh	productivity per worker in sub-worker group
$s^s_{a,t}$	a=l,w,wp,iwb,bu,wh; s=z,x	share of sub-worker group in worker process s
I_t		total environmental impact
$i_{j,t}$	j=b,l,tr	environmental impact of processes
$d_{j,t}$	j=u,r,w,l	distance of related to process
C_t		total public costs
$c_{j,t}$	j=r,inf,f	public cost of policies
γ_t		Gini coefficient
$y_{a,t}$	a=ue,l,w,wp,iwb,be,we,bu,wh	income of work group
$y_{b,t}$	b=ue,l,w,wp,iwb,be,we,bu,wh	income of work group
$e_{a,t}$	a=ue,l,w,wp,iwb,be,we,bu,wh	labour years of work group
w_a	a=ue,l,w,wp,iwb,be,we,bu,wh	wages of the actors in the work group

Meaning of Indices

	t:	time
Categories (R)	L:	"diverted from cycle"
	$\bar{R}$:	recovered
Processes (x,r)	s:	storage
	b:	burning
	l:	landfilling
	u:	re-use
	w:	formal "Western" recycling
	r:	informal recycling
Worker group (E)	f:	formal
	inf:	informal
Sub-worker group (e)	l:	landfill
	w:	formal recovery
	wp:	waste pickers
	iwb:	itinerant waste buyers
	bu:	buyers
	wh:	wholesalers
	rest:	households, institutions, factories
Worker process (s)	z:	source seperation
	x:	waste paper trade
Process activity (i)	b:	burning
	tr:	transport
	l:	landfilling
Policy (c)	l:	regular landfilling
	inf:	promote informal recovery
	f:	promote formal recovery
Income actors (y,e)	ue:	unemployed workers
	wp:	waste pickers
	be:	employees of the buyers
	iwb:	itinerant waste buyers
	we:	employees of the wholesalers
	l:	landfill
	w:	formal recovery
	bu:	buyers
	wh:	wholesalers

Appendix 2

Environmental indices

The environmental impact of each process is expressed by an index. The following steps should be followed:

The first step is to build an *eco-balance* for each relevant process (e.g., transport, burning, landfilling) based upon an inventory of environmentally-relevant inputs (e.g., energy) and outputs (e.g., air emissions, solid waste). The fuel use in landfilling comes from the bulldozer operations. Table 4.5 depicts the inputs/outputs, related to the relevant processes linked to 1 tonne of waste paper.

Table 4.5 Eco-balances

Transport by Diesel Truck in India (per km/ton waste paper)					
Input	Unit		Output	Unit	
Energy	MJ	1.3379	Particles	kg	0.001259
			CO_2	kg	0.116476
			CO	kg	0.000626
			HC	kg	0.000313
			NOx	kg	0.001566
Fuel oil (light)	*kg*	*0.03148*	SO_2	kg	0.001259

Burning Waste Paper (per ton waste paper)					
Input	Unit		Output	Unit	
Waste paper	kg	1,000	Solid waste	kg	55.87609
			CO_2	kg	939.624
			CO	kg	1.39999
			VOC	kg	0.299334
			NOx	kg	1.500028
			SO_2	kg	1.300009

Landfilling of Waste Paper in India (per ton waste paper)					
Input	unit		Output	Unit	
Waste paper	kg	1,000	Particles	kg	0.0012592
Energy	MJ	1.3379	CO_2	kg	142.35658
			CH_4	kg	51.767331
			NOx	kg	0.00156613
			HC	kg	0.00031323
			SO_2	kg	1.300009
			CO	kg	0.00062645
			VOC	kg	0.299334
			Organic matter	kg	751.22513
Fuel oil (light)	*kg*	*0.03148*	Solid waste	kg	55.87609

Source: compiled from Weaver et al. 1995, Virtanen and Nilsson 1993

The second step is to prepare an *eco-profile* from the *eco-balances*. The significance of the different inputs and outputs depends upon their contribution to environmental damage. There are seven environmental problems which are relevant to the pulp and paper industry: global warming, photochemical oxidation, acidification, nutrification, and solid waste. The Centre of Environmental Studies in Leiden provides a scoring matrix which indicates the relative contribution of different emissions to each of these environmental problems (CML, 1992). This provides the basis for deriving an *effect-score* for each process in respect to each problem. Effect scores are normalized over global levels of emissions (Guinee, 1995) to provide an eco-profile for the process. The normalisation process converts the emissions into relative contributions to environmental problems by dividing the effect scores by the total extent of the relevant effect scores for a certain area and a certain period of time. The total extent of the relevant effect scores are applied on a global scale and are derived from Weaver *et al.* 1995.

The third step is to assign weights to the different kinds of problems to reflect their differing importance to society. Weaver *et al* attach equal weights to the various problems. Whether the same weights should be applied for the Mumbai waste paper cycle is not clear. From the perspective of the munipality, the weight for climate change is probably lower than, for instance, solid waste. Yet, from a national perspective this weight configuration is likely to be different. Since all processes are described in unit terms (e.g., per tonne of product), the *environmental index* is also a unit-based index. The metric is dimensionless and consistent so that the index can be used to develop an environmental objective function. The results of the eco-profile and normalization are given in table 4.6 for the various environmental problems.

Table 4.6 Eco-profiles and indices

Environmental impacts normalised with world score for KT*(1.0 E-9)	Global Warming	Human Tox.	Ecological Tox.	Photochemical Oxydation	Acidification	Nutrification	Solid Waste	Average env. index
	3.80E+13	5.80E+11	1.10E+14	3.70E+11	2.90E+11	7.50E+10	1.60E+12	(equal weights)
Transport	0.00307	0.00906	0.00000	0.17679	0.00812	0.00271	0.00000	**0.02850**
Burning	24.72696	4.73586	0.00000	0.00000	8.10345	2.60000	34.92255	**10.72700**
Landfilling	18.73151	0.00906	0.00000	0.17679	0.00812	0.00271	34.92255	**7.69300**

Source: Compiled from Weaver et al. 1995, Nilsson and Virtanen 1993, Rao 1989.

Appendix 3

Figure 4.13 nvironmental Impact in Baseline Scenario

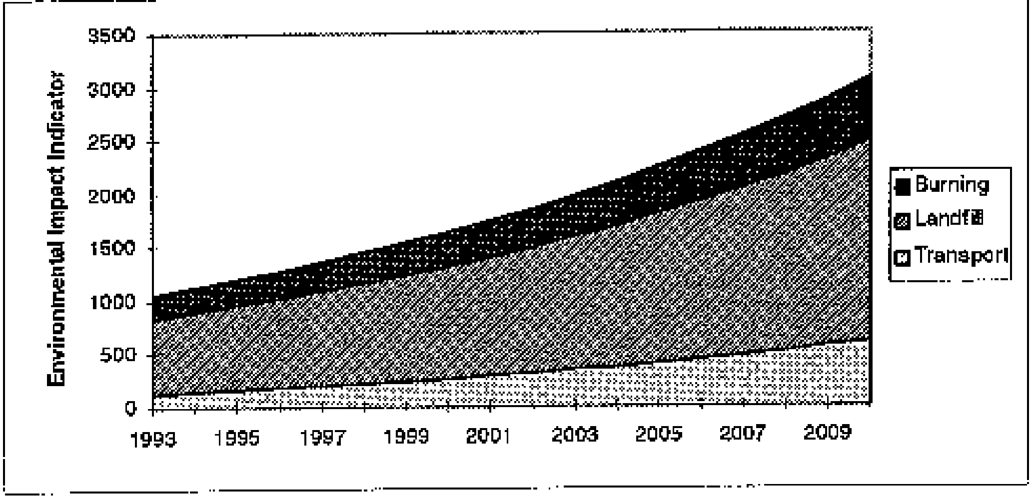


Figure 4.14 Evironmental Impact with Informal Policy and high response

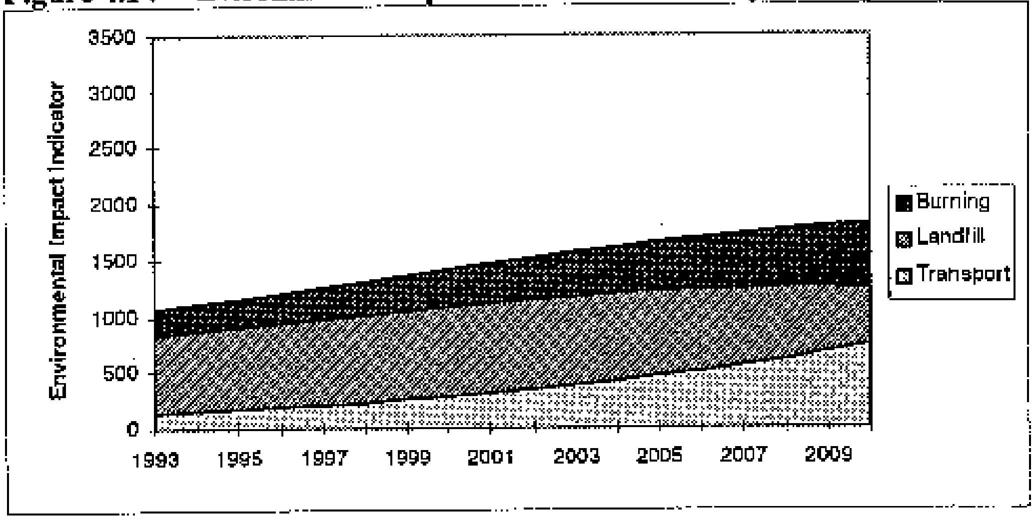
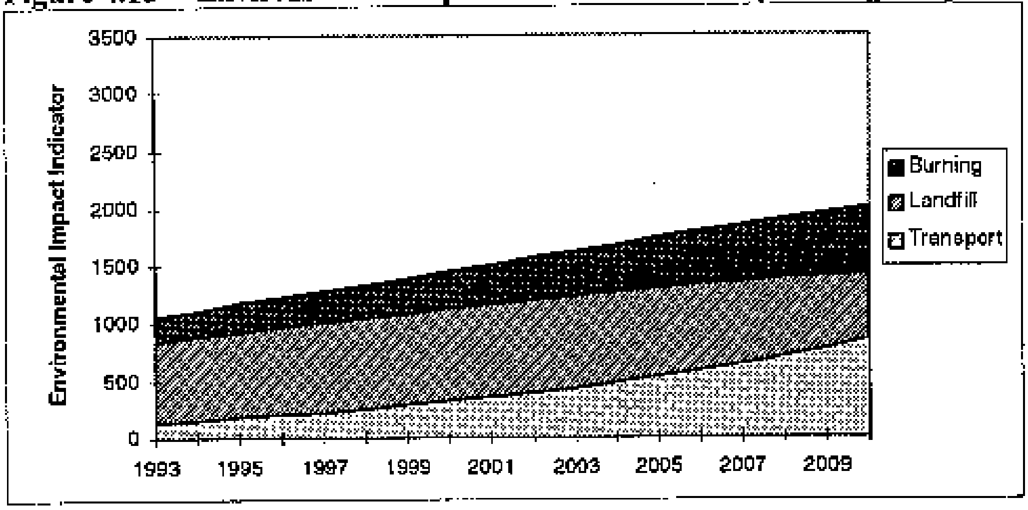


Figure 4.15 Environmental Impact with Western Policy and high response



Appendix 4

Table 4.7 Labour distribution in the "baseline", the "informal", and the Western policy scenario with maximum public response in 2010.

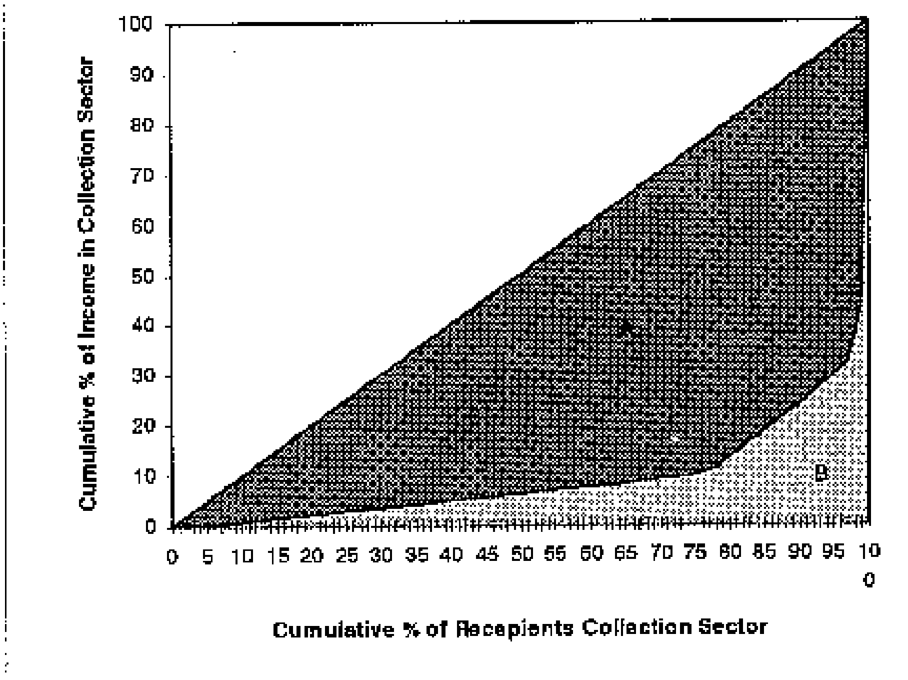
	Baseline		West 5		Informal 5	
	number	share	number	share	number	share
unemployed waste pickers	0	0.000	974	0.039	5233	0.180
waste pickers	18462	0.708	17487	0.708	13229	0.454
buyer employees	965	0.037	542	0.022	2714	0.093
IWBs	364	0.014	205	0.008	1694	0.058
wholesaler employees	1291	0.050	1631	0.066	2515	0.086
disposal workers	3993	0.153	1195	0.048	1049	0.036
formal recovery workers	0	0.000	1981	0.080	0	0.000
buyers	830	0.032	466	0.019	2336	0.080
wholesalers	182	0.007	230	0.009	355	0.012
Total	**26088**	**1.000**	**24711**	**1.000**	**29126**	**1.000**

Appendix 5

Gini-coefficient

The most common method for calculating income distribution is the Lorenz curve, which is illustrated in Figure 4.26. To draw a Lorenz curve, income recipients are ranked from the lowest income to the highest along the horizontal axis. The Lorenz itself shows the percentage of income accounted for by any cumulative percentage of recipients. The shape of this curve indicates the degree of inequality in the income distribution (Gillis *et al.* 1987). The curve must by definition touch the 45° line at the lower left corner (zero per cent of recipients must receive zero per cent of income) and at the upper right corner (100 percent of recipients must receive 100 % income). If all recipients had the same income, the Lorenz curve would lie along the 45° line (perfect equality). The inequality of the distribution curve is indicated by how far it bends away from the 45° line of perfect equality (the greater the shaded area A, the greater is inequality). The Gini concentration ratio is the value of area A divided by A plus B in Figure 4.16.

Figure 4.16 Lorenz curve for the Western policy with high public response



Chapter 5.

INPUT SUBSTITUTION IN THE INDIAN PAPER INDUSTRY

K.V. Ramaswamy
R.R. Vaidya
M.J. Bennis
J.G.M. Hoogeveen

5.1 Introduction

In analyzing the impact of international trade (and related policies) in waste paper on the local use and recycling of waste paper in India, the substitutability between the two types of inputs by the main users of waste paper, that is, the paper industry, is of critical importance. This is important in view of the uncertainty regarding future prices and availability of domestic forest raw materials and imported pulp. Prices of both imported waste paper and pulp have risen sharply in recent years as noted in Chapter 2.

To shed light on the issue of substitutability a survey was conducted in February-March 1995 amongst paper mills in Gujarat and Maharashtra. The aim of the survey was to collect cross section data for firms which use waste paper as the primary material input data from a cross-section of firms. This would serve as a basis not only for the estimation of elasticities of substitution and but also of price elasticities of (derived) demand. In addition, the collected data serve as a base for the determination of the Material Flow Model in Chapter 6.

This Chapter presents the results of this survey and the outcomes of the estimation of a variable cost production function. From these results the elasticities of substitution between imported and domestic waste paper are calculated, and also the price and cross elasticities of raw materials, labour and energy.

The Chapter is organized as follows. Section 5.2 presents a short description of the survey results. In section 5.3 the theoretical framework for the estimations is sketched, followed by their operationalisation in section 5.4. The empirical results are presented in section 5.5 after which conclusions are drawn in section 5.6.

5.2 The survey

5.2.1 Sample selection

A total of 70 paper mills have been visited for conducting the survey. Eventually 68 interviews were found sufficiently complete to be entered in a computerized data file. It was decided to select paper mills within the 700 km region around Mumbai as it is India's most important point of entry of imported waste paper. Within this area mills were selected randomly from an updated list of paper mills in the area constructed by the interview team.

Selected mills had to fulfill four criteria:

1. The mill must have been running at the time of the appointment.
2. The mill must have been using non-conventional (waste paper or agricultural residues) inputs.
3. The owner of the mill must have not been interviewed before.
4. The interview could be fixed on short notice.

The exclusion of wood based paper mills implies that the results are not representative for the whole paper sector. This limitation is only a minor drawback in view of the objective of this project: to evaluate the environmental and economic impact of international trade in waste paper. In addition, the results only hold for the Maharashtra and Gujarat region and not for the whole of India, though it can be argued that results will also hold elsewhere as waste paper mills are generally located in or near large cities.

5.2.2 Sample description

All 68 mills in the sample but one used waste paper in the production process. Eight mills indicated the use of agricultural inputs (of which one only used agricultural inputs). Two thirds of all mills (41) used imported waste paper. The main reason (40) to use imported waste paper is its quality (fibre strength), followed by the fact (21) that the required type of waste paper is not available locally, or that local supply is insufficient (17). Though only eight mills used agricultural inputs, thirty indicated that they were technically capable of processing agricultural residues. In eight mills wood or bamboo could be applied.

All mills were established between 1932 and 1994. Their average age is 15 years, while the average age of equipment is estimated at 11.6 years. This figure lies below the average age of the mills because most mills invested in the upgrading of their machinery or the expansion of their capacity. The paper mills show the effects of India's import substitution strategy. Most equipment purchased at start-up was produced in India (78%). Especially the most recently started mills used Indian equipment.

The selected mills are small in comparison to European or American mills. The average annual production of 6700 tons per annum is very small compared to the 100.000 tons / annum realized in USA/EU (Ewing 1985). The average yearly turnover is 101 million rupees. With regard to their output, the paper mills visited are hardly diversified. The majority (43) produce one type of paper, usually kraft paper in different grades (burst factors). Fifteen mills produce two types of paper, and five mills indicated having three or more main products. Table 5.1 provides an overview of the types of paper produced.

Table 5.1 Main types of paper produced

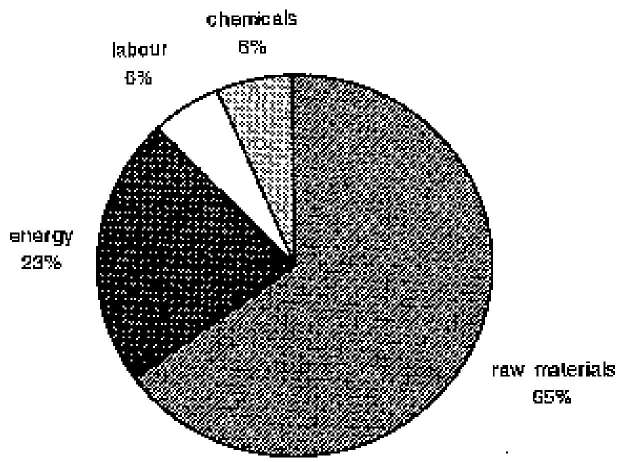
Type of paper	Observations
Kraft	42
Duplex board	5
(Other) boards	8
Newsprint	3
Writing and printing	6
Others	4
TOTAL	68

The equipment used in the paper mills is technologically not advanced. This is not only reflected by the age of the equipment and the small size of the factories but also by the types of paper most mills produce. The popularity of kraft paper among paper mills can be partly explained by the ease with which the product can be produced in comparison to writing and printing paper or duplex board.

The mills, who usually operate round the clock employ as permanent workforce between 20 and 750 people, usually men, with an average of 137 (excluding the owners). Women are rarely employed in this sector. If at all they work, then only as clerical staff, unskilled production workers or casual labourers sorting waste paper. Casual labourers are employed in nearly half the mills (33), at an average of 38 persons.

The variable production costs contain four main categories: raw materials (waste paper, agricultural inputs and wood pulp), chemicals (chlorine, rosin, soda, alum), labour and energy. The costs associated with this categories are variable on the level of production. Figure 5.1 presents the distribution of variable production costs. On an average, these costs account for 80 % of the sales price.

Figure 5.1 Distribution of variable paper production costs



The aim of the analysis in this paper is the determination of cross elasticities between different inputs and in particular the cross elasticity between imported and domestic waste paper. To this end only those firms are included in the estimation that use both imported and domestic waste paper. Of the 41 mills that use imported waste paper, one uses solely imported waste. Hence 40 mills remain in the sample.

In the estimations capital has been measured as the replacement value of the current mill. In some cases this value had to be constructed using other relevant information provided by the firm. This could be information on:

1. Cost of establishing/acquiring the mill.
2. Year of establishing the firm.
3. Age of the equipment at start up.
4. Total investments since start-up.
5. Age of the equipment at present.
6. Bookvalue of land, buildings and equipment, and
7. Market value of the firm.

Several energy sources were identified during the field survey. These were converted to joule equivalents, using the following conversion factors:

Table 5.2 Main types of Energy Sources

Energy source	Conversion factor (in millions KJ)
Coal (kg)	29
Electricity (kWh)	3.6
Natural Gas (m3)	30
Wood (kg)	16
Oil (l)	33

The price of materials is calculated as weighted average of the price of domestic and imported waste paper whereby the weights are the shares of the values of domestic and imported waste in the total material value.

Table 5.3 Variables used in econometric analysis

	Mean	Standard deviation	Maximum	Minimum
Capital (million Rs)	125	220	1140	7.5
Wage (Rs/employee/year)	26629	7690	44000	13817
Price of imported waste (Rs/ton)	9182	2434	17000	5500
Quantity of imported waste (ton/year)	4311	3618	15188	151
Value of imported waste (million Rs/year)	37.9	30.9	120.8	1.8
Price of domestic waste (Rs/ton)	5415	1427	11000	2000
Quantity of domestic waste (ton/year)	5141	3056	14532	948
Value of domestic waste (million Rs/year)	27.9	17.1	79.9	4.5
Value of materials (million Rs/year)	65.9	41.1	146.9	13.2
Price of materials (Rs/ton)	7393	1888	14029	4445
Price of energy (Rs/million KJ)	0.15	0.05	0.34	0.08
Energy costs (million Rs/year)	21.6	20.1	94.9	3.9
Total variable production costs (TVPC)	93.1	57.6	236	18.5
Share of labour in TVPC	0.06	0.04	0.22	0.02
Share of imported waste in TVPC	0.37	0.16	0.66	0.07
Share of domestic waste in TVPC	0.34	0.14	0.67	0.03
Share of energy in TVPC	0.23	0.09	0.56	0.13
Share of materials in TVPC	0.71	0.13	0.88	0.29
Share of imported waste in materials	0.51	0.19	0.96	0.11
Share of domestic waste in materials	0.49	0.21	0.95	0.04

5.3 The theoretical framework

The estimation of elasticities of substitution and (derived) input demand is an exercise in applied production analysis. The conceptual framework is briefly explained below. For further details see Chambers 1988.

Given the technology, producers make decisions regarding the use of inputs based on the technical possibilities embodied in the production function and on relative input prices. The concept of production function is used to represent the technical relationships between maximum output and a set of inputs, given the state of technology. A specific functional form for the production function is assumed. The parameters of this function provide information on important characteristics of the technology, namely, elasticity of scale and elasticity of substitution. Elasticity of scale measures the proportional change in output due to a proportional change in all inputs.

The concept of elasticity of substitution measures the ease of substitutability between two inputs with constant output.

As an example, consider the well known Cobb Douglas production function:

$$Q = AK^aL^b,\ A > 0,\ a > 0,\ b < 1$$

where Q is output, K is capital and L is labour input and A is referred to as an efficiency parameter. It can be shown that a and b are parameters representing partial output elasticities of capital and labour and their sum (a + b) measures the elasticity of scale. The elasticity of substitution is unity for the above function. The implication is that all factors are "equally substitutable" with each other. Consequently the share of factors in total cost remains constant for all firms in the industry. This is a restrictive assumption.

In this chapter the cost function is specified as the translog (or transcendental logarithmic) form. The translog cost function is a flexible functional form. It is flexible in the sense that it imposes few restrictions on the scale and substitution properties of the technology. In contrast to the Cobb-Douglas functions, the estimated elasticities of substitution can now be different for each firm in an industry.

Direct estimation of a production function has several disadvantages. Note that the explanatory variables in the above function are factor quantities which are assumed to be exogenous to the firm. Entrepreneurs make decisions on factor usage by taking factor prices as given. In this case, factor quantities are endogenous decision variables. If cost minimization is taking place then direct estimation of production function ignores such information. Therefore we model explicitly the cost minimizing behavior of firms by means of a cost function. It shows the minimum cost of producing a given output level expressed as a function of given input prices and this enables us to answer questions relevant to the present study. In other words what happens to input utilization if the i th input price changes.

To do so we follow the modern duality theory which shows that under certain regularity conditions, production and cost functions are two equivalent representations of the technology of production. Let us assume that there exists a production function:

$$Y = f(X)$$

relating output (Y) to the vector of inputs $(X = x_i, i = 1...n)$. The cost function is:

$$C(w, y) = \min(wx;\ f(x) > y) \quad (1)$$

where C is the total cost and $w = (w_i,\ i = 1..n)$ is a vector of factor prices. Given C we reconstruct f. Thus the cost and production functions are dual in the sense that each may be derived from the other. Given a valid functional form for C, we can derive in principal the production function which yields C as its cost function. Further, following Shephards Lemma, if $C(w,y)$ is differentiable in w then the factor demand function coincides with the partial derivatives of C with respect to the factor prices. Consequently, the conditional factor demands (conditional on output) for the i th factor are:

$$x_i = \frac{C(w, y)}{w_i}. \quad (2)$$

If we define:

$$S_i = \frac{w_i x_i}{\sum w_j x_j} \quad (3)$$

as the share of factor i in the costs of production then the cost share equations can be obtained as

$$S_i = \frac{lnC(w,y)}{lnw_i} = S_{i(w,y)} \quad (4)$$

It is clear that (2) and (1) are equivalent representations of the technology since (2) is obviously derived from (1). We can add disturbances u_i to the demand equation to represent errors in cost minimization and estimate the parameters as a multivariate regression.

5.4 The model

The model for the paper industry that follows is based on the following assumptions:

(1) Input prices are predetermined for the firms in the paper industry;

(2) Paper industry exhibits constant returns to scale.

The focus of the present study is on substitution and derived demand and not on scale properties[4].

(3) Firms minimize variable cost subject to a given level of output and fixed capital.

Hence we estimate a short run variable cost function with capital stock as quasi fixed input (i.e. fixed in the short run). This is justified on two grounds: First, if all the inputs in the cost function are variable, instantaneous adjustment is implied whereby all inputs are in full static equilibrium (Brown and Christensen (1981)). It is considered more realistic to assume that the firm is in equilibrium only with respect to its set of variable inputs but not necessarily with respect to its capital input. And second, prices of capital services are not available.

Thus a constant returns to scale variable cost function is defined:

$$C = Yg(P_L, P_M, P_E, K)$$

where C is total variable cost, Y is output and P_L, P_M, and P_E, represent prices of labour materials and energy respectively. K is the quantity of capital. The translog variable cost function for the paper industry then takes the following form:

$$\ln c = \ln \alpha_0 + \Sigma\alpha_i \ln P_i + 1/2 \,\Sigma \,\Sigma \, b_{i,j} \ln \underline{P_i} \ln P_j + \gamma_k \ln K + 1/2 \, g_{kk} (\ln K)2 + S \, g_{i,k} \ln P_i \ln K \quad (5)$$

where $b_{i,j} = b_{j,i}$, $i,j = L$ (labour), M (material), E (energy) and $c = C/Y$.

[4] One of the referees pointed out that we should relax the assumption of constant returns to scale. We attempted this without success. Estimation of scale parameters requires the addition of the cost function to the system of share equations to be estimated. Severe multicollinearity led to meaningless results.

For a cost function to be well behaved, it must be homogenous of degree one in prices, given Y: i.e. if all input prices double, costs double too. To this end the following restrictions apply:

$$\Sigma a_i = 1 \text{ and} \quad (6a)$$

$$\Sigma b_{i,j} = S\, b_{j,i} = S\, g_{i,k} = 0 \quad (6b)$$

Logarithmic differentiation of the variable cost function (5) with respect to P_L, P_M, and P_E yields three cost share equations:

$$\Sigma_L = a_L + b_{LL} \ln P_L + b_{LM} \ln P_M + b_{LE} \ln P_E + g_{LK} \ln K \quad (7)$$

$$\Sigma_M = a_M + b_{LM} \ln P_L + b_{MM} \ln P_M + b_{ME} \ln P_E + g_{MK} \ln K \quad (8)$$

$$\Sigma_E = a_E + b_{LE} \ln P_L + b_{ME} \ln P_M + b_{EE} \ln P_E + g_{EK} \ln K \quad (9)$$

where S_L, S_M and S_E are cost shares of labour, materials and energy, that have to sum to unity (restriction 6a).

We impose the linear homogeneity restrictions (6b) by dropping the energy share equation (homogeneity implies that the three equations are no longer independent) and estimating the labour and material share equations with the price of energy (P_E) as the numeraire. The coefficients of the third share equation can be easily retrieved from the coefficients of the two estimated equations by substitution.

Using the estimated parameters of the above translog cost function the following elasticities of substitution and price elasticities can be calculated.

1) Allen Partial Elasticities of substitution:

$$s_{i,j}^{A} = (b_{i,j} + S_i S_j) / \; S_i S_j \quad i = j$$

$$s_{i,i}^{A} = (b_{i,i} + S_i^2 - S_i) / \; S_i^2$$

and the factor price elasticities by

$$h_{i,j} = s_{i,j} S_j$$

2) Morishima elasticities of substitution[5]:

$$s_{i,j}^{M} = h_{i,j} - h_{j,j}\,.$$

The Morishima elasticity measures the percentage change in the ratio of input j to input i,when the price of input i changes. Elasticities of substitution and cross elasticities of demand are positive for substitutes and negative for complements. Note that Allen partial elasticities of substitution measured by $s_{i,j}^{A}$ are one price-one factor elasticities of substitution. They are symmetric. It is a derived demand elasticity divided by a cost share. The price elasticities of factor demand given by $h_{i,j}$ are not symmetric. The Morishima elasticity measures relative input adjustment (or response of input ratios) to single factor price changes. This in contrast to $s_{i,j}^{A}$ which measures how a single input adjusts to changes in a single input price. Morishima elasticities are not symmetric and they measure the ease of substitution between two inputs. When two inputs are Allen substitutes they are also Morishima substitutes.

[5] For formal proof of these formulas see Binswanger (1974) and See Kang & Brown (1981), Thomson and Taylor (1995), for a discussion of the properties of the Morishima elasticities.

5.5 Analysis

5.5.1 Estimation procedure

Our modelling strategy was to estimate first a full model including three factors, namely, labour, energy and materials (materials being a sum of imported and domestic waste paper). A distinction between domestic and imported waste paper is not made and the concept of *materials* is thus used to calculate the elasticities between waste paper, energy and labour.

The share equations to be estimated are given in the earlier section (7, 8, 9). There are three share equations pertaining to three factors of production, viz. labour, materials and energy in the case of the first model. For the estimations we chose to drop the share equation corresponding to energy.

As the sum of the three factor shares comes to unity, a non zero contemporaneous covariance between the disturbances of the two share equations can be expected. Due to the presence of contemporaneous correlation, Ordinary Least Squares (OLS) estimators are not efficient. This is solved by estimating the two equations as a system of Seemingly Unrelated Regression Equations (SURE). Efficiency then is assured by using the iterative SURE method to estimate the two equations[6].

In brief the iterative SURE method involves the following steps. Initially each of the equations is estimated using OLS. From these estimates the residuals are calculated and the covariance matrix of the residuals is estimated. The coefficients derived at the initial stage are then revised to take into account the covariance between the residuals. The residuals are recalculated and the same procedure is repeated till convergence is achieved. This iterative SURE method yields estimates which converge to maximum likelihood parameter estimates. An important property of these estimates is that the parameters are unique and independent of the share equation that is dropped. In other words the estimation method yields the same estimates of parameters irrespective of the equation dropped.

5.5.2 Materials sub-model

Since the firms in our sample predominantly use two types of raw materials (and not one material M) namely imported waste paper (M_I) and local waste paper (M_D) and as the question of substitutability between imported and domestic waste paper is of intrinsic interest to the present study, we also estimate a material sub model. Such a model can be estimated assuming that material inputs adjust to their optimal cost minimizing level keeping the total material output and non material inputs constant. This allows the cross elasticities between imported and domestic waste paper to be calculated. A weakly separable variable cost function corresponding to this can then be written as:

$$C = Yg\,[P_L,\ P_M\,(P_{MI},\ P_{MD},\ K),\ P_E,\ K] \qquad (10)$$

where P_{MI} and P_{MD} are prices of imported and domestic waste paper respectively and where it is assumed that (quasi) fixed capital influences the substitution between imported and domestic waste. Since P_M is the price per unit of material input, it is also

[6] For a detailed discussion of this procedure see Johnston , 1984, pp 330-342.

the cost per unit to the cost minimizing firm. We can estimate a translog material price function which results in the following two material share equations.

$$S_I = a_I + a_{II} \ln P_{MI} + a_{ID} \ln P_{MD} + b_{IK} \ln K \quad (11)$$

$$S_D = a_D + a_{DI} \ln P_{MI} + a_{DD} \ln P_{MD} + b_{DK} \ln K \quad (12)$$

if the following restrictions are imposed:

$a_I + a_D = 1$, $a_{II} + a_{ID} = 0$, $a_{ID} + a_{DI} = 0$, $b_{IK} + b_{DK} = 0$.

The elasticities of substitution and factor price elasticities can be calculated from the parameters as described for the earlier model.

In the materials sub model we have two share equations pertaining to share of imported waste paper and domestic waste paper. The restrictions imposed imply that we need to drop one equation and the parameters of the other share equation can easily be retrieved from the parameters of the estimated equation. We choose to drop the share equation pertaining to the share of domestic waste paper. As only one equation needs to be estimated, we use the OLS method to estimate the materials sub model.

The Allen partial substitution elasticities and own demand and cross price elasticities are then calculated using the formulas given in the previous section.

5.6 Results

The results of the regression pertaining to the model with three inputs are reported in Table 5.4 below. Note that the estimated share equations satisfy the regularity condition i.e. the predicted values of the factor shares are in all cases positive. The R^2s are not very high. The coefficients of the price variables are all significant at the 5 % level except the coefficient of price of labour in the labour share equation. For brevity we have not reported the coefficient of capital. It is significant in both equations. The model was also estimated using 67 observations (i.e. including those firms who only use domestic waste paper and the one that uses only imported waste paper). The results of this exercise are similar to those obtained when only 40 observations are used but are not reported here.

Table 5.4 Estimates of the coefficients of the restricted translog cost function and T ratios

Dependent Variable	Constant	Price of Labour	Price of Materials	Price of Energy[1]	R^2
Share of labour	-0.047	0.022	-0.032	-0.01	0.17
	(-0.467)	(1.487)	(1.846)		
Share of materials	1.891	-0.032	0.061	-0.029	0.44
	(7.435)	(-2.077)	(2.561)		
Share of energy[1]	-0.844	-0.01	0.029	0.019	

[1]. *Implied estimates computed using homogeneity constraint.*

Table 5.5, Table 5.6 and Table 5.7 present the Allen Partial and Morishima elasticities of substitution and own factor demand and cross demand elasticities. They are calculated at the means of the actual factor shares.

It should be noted that the estimated elasticities are valid only for the levels of the fixed factor (capital in our case) at which they are evaluated. From the tables below it is clear that all factors are substitutes with respect to each other. The elasticities of substitution are rather small. All own elasticities of factor demand have the correct sign and none of them are close to one. The own elasticity of materials is the lowest. The responsiveness of all the three inputs to their own prices is surprisingly low. Demand for all the three inputs are price-inelastic.

We have not reported the standard errors of the computed elasticities. The pimary reason for this is that the conventional method of calculating the standard errors has been severely criticized in the literature. The conventional method of estimating the standard errors is basically an approximation and little is known about the properties of this approximation in small samples. Thus, in studies which use small samples, like our own, it is advisable not to use the standard errors calculated on the basis of an approximation, to test for the statistical significance of the various elasticities computed.

Table 5.5 Estimates of Allen partial elasticities of substitution[1]

	Labour	Materials	Energy
Labour	-9.271	0.291	0.277
Materials		-0.293	0.823
Energy			-2.616

[1]: *The elasticities of substitution are symmetric. The own elasticity of substitution has little economic meaning.*

Table 5.6 Estimates of Morishima elasticities of substitution[1]

	Labour	Materials	Energy
Labour	-	0.412	0.617
Materials	0.618	-	0.787
Energy	0.662	0.788	-

[1]: *The Morishima elasticities of substitution are not symmetric.*

Table 5.7 Factor demand and cross elasticities implied in the estimated translog cost function[1]

	Labour	Materials	Energy
Labour	-0.599	0.205	0.063
Materials	0.018	-0.207	0.188
Energy	0.017	0.581	-0.599

[1]: *Each element in the table is the elasticity of demand for the input in the row with respect to a price change of the input in the column.*

Let us now turn to the materials sub-model. The regression results are presented in Table 5.8. As before we do not report the coefficient of capital. In this case it is not significant, and our results are much weaker than earlier while the coefficient of the price of imported waste paper is significant only at the 10 % level. Again the regularity conditions are satisfied and none of the predicted shares are negative. The implied cross elasticity of substitution is 0.157 suggesting that the two inputs are (weak) substitutes[7]. The implied own elasticities of demand of imported and domestic waste paper are negative but at -0.075 and -0.082 respectively, have extremely low values.

Table 5.8 Estimates of the coefficients of the translog cost function in the materials sub-model and T ratios

Dependent Variable	Constant	Price of Imported Waste Paper	Price of Domestic Waste Paper[1]	R^2
Share of Imported Waste Paper	-0.250 (-0.523)	0.208 (1.802)	-0.208	0.12
Share of Domestic Waste Paper[1]	1.250	-0.208	0.208	

[1]: *Implied estimates computed using homogeneity constraint.*

5.7 Conclusions

Industries differ with respect to technological changes, resource constraints and input substitution possibilities. We have, in this chapter attempted to shed some light on the input substitution possibilities in a segment of the Indian paper industry. Our focus is on firms which use waste paper as the primary material input. We used the cost function approach to arrive at estimates of the elasticities of substitution and price elasticities of demand.

The signs of the estimates of the substitution and cross price elasticities suggest that there exists a substitution relationship between the three inputs namely, labour, materials and energy. The numerical values of these estimates are found to be rather low. This suggests that substitution possibilities between the three specified inputs, are limited. The same conclusion holds for the substitution between imported and domestic waste paper, given the total material cost. In addition, the derived demand elasticities indicate that input usages are relatively unresponsive to changes in the relative prices of inputs.

The low values of the elasticities signify that, given the level of capital stock, the flexibility of the production structure to respond to relative price changes is very restricted. We have already documented that the Indian paper industry is saddled with obsolete capital equipment. Consequently, the limited ability of the firms in the paper industry to adjust in the short run to unpredictable changes in the relative prices of inputs through substitution is likely to result in high adjustment costs. Implications of our findings related to waste paper recycling industry and the environmental impacts are dealt with in a separate paper.

[7] These are called gross elasticities in the literature. We also estimated the net price elasticities, which allow all inputs to adjust to new cost minimizing levels. They are found to be higher than the gross price elasticities but still low at -0.33.

Chapter 6.

WASTE PAPER TRADE AND RECYCLING IN INDIA: A MATERIAL BALANCE APPROACH

Anatha Duraiappah
Pieter van Beukering

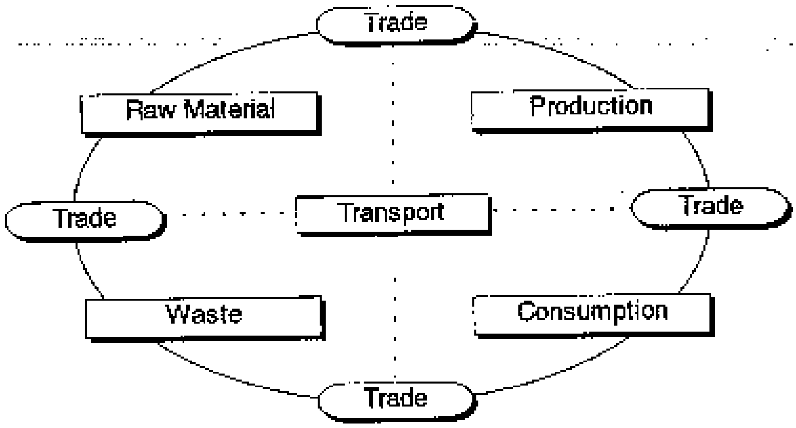
6.1 Introduction

Each country has a unique material flow configuration consisting of domestic raw materials, imported and exported materials, generation of consumption waste, and basic materials demand. Each nation also has a unique environmental profile involving population density, industrial agglomeration, environmental assimilative capacity, and social demand for environmental quality. International trade can perform a crucial function by matching variations in supply and demand of products and services between countries (Grace *et al.* 1978). Whether the influence of trade is positive or negative for the environment is difficult to determine in advance due to the complexity of the interlinked socio-economic and ecological systems. The institutional struture in a country plays an important role. If rules and regulations are proporely defined, trade can promote a sustainable development. Yet, if the institutional framework fails to capture the externalities the contrary will occur. Trade acts as a 'magnifier' of environmental effects in either direction (GATT 1992).

The difficulty in defining an accurate trade policy which internalizes all environmental costs is that the decision makers concerned need to have a complete overview of the effects which occur in the whole life-cycle of a product. Figure 6.1 demostrates a simple life cycle for a product. Trade is an integrated link between each single step in the cycle and therefore cannot be regarded as a separate entity (Andersson *et al.* 1995). In essence, two effects take place in a situation of increased trade. By facilitating specialisation of production in different countries higher income levels are attained and technological development is promoted achieving higher levels of social welfare than without trade. On the other hand, it can be argued that expanding transport and production increases pressure on the environment.

Although national policies are aimed at selfsufficiency in the supply of paper and paperboard, international trade still plays an important role in the Indian paper cycle. Forest resources are scarce and so is the level of waste paper recovery. Agro-residues are abundant but are still found to be too polluting to fully replace the conventional raw materials. The obvious solution would be to import either paper, woodpulp or waste paper from abroad. Given these facts, the following questions emerge. First, what would be the environmentally optimal solution to the problem of the raw material shortage in the paper cycle in India? Should the pressure on the foreign or Indian forest be increased by expanding the virgin fibre capacity in the Indian paper industry, or should the excess supply of waste paper in Northern countries be utilised by importing the recovered paper to India? Second, what would be the most economically feasible solution to the problem of the raw material shortage? Waste paper is generally cheaper than woodpulp, and thereby foreign currency can be saved by importing the latter material. On the other hand, developing Indian forest plantations or improving local waste paper recovery may be more cost-effective.

Figure 6.1 General life cycle of a product and the role of trade and transport



Source: Based on Andersson et al. 1995

Because the answer to these questions involves the complete paper cycle from cradle to grave, a material balance flow model is developed in which the life cycle of paper in and outside India is assessed. A detailed description of this cycle will be provided in Section 6.2. Economic, environmental and social parameters will be explained and coefficients will be set. In Section 6.3, the material balance flow model will be introduced. The methodology and the economic and environmental assumptions under which optimaliztion will occur are elaborated on. The results of the optimalization exercise are presented in Section 6.4. Finally, conclusions and policy implications are given in Section 6.5. A specification of the applied data and the model structure is given in the appendix.

6.2 The paper cycle

In the following section the different processes in the paper cycle will be described in terms of input and output requirements. Besides considering physical relationships such as chemical inputs and air-emissions, socio-economic variables such as labour and capital will be estimated. In order to take into account the efficiency differences between the North and India, sets of input-output data will be summarized for these regions for each process in the cycle. The input-output tables are given in the "data" appendix. In the following sections, the different processes in the cycle are described.

6.2.1 From forest to wood

The cycle starts at the biomass formation of trees. Atmospheric carbon dioxide and water from the soil are joined into photosynthesis to form glucose which is the material basis for the tree growth. The oxygen is released back to the atmosphere while carbon remains fully in the biomass. In general, most forest for pulping in the North are already cultivated forests, while cultivated forests in the South are of relatively minor importance.

Productivity of the Indian forest is very low with a mean annual increment of only $0.5m^3$ per ha, as compared to an average of 2.5 m^3 per ha in Europe and the USA (Rao 1989). In 1991, coniferous tree species make up 70% of the source for pulp. However, the share of pulpwood coming from tropical and sub-tropical hardwoods (principally eucalyptus) grown in plantations is increasing. Two-third of the pulpwood is cut directly from the forests while one-third comes from wood-chips and residues recovered from the manufacture of lumber, plywood and veneer, mainly from developed countries. The wood used by the pulp and paper industry in developing countries is primarily in the form of pulpwood coming directly from the forest (Durst and Jensen 1995).

The harvesting of wood is the first significant step in the paper cycle. Harvesting efficiency has increased in the last decades. As a result more pulp is extracted from the forest. Despite this advancement a major part of the felling and limbing is still based on manual technologies. About 65% of the biomass is eventually extraded from the forest. In time, the remaining materials, such as roots, branches and leaves, degrade into carbon dioxide, methane and organic matter (Virtanen and Nilson 1993). These emissions of biodegradation of harvesting waste are not included in the material balance because by feeding the humus lair in the forest, it also facilitates forest growth. In other words, the environmental impact of biodegradation is assumed neutral.

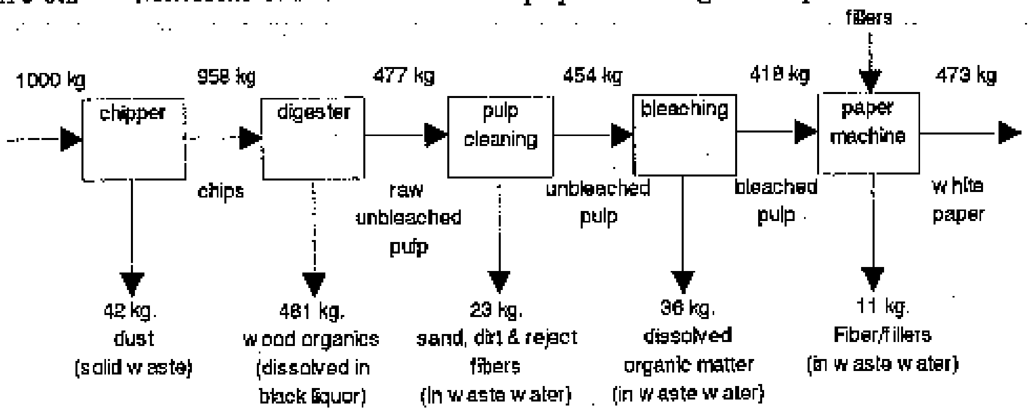
Trees can be classified into two groups - hardwoods and softwoods. Hardwoods are the main deciduous trees, such as maple birch, beech and eucalyptus, and these provide short cellulose fibres (1 to 2 mm long). Softwoods are coniferous trees, such as pine, spurce and fir, and these provide long cellulose fibres (3 to 5 mm long), resulting in strong pulps. Hardwood contains a higher proportion of cellulose fibre; softwood contains more resins (Greenpeace 1990). Plantation and forestry management will provide about one man-year employment for every 12 to 20 hectares including the harvesting of the trees (IIED 1995). Taking into account the productivity differences of Indian versus the European or North American forest, it is assumed that the production of one tonne of logs generates 1.4 days of work in the North and 6.2 days of work in India in the forestry sector. Given the labour intensive nature of wood harvesting and the limited data availability, capital costs will be ignored in this process.

6.2.2 From wood to woodpulp

Although woodpulping and paper making are often performed in an integrated manner, these processes will be discussed seperately. In figure 6.2, an example of the complete production process is provided. Material losses are also indicated. There are two principal types of technologies for wood pulping: chemical and mechanical. For chemical pulping the cellulosic raw materials are first chipped to suitable size (in dry or wet condition). The chips are cooked with chemicals such as caustic soda to dissolve out lignin and free the cellulose fibres. This digesting process takes place at a temperature of 170-180 °C with a pressure around 10 atmosphere. The digesting conditions vary with the type of raw material used. After digestion is complete the contents are blown to tanks and the chemical solution (black liqour) is seperated for chemical recovery.

In mechanical processing, the fibres are seperated by forcing the debarked logs against a grinding stone to produce groundwood pulp. Basically there are two processing principles for mechanical pulping: grinding and refining the wood. A major part of the mechanical pulp is bleached. Instead of using chlorine, however, different peroxides are frequently used as bleaching agents in modern mechanical pulping plants. Mechanical pulping converts 95% of the wood chips into pulp, compared with only 45 to 50% in the chemical process. Therefore mechanical pulp is cheaper and less wasteful in trees than chemical pulp. Mechanical pulp is the main input for newsprint (Biermann 1993).

Figure 6.2 Material balance of wood in paper making-kraft process

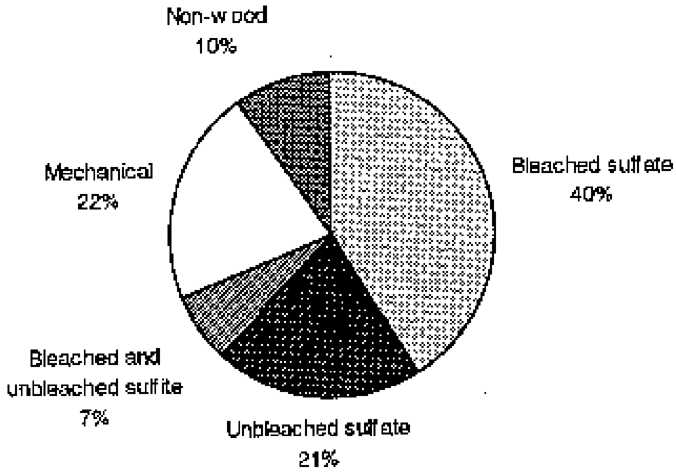


Source: CPCB 1991, p.9

Chemical and mechanical pulping differ in various ways. First, chemical processing can be practically energy self-sufficient due to utilisation of heat potential of extracted lignin and bark. Mechanical pulping is fully dependent on external energy. The specific electric energy demand for chemical pulping is roughly one-third of that for mechanical pulping. The pulp yield from mechanical processing is roughly twice as much as the yield from chemical processing. Thus the larger energy consumption of mechanical processing is compensated by smaller raw material consumption. Generally, chemically produced pulp has more permanent optical and strength properties than mechanically produced pulp. Therefore, chemical pulp can be used for more purposes; mechanical pulp is normally limited to products with relatively short lifetime. Chemical pulp, such as kraft pulp is much stronger than mechanical pulp. It is used for making cardboard and corrugated cardboard, but also for printing and writing paper (Virtanen & Nilson 1993).

In chemical pulping there are two prevailing process principles: the sulfate principle and the sulfite principle. These differ from each other by the type of cooking chemicals used to extract lignin from cellulose fibers. Until the 1960s sulfite technology formed the major market share in pulp production, but during the past 20 years it has decreased rapidly and today represents less than 15% of the overall chemical pulp production in Western Europe. The sulfate, or kraft process involves boiling wood chips with caustic soda. The resulting pulp is dark brown in colour. As mentioned before, kraft pulping without bleaching employs a closed-loop system. The wood wastes, which contain toxic chemicals such as resin acids, are burned, and more than 95% of the pulp in chemicals are recovered for use in the next batch. Sulfite pulp is produced by boiling the wood chips in sulphuric acid. It is lighter in colour, weaker, and softer than kraft pulp. It is often used in the production of tissue paper. Although the technology available to recover chemicals is less efficient than the sulfate technologies, a closed-loop system can be operated (Greenpeace 1990). In India the sulfate process is used in all the wood-based mills except for one mill which applies sulfite (CPCB 1991). The global distribution of the various types of pulp is depicted in figure 6.3. Capital and labour intensity are discussed in the paper making section.

Figure 6.3 World distribution of pulp production 1991



Source: IIED 1995

The paper industry is a rather energy intensive sector. Processes require energy mainly in the form of electricity and steam. This can be internally supplied by on-site co-generation with steam using renewable fibre such as wood, bark, and recovered digesting "black" liquor. Particularly, the chemical pulping mills have great potential for co-generation. Energy efficiency of the pulping process differs between the Indian paper industry and the North. Rao (1986) reports an energy conversion difference of 76% and an energy operation difference for electricity and steam of respectively 70% and 7%. Based on these facts, total energy requirements are assumed to be 58% higher in India for the production of pulp than in the Northern industry. This ratio corresponds with the findings of TERI (1995) which reports a difference in the thermal and electric energy consumption of respectively 67% and 33%.

6.2.3 From harvest to non-wood pulp

As can be seen in figure 6.3 a small portion of the fibre furnish for paper production comes from non-wood fibre such as bagasse and straw. This type of pulping is mainly performed in developing countries. There is very little trade in non-wood pulp. Therefore, importing agro-residues or non-wood pulp is ignored in the model. Since the inputs are generally seasonal, the industries store the stock for the year by collecting it from local farms. This generally leads to losses in the storing process. Bagasse is generated by sugar mills as a residue of sugar cane. Sugar mills usually burn the bagasse in order to provide power to the mill. Any excess bagasse is sold to paper mills. India pioneered the use of "substitution" bagasse. This concept implies that paper mills purchasing bagasse from sugar mills, in return provide the latter with fuel (Roberts 1995). Because the yield percentage of non-wood fibres is rather low (33% for bagasse and 38% for straw) transportation is important. It is reported that the economic distance for hauling the straw is 50 kilometer from the mill although examples are known of a radius of 100 km (Roberts 1995). In order to reduce the volume to be transported, paper mills sometimes facilitate depithing of the bagasse at the sugar mill. Pith can be used for fuel but is of no use in paper production. In terms of labour, harvesting agro-residues need to be approached carefully. Agro-residues can be considered a by-product and as such do not generate labour; harvesting would also take place without paper production. Yet, some additional effort is required for the preparation for pulping. Therefore, 2 days of work are taken into account for the supply of one tonne of agro-residues.

Chemical pulping by applying sodium hydroxide as cooking-agent is the most common method in India to transform non-wood fibres into pulp. Chemical recovery is rarely perfomed. The pollution load is therefore very high for non-wood paper mills in India. Increasingly, this feature of agro paper mills forms a threat for the mills as enforcement of environmental standards is becoming more strict. Numerous agro paper mills have been closed down in the last few years by the Indian government for this reason. Yet, the National Productivity Council (NPC) estimated that given the current profit margins of agro paper mills, installing waste water treatment is generally not economically feasible. This explaines why several agro paper mills shifted to using waste paper in order to reduce their waste water pollution. Another constraint for non-wood pulping is the limited fibre lenght of 1 to 2 mm (CPB & CWP 1986). This leads to a generally lower quality pulp. As a result the average price of paper from agro-based mill is between Rs.1,000-2,000 less than paper from wood mills (Agarwal & Narain 1995).

6.2.4 From waste to the repulping of waste paper

In chapter 4, the process of recovery of waste paper in India and the related socio-economic and environmental parameters was described in detail. It was found that at present the recovery rate in India of only 15% is rather low compared to other developing countries. Besides general inefficiencies in the collection sector, reasons for the low rate are the intensive reuse of waste paper for packaging and the use for energy recovery. Both types of post-consumer use rule out the option of recycling. Still, the potential exists for improvements in the recovery rate. Domestic supply of waste paper can increase if appropriate policies are taken.

The processes in this phase are extremely labour intensive and involve only a limited input of capital. The main sources of waste paper are households. The households save their own waste paper which they sell to waste buyers or itinerant waste buyers (IWB). Also institutions and factories participate in the informal paper cycle. Office boys or caretakers gather and sell the waste paper which is generated in the offices. The waste paper which is disposed is partly collected by the municipalities for landfilling, or removed by waste pickers who roam off the streets and dumpsites to collect recyclable waste. The IWB is also mobile, but instead of picking waste from bins or dumpsites, he goes from door to door by bicycle to buy the waste from households or shops. Since his material has not yet been mixed with disposable waste, the quality is much higher than the waste paper gathered by the waste pickers, which implies that the IWB is a major supplier of re-usable paper. Finally, the waste enters the trade sector which comprises buyers and waste paper wholesalers. These traders employ a number of workers for purchasing and sorting. It was calculated that the recovery sector employs 34.8 work days per tonne of waste paper recovered in India. No data are available on employment in the waste paper collection sector in the North. Yet, given the high degree of mechanization, the labour intensity of collection in the North is assumed to be 15 times lower than in India. Capital costs are ignored for collection in both regions.

Waste paper pulp is produced in two types of plants. For less-demanding paper qualities, the waste paper is treated in mechanical re-pulping plants. The pulp is not chemically de-inked and is used for brown paper and boards. For higher qualities of products, the waste paper is re-pulped, chemically cleaned from pigments, and sometimes also bleached. De-inked recycled pulp is used for newsprint and soft paper. In the mechanical process the waste paper is mixed with water, caustic soda and sulfate, and pulped. Solid impurities such as plastics are seperated with centrifuges and pressure sorters. The pulp is washed and sorted after which it is thickened. The quality of waste paper used in the re-pulping process is important for the yield rate. The low-quality waste paper only generates 80% of fibre yield whereas the yield for high-quality waste paper can be as much as 92% (Virtanen and Nilson 1993). For both primary and secondary fibres, varying amounts of different additives are used in the pulp, such as starch, calcium, carbonate, and titanium dioxide. The furnish share of these additives is approximately 25%. For the waste paper pulping in India, a distinction is made between pulping of imported waste paper and pulping of local waste paper. Because of the shorter fibre length, the local waste pulping is less efficient. For the production of one tonne of waste paper pulp in India, 1.35 tonne of local waste paper is required while the same pulp only requires 1.237 tonne of imported waste paper. This implies also that the consumption of energy is less in the latter case.

6.2.5 From pulp to paper

After the pulping and possibly the bleaching process, blending provides the required pulp to water ratio before sending it to the paper machine. Further conditioning by chemicals such as alum, rosin, talc and acid to suit the requirements of the final paper quality is adopted. The paper machine consists of a moving wire mesh, followed by rotary driers. Steam is used in driers to drive the moisture from the sheet of paper formed on the wire mesh and picked up by driers. The finished paper is taken on rollers and is cut to the appropriate size before it is sent to store. The waste water from the paper machine, known as white water, is taken through air flotation savealls to recover as much fibre as possible. Also, the white water is mostly reused.

Similar to the forestry and harvesting process, significant differences between labour intensity in the pulp and paper industry in the North and India can be recognized. Since labour statistics from the International Labour Organization (1992) are only available for the pulp and paper industry as a whole, no separate estimation for pulping and paper making can be made. The labour required for the production of one tonne of paper in India was determined at 21 mandays. Compared to the average labour intensity of the pulp and paper industry in various other developing countries, the Indian labour intensity works out to be more than three times higher[8]. However, if this figure is compared with the Northern industry the difference is enormous; compared to India the labour intensity is ten times less for the Northern paper industry[9].

[8] An average labour intensity was calculated for developing countries including Kenya, India, Chile, China, Mexico, the Philippines and Indonesia (IIED 1995, FAO 1994, ILO 1992).
[9] An average labour intensity was calculated for the North including Finland, Sweden, Canada, New Zealand, United States, Japan and Austria (IIED 1995, FAO 1994, ILO 1992).

Capital requirement is another important variable in the input-output matrix. Similar to labour intensity, it is difficult to separate the capital costs for the pulping process and the paper making process. Therefore, capital costs treated in an integrated manner are only considered in the pulping phase. Two studies mention the costs of capital. Calvo (1993) gives the investment costs for two types of mills. Under the assumption that a paper mill has a life-time of 25 years and produces at 90% of the capacity, capital costs per tonne of bleached kraft pulp and de-inked recycled paper are respectively US$.74 and US$.7. The FAO (1994) published comparable results. Under the same assumptions, capital costs for bleached kraft pulp were US$.53 per tonne, unbleached recycled paper US$.4, and de-inked recycled paper US$.18. These latter capital costs will be used in the input-output matrix. For the Indian case the lifetime of a paper mill will be extended to 40 years and the capacity utlization will be reduced to 70%. As a result the capital costs for bleached kraft pulp were US$.40 per tonne, unbleached recycled paper US$.3, and de-inked recycled paper US$.13.

6.2.6 From paper to waste

Consumption of paper is very low in India (3 to 4 kg per capita). With a population of 900 million people, this implies an aggregate consumption of 2,7 billion kgs. However, given the present and foreseen economic growth, this figure is expected to be more than 4 kg by the end of this century. The environmental impact of consumption of paper lies beyond the aims of this project. Yet the relevance of this step in the cycle can be quite significant. Especially in the North, developments of eco-labelling schemes and public procurement programmes are strongly felt by the paper industry.

A form of consumption which does have a significant indirect impact on the Indian environment and economy is reuse of paper. Because this type of consumption goes unregistered, no data are available on this issue. Yet, as reuse is very important for a country like India, it is included in the model at a level of 0.3 kg per capita. This has two implications. First, the total level of consumption in this analysis will be higher than the formal level of consumption. Second, as re-use has a negative effect on the quality of the waste paper, it is assumed that paper which is re-used can no longer be available for recycling. This implies that the quantity of unrecoverable waste paper for disposal will increase if more waste paper is re-used.

If paper is not recovered, two options remain. First, paper is permanently diversed from the cycle through storage and sanitation losses. The latter can be ignored in India. Long term storage in libraries and archives is estimated to consume 10% of the formal consumption. Second, the waste is disposed. In India two forms of disposal are relevant. Either, the waste paper is burned in order to reduce the volume. The energy value of paper is not utilized. This creates considerable air pollution in the Indian metropolises. Instead of burning the waste paper, it can be mixed with the household waste. In that case it will end up at the dumpsite where it decomposes into organic matter. Given the composition of waste on Indian dumpsites (NEERI 1993), it is estimated that 10% of the consumed paper is burned and the remaining is landfilled. Labour intensity of waste collection for disposal is calculated at 2.7 work days for 1 tonne of waste paper. The most likely alternative for waste paper in the North is incineration in order to capture the energy value. Labour and capital of this activity in the North are ignored.

6.2.7 Transport

A process in the paper cycle which is particularly relevant for international trade is transport. Throughout the paper cycle, materials are moved from one process to the other causing environmental damage. IIED (1995) states that "transport is the fastest growing source of air pollution in both industrialized and developing countries." In addition, is is mentioned that "within the OECD region as a whole, the transport sector as a whole accounts for 70% of carbon monoxide (CO), 50% of nitrogen oxide (NO_x) and 25% of all carbon dioxide (CO_2)." Other problems are noise pollution, changes in landscapes and exploitation of exhaustable resources. Particularly for international transportation, such damage is not reflected in the price for fuels. Governments continue to subsidize transport through public provision of infrastructure and not taxing fuels. If internalization occurs, production and consumption patterns would be quite different. For the paper cycle, two modes of transport are considered: truck and ship. Similar to differences in energy efficiency in the paper industry in the North and India, differences are seen in the transport sector too. For the paper cycle in India, averages are calculated from the relative share in imports of a particular material multiplied by the distance to India. In the appendix the input-output tables are given for "transport".

6.3 The model

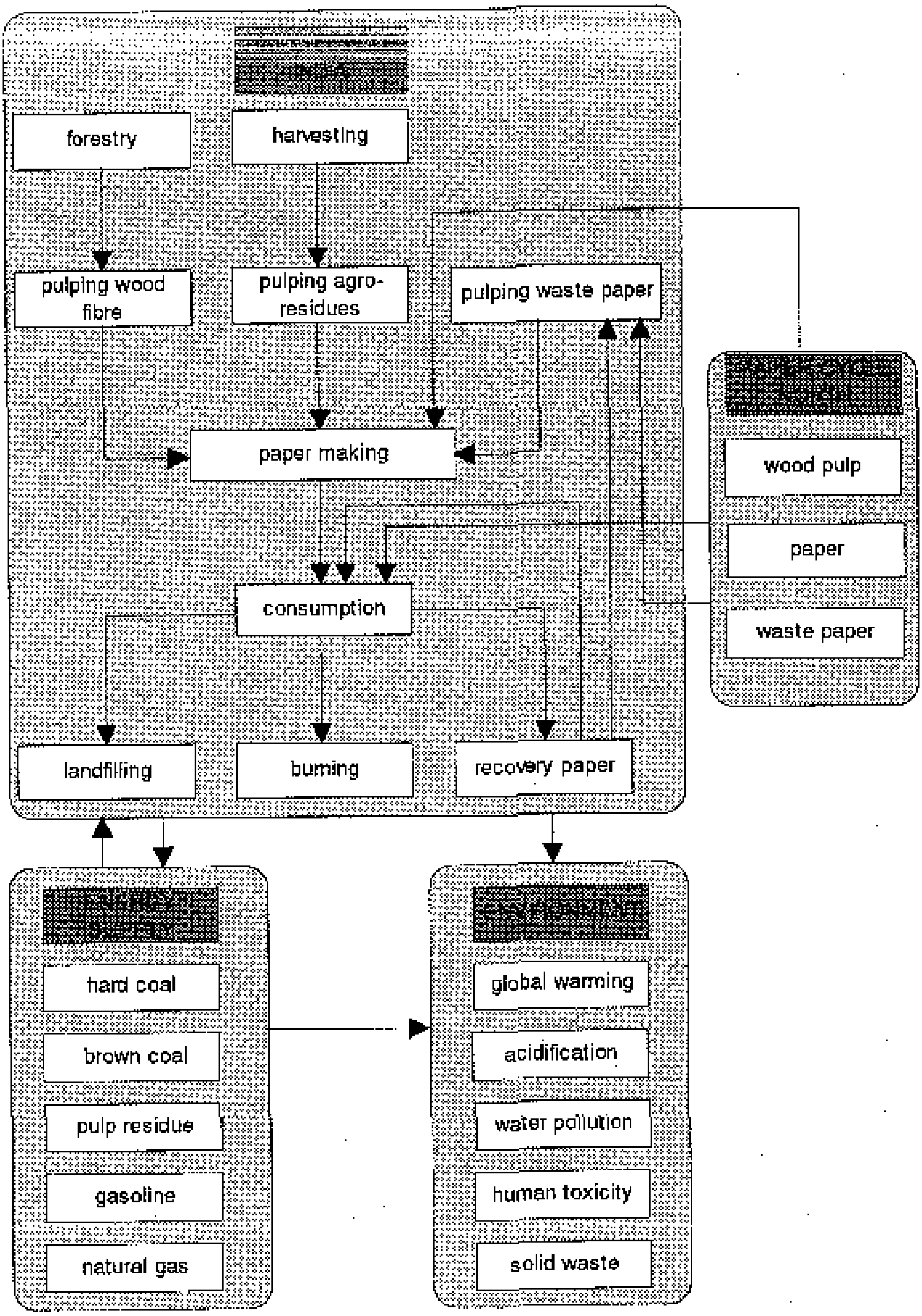
A sectoral model is developed to analyze the economic and environmental effects of international trade in waste paper for the paper sector in India. A mathematical description of the model is provided in the appendix. Sectoral models have been extensively used in the design and planning of industrial sectors (Kendrick and Stoutjesdijk 1978). However, the early models did not focus on environmental impacts and were primarily formulated as economic planning models. As the importance of environmental issues grew over the last decade, it became imperative to look not just at the economics of sectoral planning but also at the environmental aspects.

The sectoral model formulated for this study captures in essence the life cycle of the paper industry at each stage, starting from the harvesting of forests to the disposal of the waste paper. By incorporating a life cycle within a sectoral model framework, it is possible to: (1) keep track of the use and production of the various materials (life cycle analysis); and (2) to evaluate the trade-offs that occur between economics and environmental impacts at each stage of the paper cycle (sectoral analysis). Moreover, the paper industry is characterized by multi-processes and multi-products at each stage. Therefore, to ensure that these processes and products are captured by the model, the single product model is extended to a multi-process, multi-product life cycle sectoral model. Furthermore, to facilitate comparisons between different objectives which can be adopted by the decision maker, the model is developed as a static optimization model.

The analysis is simplyfied by assuming the rest of the world as exogenous and reduce its role to a supplier of waste paper, pulp and finished paper. It is beyond the scope of this paper to investigate the global economic and environmental impacts of the liberalization of trade in waste paper. Figure 6.4 showed a schematic illustration of the Indian paper cycle. As depicted in this figure, the environmental impacts caused by energy use in the paper industry are also included. However, unlike many of the existing studies (Weaver

1995 , Virtanen and Nilsson 1993), the decision maker is allowed to choose the optimal mix of fuels which are complementary to his objective.

Figure 6.4 Material flow balance of the Indian paper cycle



Surplus energy property of some pulping processes are also taken into account. For example, the unbleached sulfate pulping process produces wood residue which is a by-product of the pulping process which in turn can be used to produce electricity and steam. The environmental impacts caused by each energy producing process is tabulated to the cumulative pollutant emission for the paper industry. In this manner, in the optimizing process, an analysis of trade-off can be made with respect to the cost of the fuel versus the environmental impacts caused by the particular fuel. For example, brown coal may be a relatively abundant and cheap source of fuel but is considered environmentally unfriendly whereas natural gas may be a relatively scarce fuel with high import costs but is considered more environmentally friendly.

Six main pulping processes are included which are presently relevant in India: bleached sulfite, unbleached sulfate, unbleached local waste paper, unbleached imported waste paper, bleached sulfite, and bleached agro. These six processes can be basically categorized into three main methods. The first method uses wood fibre as the main input, while the second uses agricultural residue and the third relies on waste paper. The three processes (bleached sulfite, unbleached sulfate, bleached sulfite) within the wood fiber category are in turn differentiated by chemical use and intensity, energy intensity, and finally the pollutant emission intensity. Each of these three processes then produces a unique type of pulp which is then used in the final paper making process. In the agro based category, only one process is identified. The third category has two processes, one using local waste paper and one using imported waste paper.

Similar to the choice of energy sources, the choice of pulping processes is dependent on the objective. Once an objective has been specified, the optimal choice selection process undergoes a rigorous analysis of trade-offs. However, unlike in the energy selection process, the analysis of trade-off at this stage is a bit more complex involving two layers. At the first layer of analysis, the economic costs of pulp production has to be weighted against the environmental costs caused by the respective pulping processes. In the case of imported waste paper pulping process, the environmental costs accruing from transportation is included in the analysis. The second layer of analysis entails taking into consideration the economic and environmental costs and benefits which are derived from some of the pulping processes which are able to produce surplus energy.

In the paper making stage, four main types of paper are identified, differentiated primarily by quality which in turn are characterized by a certain mix of pulps. The input-output coefficient for this stage are formulated as an endogenous variable which is determined by the optimization process. The process is modelled in the following way. The total amount of pulp which is required for each paper type is fixed. Next, a pulp combination possibility matrix is set which in essence specifies the maximum percentage (an upper bound) a particular pulp can be used for a particular paper type. For example, given the quality characteristics waste paper can only be used to a limited extent for the production of writing paper. It is then left to the optimization process to choose the optimal mix of the different pulps to make the respective paper types.

The disposal stage is characterized by four different options. First, the waste paper is collected which by itself entails a certain economic and environmental cost. Once collected, the waste paper can be either burned, landfilled, used as waste paper in the pulping process or reused to meet final demand of the lowest quality paper. The options are not mutually exclusive. Each option is characterized by its unique economic and environmental properties.

Five major environmental impacts, regional as well as global, are specified for this model: (1) Global warming potential; (2) Human toxicity; (3) Water Pollution; (4) Acidification; and (5) Solid waste toxicity. The mapping from production to environmental impact was done in the following manner. Each stage of production is characterized by a technological input-output matrix. From these technological matrices, the emissions of all the pollutants from every activity are tabulated. The emissions are then added and a final emission level for each pollutant is determined. The next stage involves mapping the pollutant emissions to the five environmental impacts. This is done with the help of an environmental impact matrix which, similar to an input-output matrix, lists out the contribution a unit of each pollutant makes, to each of the five environmental impacts. The data for this environmental impact matrix was largely developed from Lim and Lindemeyer (1994) and the IPCC (1996).

At this point, two options of modelling the environmental factor in the model prevail: either monetize the eco-profiles or specify eco-profile constraints explicitly in the model. In this study the former method was followed as it allowed to conducting of an extended cost-benefit analysis. The latter will only allow a partial cost-benefit analysis. The decision was further motivated by the existence of, albeit crude damage estimates, for five environmental impact causes. The second method would involve the specification of constraints for each of the five environmental impacts. This method requires to first identify the upper bounds for each environmental impact at the national or international level, after which a certain portion of that constraint needs to be allocated to the paper industry. It was felt that a complete cost-benefit analysis, even with crude cost estimates, would provide more insight into the problem than a partial cost-benefit analysis with exogenously specified environmental constraints. However, the model structure can be easily modified to include the constraints at a later stage if necessary.

The economic valuation of the five environmental effects was based on existing literature. Because the main objective of this paper does not specifically address valuation aspects of externalities we only briefly explain this step in the analysis. To calculate the effect scores the "impact equivalency assessment" is used. This approach derives scores by aggregating emissions to their potential effects without any exposure analysis (Guinee 1995). The scores are derived by multiplying the aggregated emission levels by the equivalency factors. For example in the case of global warming, which is expressed in terms of "Global Warming Potentials" (GWP), carbon dioxide has an equivalency factor of 1 while the same unit of methane contributes 6 times as more to global warming. In this manner, effect scores for the five environmental effects are calculated.

Next, for each of these effects a per unit cost-price per effect score is derived from existing studies. For global warming, Fankhauser (1996) provides a damage estimate of 0.0055 dollar per GWP. From the World Bank study URBAIR which estimated the health impact of air pollution in Bombay, a damage estimate was retrieved of 0.0065 dollar per unit of Human Toxicity (Larssen *et al.* 1996). The study, "the Sustainable Paper Cycle" (IIED 1996) mentions a mitigation cost of 0.004 dollar per unit of water emission. In a study by Markandya (1994), acidification was valued in terms of damage to forests ecosystems at 0.016 dollar per acidification unit. Finally, a damage estimate was adopted from a hedonic price approach for solid waste by Powell *et al.* (1995) of 0.010 dollar per unit of solid waste. Although this valuation approach can be improved in many ways, for instance by incorperating exposure analysis or paying more attention to the valuation issue of benefit transfer, it still seems to be the most feasible option in this study to internalise the external effects.

As trade is an important element in this study, the possibility of imports at a number of stages is allowed. At the pulping stage, the decision maker can choose between producing pulps domestically or importing the pulps. The imports of all pulps are allowed, except that of agro-residue as it is highly unlikely that there will be any international trade of this commodity. However, as there is existing capacity in the different pulping processes, the decision to import would imply an additional cost in terms of unused capital. Similarly, the import of waste paper is also allowed. The same treatment is applied to the paper production stage. However, the import of final goods is constrained by an import bound which stipulates that only 20% of final demand can be met by imports.

There are two sets of prices which are exogenously determined in the model. Domestic prices for primary inputs sourced in India. The model is formulated in a manner in which it is the prices of the primary or "raw" commodities which matter. The price of intermediate and final goods which are produced in India do not have to be declared as the cost of producing these goods are computed as they are produced using the "raw" commodities. Therefore, intermediate goods like pulp, electricity and final goods like paper do not have domestic prices. International prices given are for all commodities which are sourced from outside India. In the model, these would be all imports irrespective of whether they are primary, intermediate or final goods.

6.4 Results

The driving factor behind an optimization model is the objective function. To understand the trade-offs between environmental and economic goals, the model is analysed when different objectives are specified. For this paper, we identified three strategies having the following objectives:

1. The *economic strategy* which implies the traditional sectoral modeling objective of economic cost minimisation;
2. *the environmental strategy* representing the strong environmentalist position in which just environmental costs are minimised;
3. the *sustainable strategy* is more in line with sustainable management which implies minimization of total costs including both economic and environmental costs.

The main purpose of this model is to analyse the outcome under different trade regimes. Therefore, the above strategies are analysed under three different scenarios. As a result, nine (3 strategies times 3 trade regimes) simulations are performed. The three trade regimes are:

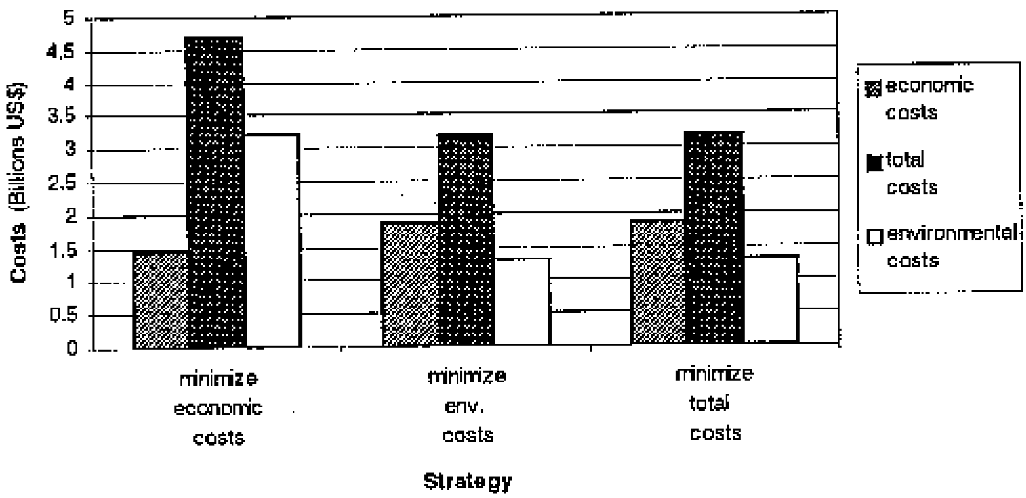
1. The first set of the simulations describes a situation in which *no trade in waste paper* is allowed but trade in wood pulp is allowed;

2. In the second set, a situation is simulated in which *trade in waste paper and wood pulp is allowed*:

3. In the third set of simulations waste paper trade is allowed but an *import contraint on wood pulps* is introduced.

The first set of the simulation demonstrates the results in a situation where no trade in waste paper is allowed. As Figure 6.5 below illustrates, in the *economic strategy*, the real cost (the total cost or social cost) is significantly higher than the economic cost. This is because the environmental costs are high under this strategy and is primarily caused by the adoption of the cheap but polluting agro-residue pulping manufacturing process. Under *the environmental strategy*, economic costs are higher than in the economic strategy but, as expected, the environmental costs are significantly reduced. One can observe that the decrease in environmental costs is much larger than the increase in economic costs, thus giving the environmental strategy an edge in terms of total costs. In the *sustainable strategy*, the final results are similar to the environmental strategy but with economic costs being reduced further.

Figure 6.5 Cost comparisons with no import of waste paper

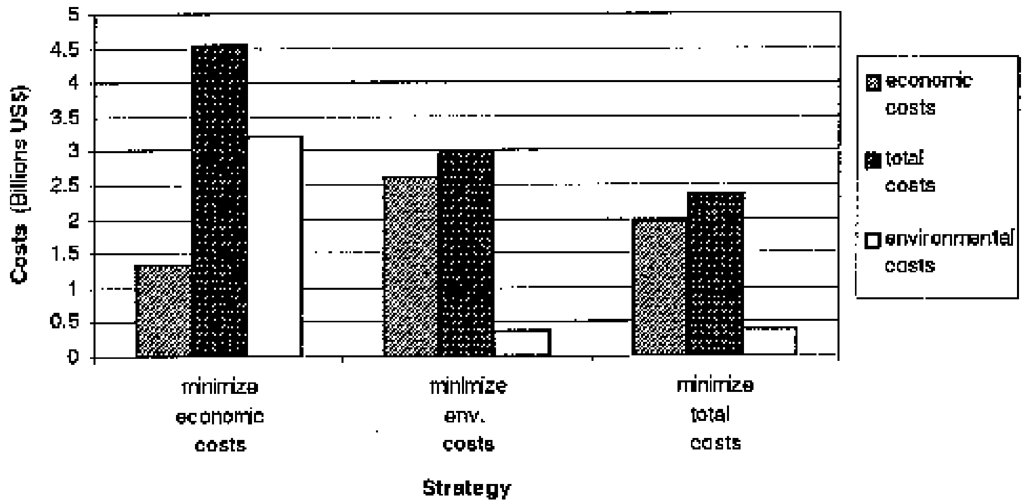


The next set simulations describe a situation in which free trade in imported waste paper is allowed. As Figure 6.6 below illustrates, a similar trend as in Figure 6.5 is observed but with more significant differences between the environmental and sustainable strategy. First, the economic and environmental strategy are explained. As observed in the case with no imports, the economic strategy chooses the cheap but dirty agro-residue pulping manufacturing process while the environmental strategy does not. The drop in environmental costs caused by adopting the environmental strategy is 2.8 billion dollars while the marginal increase in economic costs is 1.28 billion dollars. It is evident that in both cases, with and without imports, a reduction in environmental costs can be achieved at a relatively low cost.

In comparison with the sustainable strategy, the economic costs are further reduced vis a vis the environmental strategy but with environmental costs showing a slight increase. The economic costs decrease by 0.67 billion dollars while the environmental costs increase by 0.03 billion dollars; leaving total costs to decrease by 0.64 billion dollars. The primary factor causing the decrease in economic costs is the import of waste paper.

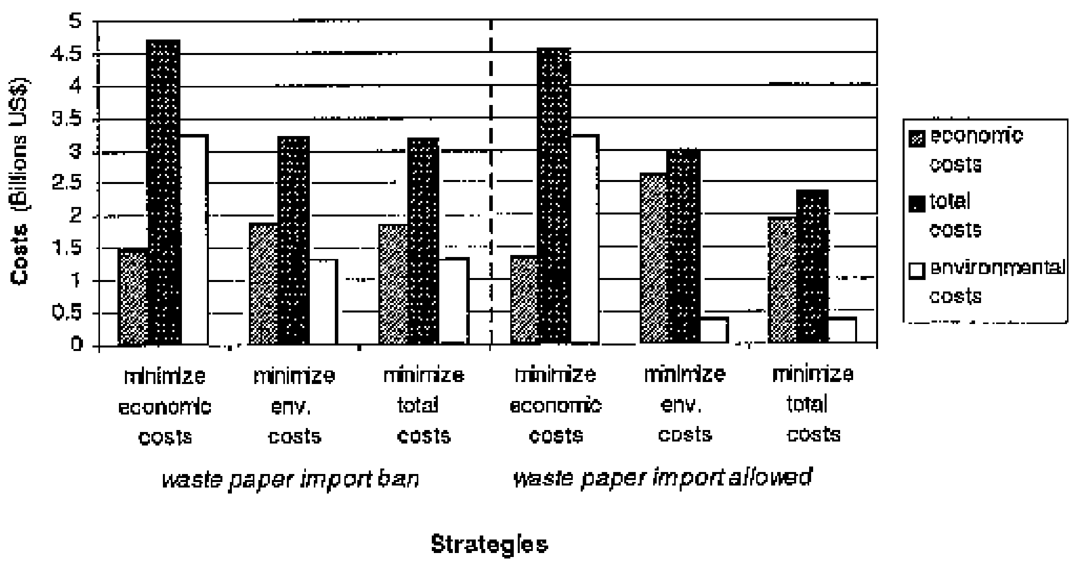
In the case of the environmental strategy in which economic costs are of no concern, there is a tendency to resort to the import of pulps to reduce the environmental impacts. Yet, when economic costs are also included in the objective, a search is made for cheaper alternatives to imported pulps and this leads the local paper sector to use both local and imported waste paper pulping processes. The adoption of these processes causes the environmental costs to increase by the 0.03 billion dollars.

Figure 6.6 Cost comparisons with import of waste paper allowed



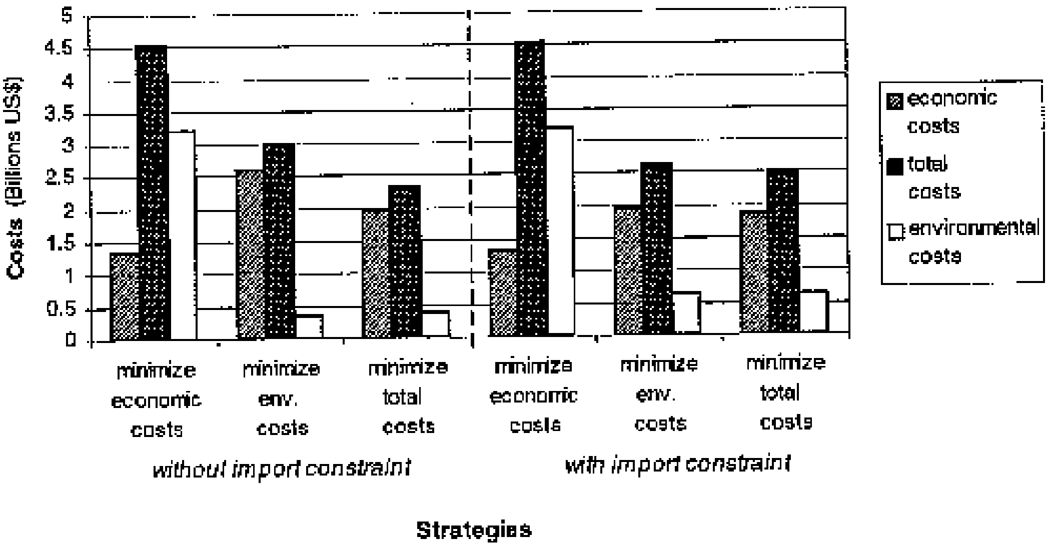
Next all the strategies from the first two previous sets of experiments are compared. As Figure 6.7 below illustrates, the strategy with the lowest total costs is the sustainable strategy in which imports of waste paper is allowed. An unexpected result is the higher economic costs that are observed in the sustainable strategy with imports as compared to the simulation without imports under the sustainable strategy. This is explained by the higher import cost. However, the higher economic cost of 0.08 billion dollars is far outweighed by the decrease in environmental costs of 0.9 billion dollars.

Figure 6.7 Costs comparisons across all strategies.



In the third set of experiments the import of waste paper are allowed but with an additional constraint on pulp imports which prevents the Indian paper sector from importing more than 50% of its pulp input requirements from foreign markets. The primary reason for this exercise was to observe how a restricted access to imported pulp will change the behavior of the paper sector in India. As was mentioned in the earlier sections, in many instances, the sector had resorted to imported pulp to reduce the environmental impacts. As shown in Figure 6.8 no differences were observed in the economic strategy with and without an import constraint on pulp.

Figure 6.8 Cost comparisons against strategies with and without pulp import constraint and imports of waste paper allowed

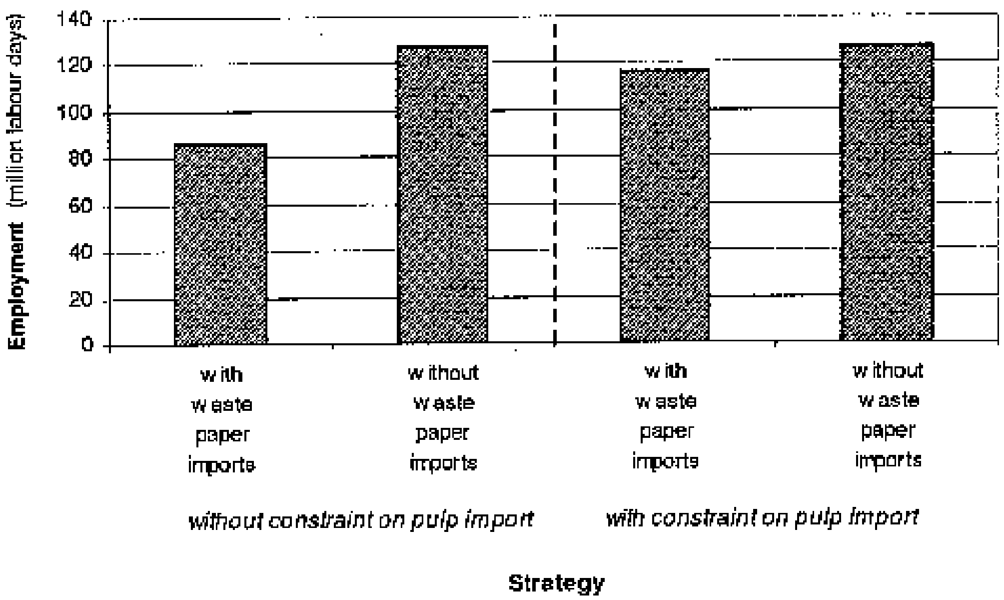


In the case of the environmental strategy an increase of environemental costs is observed when an import constraint on pulps is enforced. This is a plausible result if it is realised that in the earlier runs a shift to imported pulps took place to reduce environmental costs. Total cost is lower with a pulp import constraint because the import cost component of economic cost which had been prevented is higher than the environmental costs caused by domestic production.

In the case of the sustainable strategy an interesting result arises. Assuming a pulp import constraint in place, the model results indicate that an increase of 0.09 billion dollars in economic costs (primarily import cost) but a drop of 0.27 billion dollars in environmental cost. This then leads to the final observation that total cost in the sustainable strategy with no import constraint is lower than in the case with an import constraint. Another way of interpreting this result is that the import cost is lower than the environmental cost caused by the domestic production of pulps. The main pulp which was imported in the no import scenario was bleached mechanical pulp which logically was the cheapest pulp. In the case when an import constraint was placed, the imported mechanical pulp was substituted with locally produced unbleached sulfate pulp. The environmental cost produced by the domestic production of this pulp is higher than the import cost of mechanical pulp.

Also, attention was paid to employment effects. As the cost of unemployment in the model are not internalised, it would be useful to know if the first best solution identified above also gives the best employment figures. The comparison of strategies is limited to the sustainable strategies with and without imports of waste paper under regimes with and without a pulp import constraint. From Figure 6.9 it can be observed that the best employment figures are given under scenarios without import of waste paper while the worst situation is found in the first best solution identified (the sustainable strategy with import of waste paper under a regime without a pulp import constraint).

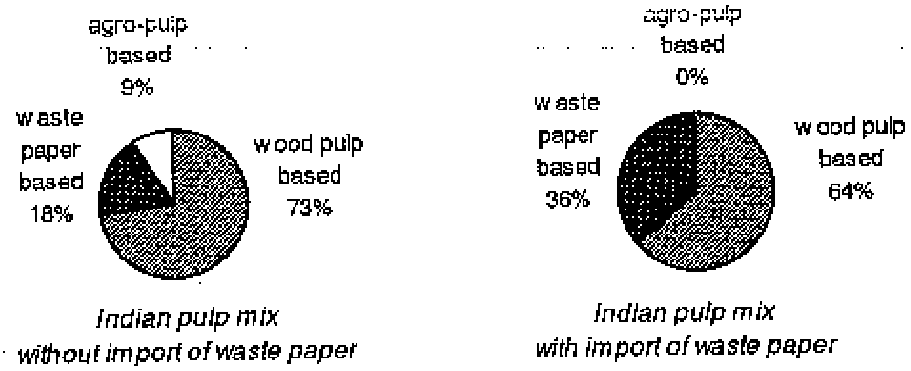
Figure 6.9 Employment figures under various strategies



Under the trade regime "with waste paper imports", the main pulping processes in operation are the waste paper based technologies (domestic and imported waste paper). These processes are over the whole life cycle relatively less labor intensive than the wood and agro based pulping processes. This is the reason why the employment figures are higher under the "no import of waste paper" scenarios where the wood and agro based processes are dominant. It may be an important policy result which dictates future investment policies towards paper based pulping processes. The case is further strengthened when a pulp import constraint is imposed. In this case, the use of domestic pulping processes is forced by the import constraint and therefore creates employment. These results are important at the national level where social costs of unemployment is an important factor. It should be highlighted here that there is a limited production capacity in the waste paper based pulping processes. The employment figures improve considerably when these constraints are relaxed.

The final element of interest is the pulp mix used under the various strategies in the final manufacture of paper. Differentiation is made for the final pulp use into three categories: (1) wood fiber pulp (WB); (2) agro-residue pulp (AB); and (3) waste paper pulp (WPB). The analysis is limited to the sustainable strategies with and without waste paper imports under a regime with no wood pulp import constraints. As Figure 6.10 illustrates, in the case when no import of waste paper is allowed, the final pulp mix is comprised of all three pulp types: wood, waste paper, and agro. However, in the case where import of waste paper is allowed, substitution occurs from imported wood pulp and domestic agro pulp to domestic produced pulp using imported waste paper. The waste recovery sector in India has long argued against the import of waste paper in fear of losing the demand for local waste paper by the paper industry. The preliminary results from the model seem to refute these arguments. The model results do not show a crowding out effect on local waste paper taking place.

Figure 6.10 Pulp mix with and without import of waste paper.



Strategies

One should be aware that the results discussed above are to a certain extent determined by the data used for the modeling exercise. The model developed for this exercise used exogenous prices for many of the inputs. This specification prevents us to investigate price effects on decision making. However, this weakness can and was mitigated by the use of sensitivity analysis on the prices of inputs which were identified as crucial to the model. This was also true for the cost parameters which we used for the various eco-profiles. It is stressed that the actual figures given by the model should not be used as forecast values if certain strategies are implemented. The results primarily give an indication of how and what would happen if certain policies are adopted. This is the major strength of this model.

6.5 Conclusions

Can trade in waste paper provide environmental and economic benefits to the Indian paper sector? The preliminary results from the sectoral model which was developed suggest that the answer to the question depends on the objective of the decision maker. If environmental criteria are the prime objective, then trade in waste paper is not the best solution. However, if economic criteria are the sole objective, then trade in waste paper is beneficial but is only part of the solution. However, if the reduction of both environmental and economic costs is the prime objective, trade in waste paper is crucial in the sector design process. In other words, if the paper sector is forced to internalize its environmental externalities, then trade in waste paper becomes a crucial variable in the industrial and environmental policy making.

A particular problem raised by the simulations is the question of employment. It was shown that with imports of waste paper, the employment situation in the paper sector in India worsens. However, this is primarily caused by the limited existing capacity in the paper based pulping processes and the results highlight a crucial bottleneck in the industry which needs to be addressed if trade in waste paper is to be maximized for the Indian paper sector.

The last point highlighted in the simulations is the pulp mix and the degree of substitutability between domestic waste paper and imported waste paper. The results show that there is no competition and that no crowding out effect takes place. The substitution occurs with agro and wood based pulp which is advantageous in many ways. A reduction in the demand for wood based pulp reduces the pressure on forest reserves. The reduction in demand for agro-residue highlights an area for future technological development. At present, agro-residue is cheap but is environmentally a disaster. The option is to find methods and technologies for reducing the environmental impact of this resource. In the long run, advances in technology in this area will further reduce the pressure on forests and would create an environment in which the use of waste, paper as well as agro, can be maximized.

Before finishing this chapter it should be pointed out that the model developed is still at its infancy and many of the linkages are represented in a simplistic manner. However, the main engine has been formulated and modifications to the existing model can be achieved with relatively little cost. The model has demonstrated the unique strength of incorporating a life cycle analysis with the option of choosing the optimal life cycle configuration for a particular sector.

6.6 Appendix

LIST OF SYMBOLS USED IN THE MODEL

Variables

z: Process level
b: Endogenous input-output
v: Import level
ru: Reuse level
w: Waste level
u: Domestic purchase level
ep: Emissions level
epf: Environmental profile
ec: Environmental costs
rc: Raw material costs
itc: Domestic waste paper costs
imc: Import costs
itc: Transportation costs
wdc: Waste disposal costs
tc: Total costs

Parameters

a: Input-output coefficients
p: Prices
$\overline{B}$: Upper bound on pulp mixture
$\overline{P}$: Pulping and paper making capacity constraints
$\overline{D}$: Final demand
$\overline{U}$: Upper bound on purchase of specified raw materials
$\overline{M}$: Middle distillate used in import of per unit of commodities
$\overline{E}$: Contribution of each unit of pollutant to each eco-profile
$E\overline{C}$: Cost per unit of eco-profile

Sets

C: Set of commodities
P: Processes

THE MATHEMATICAL MODEL

1. Material Balance Constraint on Raw Materials

$$\sum_{p \in PE \cup PS \cup PU \cup PP \cup PX} a_{c,p} z_p + u_c \geq 0 \qquad c \in CR$$

Total demand of raw materials by all processes must be less than the amount purchased domestically. We do not allow for the import of raw commodities in this version of the model. The processes are (PE: electricity production; PS: steam production; PU: pulping; PP: paper manufacturing and PX: Collection of waste paper, logging and agro-residue harvesting).

2. Material Balance Constraint for Fiber and Non-Fiber Materials

$$\sum_{p \in PRE} a_{c,p} z_p \leq \sum_{p \in PU} a_{c,p} z_p \qquad c \in CFB$$

The demand for wood and agro residue by secondary electric and steam production processes must be less than the supply of the fibers by the respective pulping processes which produce these fibers as a by-product. PRE: set of electric and steam production processes which use wood and agro residue fiber as inputs. PU: set of pulping processes.

3. Material Balance for Electricity

$$\sum_{p \in PRE \cup PE} a_{c,p} z_p \geq \sum_{p \in PU \cup PP \cup PO} a_{c,p} z_p \qquad c \equiv \text{"electricity"}$$

The supply of electricity by primary production methods as well as secondary processes must be greater than the demand for electricity by the pulping, paper manufacturing and other processes. PO: set of chemical producing processes which need electricity.

4. Material balance for Steam

$$\sum_{p \in PU \cup PP \cup PO \cup PX} a_{c,p} z_p \leq \sum_{p \in PS \cup PRE} a_{c,p} z_p \qquad c \equiv \text{"steam"}$$

The demand for steam must be less than the supply of steam.

5. Material Balance for Intermediate Tradable Commodities (Pulp)

$$\sum_{p \in PP} b_{c,p} z_p \leq \sum_{p \in PU} a_{c,p} z_p + v_c \qquad c \in CIT$$

The demand for each pulp type by all the paper making processes must be less than the total amount of the particular pulp produced by all the pulping processes plus imports. The b variable is the endogenous input-output coefficient for pulp making.

6. Material Balance for First Stage Intermediate Commodities

$$\sum_{p \in PU \cup PS} a_{c,p} z_p \leq \sum_{p \in PX} a_{c,p} z_p + v_c \qquad c \in CIIT$$

The demand for logs and agricultural residue by steam production processes as well as the pulping processes must be less than the supply from forest and agricultural residue harvesting activities plus imports. In the model, the import of agricultural residue is fixed to be zero. The v variable stands for imports.

7. Material Balance for Waste Paper

$$\sum_{p\in PU\cup PDW} a_{c,p} z_p + ru = \sum_{p\in PX} a_{c,p} z_p \qquad c \equiv \text{"wastepaper"}$$

The total use of domestic waste paper must be equal to the total amount collected. Waste paper can be either recycled, burned, land filled, or reused. The PDW process set consists of burning and land filling while the ru variable is for the amount reused. The PX process set has collection activities.

8. Material Balance for Imported Waste Paper

$$\sum_{p\in PU} a_{c,p} z_p = v_c \qquad c \equiv \text{"importedwastepaper"}$$

The import of waste paper is determined by the demand for imported waste paper by the pulping processes.

9. Paper Manufacturing Input-Output Coefficient Condition

$$\sum_{c\in IT} b_{c,p} = a_{\text{"pulp"},p} \qquad p \in PP$$

The summation of the different types of pulp used by each paper making process must equal to an exogenously specified amount.

10. Paper Manufacturing Input-Output Probability Matrix

$$\frac{b_{c,p}}{a_{\text{"pulp"},pp}} \le \overline{B}_{c,p} \qquad c \in CIT, \qquad p \in PP$$

The proportion of each type of pulp in each paper making process must be equal or less than an exogenously specified upper bound. For example, the proportion of bleached sulfite pulp in making writing paper must be equal or less than 40%.

11. Pulp and Paper Manufacturing Capacity Constraint

$$z_p \le \overline{P}_p \qquad p \in PU \cup PP$$

The activity level for each pulping and paper making process is constrained by existing capacity.

12. Material balance for Non-Tradable Intermediate Goods

$$\sum_{p\in PO} a_{c,p} z_p \ge \sum_{p\in PU\cup PP} a_{c,p} z_p \qquad c \in CINT$$

The supply of chemicals must be greater than the demand for these chemicals by the pulping and paper making processes.

13. Material Balance for Final Non-Reusable Goods

$$\sum_{p \in PP} a_{c,p} z_p + v_c \geq \overline{D}_c \qquad c \in CF$$

The total production level of each paper type by all paper making processes together with imports must meet final demand. This equation is for paper types which cannot be supplemented by the reuse of waste paper.

14. Material Balance for Final Reusable Goods

$$\sum_{p \in PP} a_{c,p} z_p + v_c + ruc_c \geq \overline{D}_c \qquad c \in CFR$$

The total production level of each paper type by all paper making processes together with imports and the reuse of waste paper must meet final demand. This constraint is for paper types which can be supplemented by the reuse of waste paper.

15. Total Waste Paper Generation

$$w = \alpha \sum_{c \in FT} \overline{D}_c$$

Total waste paper generated is equal to the recovery rate (α) multiplied by the total amount of paper used (the final demand).

16. Material Balance for Waste Paper

$$\sum_{p \in PX} a_{\text{"wastepaper"},p} z_p = w$$

The amount of waste paper collected must be equal to the waste generated. We make a distinction between equation 16 and 7 because a certain amount of loss in mass occurs between total mass of waste paper generated and the total mass of waste paper collected. The difference is accounted as an increase in solid waste material which in turn will be captured in the emission equations.

17. Reuse Level

$$ru \leq 0.3w$$

The total amount of waste paper which can be reused to meet final demand of a certain type of paper is less than 30% of the total waste paper generated.

18. Raw Material Constraint

$$u_c \leq \overline{U}_c \qquad c \in CRC$$

An exogenously specified upper bound is imposed on the purchase of a sub-set of raw materials. The raw materials are trees for logs and agricultural waste for agricultural residue.

19. Final Good Import Constraint

$$\sum_{c \in FT} v_c \leq 0.2 \sum_{c \in FT} \overline{D}_c$$

The total import of all paper types must be less than 20% of final demand. In other words, at the minimum, 80% of final demand must be met by local supply.

20. Middle Distillate Used in Transport

$$\sum_{p \in PDI \cup PX \cup PP} a_{c,p} z_p + \sum_{c \in IT, CFT, \text{"importedwastepaper"}} v_c \overline{M}_c = md$$

The total amount of middle distillate is equal to the amount used by domestic processes plus amount used in transportation for imported goods.

21. Emissions from Transport

$$et_c = a_{c,\text{"middledistillate"}} md \qquad c \in CE$$

The total emissions of various pollutants caused by transportation.

22. Emissions from Paper Production

$$\sum_{p \in PE \cup PS \cup PC \cup PP \cup PX \cup PRE} a_{c,p} z_p = ep_c \qquad c \in CE$$

The total emissions of various pollutants accruing from all domestic production processes.

23. Eco-Profile

$$\sum_{c \in CE} \overline{E}_{c,p} \left(et_c + ep_c \right) = epf_p \qquad p \in ENVP$$

The total contribution by all the pollutants from the transport and production processes towards each environmental problem.

24. Environmental Costs

$$ec = \sum_{p \in ENVP} epf_p \overline{EC}_p$$

The total costs caused by all the environmental problems.

25. Raw Material Costs

$$rc = \sum_{c \in rm} u_c p_c^d$$

Total costs of raw materials.

26. Domestic Waste Paper Costs

$$itc = \sum_{p \in PU} \left(a_{\text{"wastepaper"},p} z_p \right) p^d_{\text{"wastepaper"}}$$

Total costs of buying waste paper for pulping processes. We distinguish wastepaper from raw materials as it is a secondary good. prices used are domestic prices.

27. Import Costs

$$imc = \sum_{c \in TT \cup CFT \cup CRT \cup \text{"importedwastepaper"}} v_c \, p^I_c$$

Total costs of all imports which include waste paper, pulp, logs, and final paper types. Prices used are international prices.

28. Transportation Costs

$$ttc = \sum_{p \in PX \cup PT \cup PDW} a_{\text{"middledistillate"},p} z_p \, p^d_{\text{"middledistillate"}}$$

Total costs of transport of final goods, waste paper collection, and waste paper disposal.

29. Waste Disposal Costs

$$wdc = \sum_{p \in PDW} z_p p^d_p$$

Total costs incurred for burning or land filling of waste paper.

30. Total Costs

$tc = ttc + wdc + imc + itc + rc + ec$

Final total costs for the sector is the summation of all costs.

MEANING OF SYMBOLS

SET OF ELECTRIC PRODUCTION

GASE	Natural Gas
BCOALE	Brown Coal
HCOALE	Hard Coal
MDISTE	Middle Distillate

SET OF STEAM PRODUCTION

GASS	Natural Gas
FLIGHTS	Fuel Light
FHEAVYS	Fuel Heavy
BCOALS	Brown Coal
HCOALS	Hard Coal
DCOALS	Derived Coal
MDISTS	Middle Distillate
WOODS	Wood

SET OF RECYCLED ENERGY PRODUCTION PROCESSES

WDRES	Wood Residue
AGRRES	Agro Residue

SET OF PULPING PROCESSES

BSFI	Bleached sulphite
UBSFA	Unbleached Sulphater
UBW	Unbleached Local Waste Paper
UBIW	Unbleached Imported Waste Paper
BSFA	Bleached Sulfate
BA	Bleached Agro

SET OF PAPER PROCESSES

WRITE	Writing Paper
KRAFT	Kraft
BOARD	Board
NEWPNT	Newsprint
OTHER	Other

SET OF OTHER PROCESSES

SCHL	Production Of Sodium Chloride
TIT	Production Of Titanium Dioxide
LSTONE	Production Of Limestone
LIME	Production Of Lime
SODOX	Production Of Sodium Hydoxide

SET OF EXTRA PROCESSES

COLL	Collection Of Waste Paper
HARV	Sawmill
HARVA	Agro Harvesting

SET OF WASTE PAPER ELIMINATION PROCESSES

BURN	Burning.
DECOMP	Decomposition

ENV ECO EFFECTS

GWP	Global Warming Potential
HCP	Human Toxity
WTR	Water Pollution
AP	Acidification
SW	Solid Waste Toxicity

COMMODITY

LAB	Labor,
CAP	Capital,
TR	Tree,
CAO	Lime,
NAOH	Sodium Hydroxide,
RSTM	Recycled Steam,
NG	Natural gas,
FL	Fuel Light,
FH	Fuel Heavy,
BC	Brown Coal,
CACO3	Limestone,
HC	Hard Coal,
NACLO3	Sodium Chloride,
DC	Derived Coal,
O2	Oxygen,
H2O2	Peroxide,
SO2	Sulphur Dioxide,
SO2O	Sdioxide Output,
STM	Steam,
CL2O	Chlorine Output
ELECT	Electric,
S2	Sulphur,
RELECT	Relectric,
H2O	Water,
BSFIP	Sulfite Bleached Pulp,
BMP	Bleached Mechanical Pulp,
BSFAP	Bleached Sulphate Pulp,
UBWP	Unbleached waste Pulp,
BAP	Bleached Agro Pulp,
UBIWP	Unbleached imported waste paper pulp,
UBSFAP	Unbleached Sulfate Pulp,
PLP	Pulp,
PCLES	Particulates,
CO2	Carbon Dioxide,
CO	Carbon Monoxide,

COMMODITY (continued)

MD	Middle Distillate,
NOX	Nitrous Oxide,
TIO2	Titanium Dioxide,
VOC	Volatile Organic,
NH3	Ammonia,
MGSO4	Magnesium Sulphate
CL2	Chlorine,
AOX	Chlorinated Organic Compound,
TRS	Reduced Sulphur Compounds,
SWM	Soild Waste Muncipal,
SWI	Solid Waste Industrial,
BOD	Biological Oxygen Demand,
COD	Chemical Oxygen Demand,
DS	Dissolved Solids,
H2SO4	Sulphric Acid,
HCL	Hydrochloric Acid,
NA2SO4	Sodium Sulphate,
WRT	Writing Paper,
KFT	Kraft,
BRD	Board,
NWP	Newsprint,
OTH	Other,
BK	Bark,
WP	Waste Paper,
WPF	Waste Paper Final,
LG	Logs,
MTH	Methanol,
SIL	Silicate,
ACE	Acetic Acid,
FUF	furfural,
WW	Waste water,
PHOS	Phosphorus,
POIL	Pine Oil,
TPT	Turpentine,
H2SO4O	Sulphuric Acid Output,
HCLO	Hydrochloric Acid Output,
NA2SO4O	Sodium Sulphate Output,
AGR	Agro-Residue,
CH4	Methane,
HCO	Carbon Hydrates
AGRF	Agro Residues Final,
IWPF	Imported Waste Paper,
WDR	Wood Fibre,
AGRR	Agro Residue Fibre.

THE DATA

TABLE INPUT-OUTPUT FOR ELECTRICITY PRODUCTION.

	GASE	BCOALE	HCOALE	MDISTE
NG	-0.20			
BC		-0.91		
HC			-0.35	
MD				-0.24
ELECT	1	1	1	1
CO2	0.52	1.12	1.02	0.75
CO	0.0002	0.0003	0.0001	0.0002
NOX	0.002	0.003	0.003	0.002
SO2O		0.004	0.001	0.002
VOC	2.8E-05	2.8E-05	2.8E-05	2.7E-05
SWM	0.57	0.05	0.0004	

THE INPUT-OUTPUT MATRIX FOR STEAM PRODUCTION.

	BCOALS	HCOALS	FHEAVYS	FLIGHTS	MDISTS
BC	-0.11				
HC		-0.14			
FH			-0.03		
FL				-0.03	
MD					-0.03
STM	1	1	1	1	1
PCLES	0.0003	0.0001	3E-05	5.5E-07	3E-05
CO2	0.3	0.13	0.09	0.09	0.09
CO	0.0002	0.0001	7E-06	2E-05	7E-06
NOX	0.0002	0.0003	0.0002	1E-05	9E-05
SO2O	0.0009	0.0006	0.002		0.0002
VOC	5E-05	2E-05	10E-06	1E-05	9E-06
SWM	0.008	1.27	5E-05	4E-05	4E-05

THE INPUT-OUTPUT MATRIX FOR STEAM PRODUCTION (continued).

	GASS	WOODS	DCOALS
NG	-0.02		
LG		-8E-05	
DC			-0.04
STM	1	1	1
PCLES		0.0002	2E-05
CO2	0.06	0.14	0.13
CO	8E-06	0.001	0.0001
NOX	8E-05	0.0001	0.0001
SO2O		6E-06	0.0003
VOC	9E-06	0.0002	2E-05
SWM		0.001	0.002

INPUT-OUTPUT FOR RECYCLED ELECTRIC AND STEAM

	WDRES	AGRRES
WDR	1	
AGRR		1
ELECT	548	369
STM	6124	8890
NOX	0.42	1.3
PCLES	0.12	0.38
SO2O	0.01	0.05
CO2	365	1170

UPPER CONSTRAINT ON SUPPLY OF LOGS AND AGRO RESIDUE

TR	5.4E+6
AGR	9.2E+6

DEMAND FOR FINAL PRODUCTS

WRT	1107000
KFT	729000
BRD	459000
NWP	720000
OTH	100000

INPUT-OUPUT FOR PULP PRODUCTION

	UBSFA	BSFA	BSFI
FH	-5.2		
NG	-37.5	-42.6	
LG	-4.055	-4.837	-4.731
CAO	7.89	9.47	
H2SO4	-5.56	-5.90	
NA2SO4		-6.26	
NACLO3		32.10	
NAOH	4.89	29.53	39.89
O2		-13.86	-15.69
S2			-11.09
SO2		-3.3	-36.00
H2O	-11769	-56103	-45176
HCL		-7.98	
MTH		-2.21	
MGSO4		-1.32	-13.69
ELECT	737	899	908
STM	13519	14605	18235
LAB	-19.24	-20.15	-20.15
ACE			146.22
FUF			39.3
PCLES	0.104	0.16	0.774
CO2	1894	2670	1031
SO2O	2.16	3.06	5.29
TRS	0.94	1.35	
CL2O		0.10	
NA2SO4O		9.54	
DS	1.85	10.17	5.95
BOD	2.33	9.7	50.92
COD	48.55	199.07	78.54
AOX		3.85	0.43
WW	60251	265529	198833
PHOS	0.48	0.21	
POIL	128.46	38.98	
TPT	9.26	2.77	
SWI		70	81.8
SWM	20	20	
UBSFAP	1.0		
BSFAP		1.0	
BSFIP			1.0
WDR	1.756	2.205	2.145

INPUT-OUPUT FOR PULP PRODUCTION (continued)

	UBIW	UBW	BA
IWPF	-1.125		
WPF		-1.300	
AGRF			-3.0
NACLO3			6.82
NAOH			40.91
H2O	-13333	-15409	
ELECT	742	857.9	848
STM	1761	2035.58	15453
LAB	-10.4	-10.4	-26.46
ACE			48.74
FUF			13.1
PCLES			0.35
CO2			1864
SO2O			3.5
TRS			0.76
CL2O			0.03
NA2SO4O			3.18
DS	25.71	29.71	27.29
BOD	30.85	35.65	183.85
COD	66.77	77.17	386.87
AOX			2.67
WW			415425.5
SWM	75.97	87.80	75.97
UBIWP	1.0		
UBWP		1.0	
BAP			1.0
AGRR			1.15

INPUT-OUTPUT FOR PAPER PRODUCTION

	WRITE	KRAFT		BOARD	NEWPNT	OTHER
PLP	0.928	0.951	0.919	0.916	0.916	
TIO2	72.2	48.8		81.47	83.88	83.88
CACO3	9.03	6.11		10.18	10.49	10.49
CAO	9.03	6.11		10.18	10.49	10.49
ELECT	841	769		706	1340	942
STM	5407	5167		4205	2824	5722
LAB	-9.37	-9.37		-9.37	-9.37	-9.37
DS	2.30	2.30		2.3	2.3	2.3
BOD	10.79	10.79		10.79	10.79	10.79
COD	21.23	21.23		21.23	21.23	21.23
AOX	0.14	0.14		0.14	0.14	0.14
WW	22067	22067		22607	22607	22607
WRT	1.0					
KFT		1.0				
BRD				1.0		
NWP					1.0	
OTH						1.0

PULPING CAPACITY CONSTRAINT

UBSFA	1.4E+6
BSFA	0.9E+6
BSFI	0.03E+6
BA	0.9E+6
UBW	0.4E+6
UBIW	0.4E+6

INPUT-OUTPUT FOR PRODUCTION OF OTHER MATERIALS

	SCHL	TIT	LSTONE	LIME	SODOX
ELECT	5.8	0.04	0.09	0.56	0.004
STM	2.68	16.9	0.18	6.9	13.77
NACLO3	1				
TIO2		1			
CACO3			1		
CAO				1	
NAOH					1

INPUT-OUTPUT FOR PRODUCTION OF OTHER MATERIALS

	SCHL	TIT	LSTONE	LIME	SODOX
ELECT	5.8	0.04	0.09	0.56	0.004
STM	2.68	16.9	0.18	6.9	13.77
NACLO3	1				
TIO2		1			
CACO3			1		
CAO				1	
NAOH					1

INPUT-OUTPUT COEFFICIENTS

	COLL	HARV	HARVA
AGR			-1.075
TR		-1.538	
WP	-1.087		
FL	-0.027	-0.29	-0.044
LAB	-34.8	-6.2	-2
MD		-3.98	-0.6
PCLES	0.001	0.01	0.003
CO2	111.89		
CO	0.0005	0.21	0.05
HCO	0.0002		
NOX	0.001	0.14	0.04
SO2O	0.001		
SWM	87.84		75
WPF	1.0		
VOC		0.13	0.03
HCLO			
LG		1.0	
AGRF			1.0

INPUT-OUTPUT COEFFICIENTS

	BURN	DECOMP
WPF	-1.0	-1.0
FL		-0.056
LAB		-2.7
PCLES		0.002
CO2	940	223.78
CO	1.4	0.001
HCO		0.0005
NOX	1.51	0.002
SO2O	1.3	0.002
SWM	87.84	55.87
VOC	0.3	

INPUT COMBINATIONS FOR PULPS

	WRITE	KRAFT	BOARD	NEWPNT	OTHER
BSFIP	1	0	1	1	0
BSFAP	1	0	1	1	0
BMP	0.75	0	0.8	1	0.8
UBWP	0.1	0.8	0.4	0.7	0.4
BAP	0.75	1	1	0.8	0.8
UBIWP	0.2	1	0.5	0.9	0.5
UBSFAP	0.3	1	0.4	0.7	0

PAPER PRODUCTION CAPACITY CONSTRAINT

WRITE	1.2E+6
KRAFT	0.9E+6
BOARD	0.5E-6
NEWPNT	0.4E-6
OTHER	0.11E-6

COSTS FOR BURNING AND LANDFILL

BURN	0
DECOMP	45

DOMESTIC PRICES FOR RELEVANT COMMODITIES

TR	84
NG	0.092
FH	0.186
DC	0.05
MD	0.500
FL	0.667
HC	0.70
BC	0.02
WPF	160
AGR	39
O2	0.525
H2O2	0.525
SO2	0.525
S2	0.525
DTPA	0.525
MGSO4	0.525
H2SO4	0.525
NA2SO4	0.525
HCL	0.525
MTH	0.525
SIL	0.525

EMISSIONS FOR TRANSPORT

	MD
PCLES	0.026
CO2	7.41
CO	0.001
HCO	0.001
NOX	0.004
SO2O	0.05

IMPORTED PRICES

LG	153
BSFIP	675
BSFAP	760
UBSFAP	697
UBWP	1E+6
IWPF	287
BMP	670
AGRF	1E+6
WRT	1303
KFT	743
BRD	774
NWP	1192
OTH	500

ECO-PROFILE

	GWP	HCP	WTR	AP	SW
PCLES	1.6	0.42			
CO2	1				
CO		0.02			
NOX		0.78		0.7	
VOC		1.6	0.42		
CL2O		0.33			
AOX			0.2		
BOD			0.17		
COD			0.03		
ACE		0.04	0.443		
SO2O		0.77		1	
HCLO		0.14		1.88	
SWM					1
SWI				1	
TRS		1.0			
DS			0.001		
FUF		0.125			
WW		1			
PHOS		0.007			
POIL			0.001		
TPT			0.1		
H2SO4O		1			
NA2SO4O		0.1			
CH4	6				
HCO		1.6			
NH3		0.06	0.05	1.8	

SCALAR CHEMP CHEMICAL PRICES AND ALPHA

CCP	0.525
ALPHA	0.55

Chapter 7.

CONCLUSIONS AND POLICY RECOMMENDATIONS

V.K. Sharma
Pieter van Beukering
K.V. Ramaswamy

7.1 Introduction

The main objective of this study was to determine the economic, social and environmental impact of international trade of waste paper for recycling purposes between industrialized and developing countries. In course of time it became clear that this fairly innocuous discussion encompassed a task of a much broader dimension than originally foreseen. It requires an in-depth coverage of international, national as well as local issues related to the trade and recycling of wastes. This broad perspective resulted not only in a comprehensive overview of economic, social and environmental factors related to the waste paper cycle in India, but also in the paper recycling processes abroad. In addition to revealing useful empirical findings, the study provided a broad analytical framework for exploring international trade in waste paper which could be generalized for trade of other secondary materials.

In terms of methodology, the study did not develop any novel approach. The techniques applied are fairly standard. Also, the issues discussed in this study are not entirely new in the field of environmental economics. Yet, it is the integrated approach to the problems addressed which makes the study important. First, it contributes to the limited literature on the impact of international trade of recyclable wastes on the economy and environment of developing countries. Second, it provides a better understanding of the socio-economic and environmental aspects of solid waste management and recycling in developing countries. An attempt has been made to suggest inter-relationship of these aspects, both qualitatively and quantitatively.

This Chapter is organized as follows. First, the preliminary results and conclusions of the study are summarized in Section 7.2. Then, section 7.3 presents the suggested policy recommendations at the relevant operational levels, namely, international, national and local. Finally, in section 7.4 some suggestions have been made for the future research in this area.

7.2 Results and conclusions

7.2.1 International waste paper trade

The study first documented the trends in the international trade, recovery and utilization of waste paper. Developing countries are found to be net importers and the developed countries are net exporters of waste paper. During the last two decades, a substantial increase in the volume of internationally traded waste paper is found along with an increase in both recovery and utilization rates of waste paper across countries. Determinants of inter-country differences in recovery rates and utilization rates were examined, using time series data on a cross section of 45 countries. Per capita GDP and utilization rate are found to be significant determinants of recovery rate for the group of developing countries but not for the developed countries. This supports the hypothesis that the recovery of waste paper in developing countries is a much more market driven phenomenon than in high income countries. Cultural and institutional factors become important once a certain level of income is reached. Expectedly, the rate of utilization of waste paper is found to be lower in countries with a high per capita forest area. The importance of relative prices of waste paper, that is relative to virgin materials and the quality of domestically recovered waste paper as determinants of utilization rates, are emphasized. Next the study focussed on the Indian paper industry in detail.

7.2.2 The Indian paper cycle

In 1993, India emerged as the 17th largest producer of pulp and ranked 20th in terms of production of paper and board in the world. However, the per capita consumption of paper and board in the country is very low at 3 to 4 kilograms per annum (for 1995). Rapid urbanization, increasing literacy rates and industrial development are expected to create a growing demand for paper and paper products. The study revealed that India produces a variety of paper types using both conventional and non-conventional raw materials. Utilization of non-conventional raw-materials (i.e., agro residues and waste paper) has been rising due to increasing depletion of forest based raw materials. The share of wood pulp based paper declined from 65 % in 1985 to 49 % in 1992. During the same period the share of waste paper based paper rose from 13 % to 22 %. The principal users of waste paper are small paper mills. Government policies actively encouraged the formation of small paper mills by liberalizing import of second hand machinery and fiscal concessions. India's average waste paper utilization rate (for 1990-91) of about 29 % is low in comparison to the global average of 36 %. This is partly because the recovery rate is also found to be low. India recovered only 14 % of its total paper consumption in contrast to the global recovery rate of 37 % in 1990-91. Diversion of recovered waste paper for cheaper grocery packing purposes further reduces the recycling levels. Domestic supply is augmented by the imports of waste paper. Utilization of imported waste paper is increasing because of its longer fibre length and thus better quality.

Imports of waste paper currently constitute 60 % of India's imports of pulp and waste paper. Landed cost of both imported pulp and waste paper is found to have risen sharply in recent years, partly due to exchange rate devaluation, making imported waste paper costlier relative to domestic waste paper. The current imports of waste paper in India are around 250,000 tonnes annually and it is estimated that in the near future India will require about one million tonnes of waste paper annually. Waste paper utilization rate in

India is much higher than the recovery rate. Evaluation of the impact of waste paper imported to meet this gap required an analysis of recovery systems (aspect of domestic supply) as well as the demand from paper mills.

In general, environmental impact of waste paper based production in India was found to be positive. Average water consumption in waste paper base mills is only 125 M^3 in comparison to around 275 M^3 or more per tonne of paper produced for wood and agro-based mills. This obviously reduces volume of waste water discharge. Absence of digesting chemicals and black liquor as byproducts during the production process reduces the strength of waste water upto an extent of 3 to 10 times than that of paper produced with non-waste paper mills. Solid waste generated is also much lower. Similary average power consumption in most of the waste paper based mills is 3-4 times less than for other raw materials. These advantages, coupled with economic merits, have encouraged the use of more and more waste paper as raw material in India. Environmental policy of the government of India has been framed for all round improvement of the environmental quality. This has its impact on paper industry also. Stricter enforcement of environmental standards has forced the small mills to switch from agro-residues to waste paper because of lower pollution levels associated with waste paper usage.

7.2.3 Waste paper recovery

Utilization and recovery of waste do not grow at similar rates in India. Low levels of waste generation and lack of policy interest in increasing waste recovery lead to a lack of waste paper for the Indian paper industry. But not only is increasing recovery essential for the recycling industry in India, improvement of the recovery rate appears to be one of the most efficient solutions to the growing problem of urban solid waste. An assessment of waste management systems in developing countries revealed that the city municipalities in developing countries have insufficient financial resources to manage the growing burden of solid waste. In this study, an illustration was developed to indicate that an increase in the recovery can often be an efficient solution to the growing problem of uncollected urban solid waste. In practice, however, municipalities in developing cities only concentrate on the improvement of the existing waste collection, processing and landfilling practices.

A case study for Mumbai (India) is presented in which the possibilities for improved recovery in developing cities is explored. For this purpose, a simulation model of the waste paper cycle in Mumbai is developed which contains both a formal and an informal sector. The informal recovery sector consists of various actors such as waste pickers, itinerant waste buyers and a comprehensive trading network. This group is mainly driven by market forces. The formal waste sector is managed by the municipality and operates on public funds.

Two policy options under varying degrees of public response are considered: the encouragement of the existing informal recovery sector and introduction of a western style recovery system. Extrapolations of four type of effects are provided for a period till 2010. First, employment effects in the formal and informal waste sectors are considered. Second, the environmental impact of transport, landfilling and waste burning is analysed. Third, public expenditures which include landfill and recovery cost are determined. Finally, the income distribution effects of the different policy scenarios are assessed. Simulations with the model indicate that policy makers in developing cities should be reluctant to introduce a Western collection system unless they are sure about a significant positive response of the public. As yet, the probability that the public in developing countries is anxious to voluntarily separate their waste without financial compensation is limited. In fact, it seems better to do nothing (the base line scenario) than to initiate a Western recovery system. Promoting informal recovery seems to be a cost-effective and environmentally optimal policy measure. The municipal costs of this policy are limited while at the same time landfill costs are avoided in case of a succesful campaign. A paradoxical finding of the study is that waste pickers who are generally considered as the engine of the informal recovery sector suffer as much from the informal than the formal recovery policies. Their role is substituted by the generators of waste such as households and institutions. A trade-off exists between economic and environmental gains on the one hand and social costs on the other.

The main conclusion of the waste study is that the present trade network forms a solid foundation for the improvement of the recovery rate. Replacement of this informal network with a Western collection system may have devastating effects. It would be a classic case of an attempt at intervention without knowing the local circumstances, overlooking the informal traditions, and ignoring market forces. The disadvantage of a market driven informal sector is the vulnerability to demand and price fluctuations. The surveys suggested that in the short to medium term, the supply of domestic waste paper is fixed provided there is no dramatic change in the recovery rates of domestic paper waste. Lack of data precluded an analysis of determinants of trends in domestic waste prices. However, restricting imports may not be the first best solution.

7.2.4 Waste paper utilization

A comprehensive survey of paper mills using non-conventional raw materials was carried out to collect the technical, financial and production data. As waste paper is an input to the paper industry, their demand for waste paper is a derived demand. A paper mill's demand for waste paper is derived from the demand for its output. The derived demand for inputs depend upon the substitution possibilities among inputs allowed by the production technology and the relative prices of all inputs. The cost function approach was used to estimate the elasticities of substitution and price elasticities of demand. The econometric estimates suggest limited substitution possibilities between domestic and imported waste paper. The low values of elasticities indicate that the flexibility of the production structure to respond to relative price changes is very limited. Consequently unpredictable changes in the relative input prices is likely to result in high adjustment costs. This is consistent with the reported findings from the surveys of paper mills that domestic waste paper is of a lower quality and furnish and needs to be mixed with imported waste paper to maintain the fibre strength and upgrade the quality of the end product. It was also documented that the Indian paper industry is saddled with obsolete capital equipment and technology.

7.2.5 Overall economic and environmental effects

Finally, the main question was addressed whether the increasing pressures by governments and NGOs to restrict international trade in waste in the conviction that each nation has to take care of its own waste, is justified. A static material balance flow model was developed to investigate if free trade in waste paper to India can support economic development and simultaneously reduce environmental degradation. The model describes the various stages of paper production starting from logging to pulping and paper production, transport of inputs and outputs, and waste disposal. At each stage, the environmental impacts are tabulated and the cumulative impact is transferred into monetary values by applying values of existing studies. The paper cycle in India form the boundaries of the model. The model was formulated as an optimization problem with an objective function which minimizes economic and environmental costs, either seperately or combined.

The results indicate that with increased trade in waste paper the environmental impacts are less than those without free trade. For example, the environmental benefits of increased waste paper recycling exceed the environmental costs accruing from increased transport. Economically, the paper sector in India benefits from free trade in waste paper as a result of a more stable supply of raw materials. At the same time, the domestic waste recovery does not suffer from foreign imports due to the small substitutability betweem domestic and imported waste paper in the final production of paper. Foreign waste paper is of a better quality and therefore can upgrade the products of the Indian waste paper recycling industry, without substituting the local supply of waste paper.

7.3 Policy recommendations

The study raised several policy issues and many of them are independent of each other because of the differences of operational levels of waste paper and socio-economic structure and environmental conditions in exporting and importing countries. For example, the issue of general appropriateness of trade of secondary materials is international while the analyses of effects of this trade on paper industry in the importing country is predominantly a national issue. Yet, it was also shown that the impact of national policies in industrialized countries may have various implications on the recovery and utilization of secondary materials in developing countries. As a result, it seems difficult to formulate a consistent set of policy recommendations which involve international, national and local scales. In view of this, some policy recommendations at different levels is suggested below.

7.3.1 International policies

At the international level, policy interventions affect trade and recycling of secondary materials in two principal ways. First, international agreements such as the Basel Convention have a significant impact on trade of recyclables by developing international laws. Since the study deals with waste paper which is considered a relatively "green" material, it does not come under the purview of the Basel Convention. Yet, for many other waste materials, a tendency can be recognised in which international trade of waste is increasingly rejected. This trend is initiated by incidents of illegal exports of hazardous and unrecyclable wastes under the disguise of recyclable wastes. Thus, international agreements are required to find a workable solution to prevent such undesirable dumping practices. At the same time these should avoid restrictions on the beneficial transfers of intermediary goods between countries. The core-issue in this matter is to develop an appropriate definition for "hazardous waste" and "secondary materials". Another recommendation focuses on the institutional framework in which trade in secondary materials occurs. At present no appropriate formal infrastructure for trading of secondary materials exists. A formal trading system could alleviate the uncertainty and unpredictability of the waste supply and prices. The first steps towards such a trading system are initiated by the Recycling Advisory Coalition and the Chicago Board of Trade.

Second, national governments intervene in international transactions by creating trade barriers through the establishment of import and export tariffs or quota on secondary materials. Several arguments were found which opposed such policies. Export controls on secondary materials may yield short-term economic gains, but only at significant long-term and environmental costs. Export restrictions depress the price of secondary materials and thereby discourage recovery. Theory teaches that liberalization of waste trade flows between countries so that it benefits all sides. It explains that it is in the interests of all partners - importers and exporters of recyclable waste - to liberalize the trade, because markets would be bigger, thus making recycling operations more attractive and ultimately leading to conservation of natural resources. In addition, the increase in the volume of international waste markets reduces the price fluctuations which presently hamper the global recycling industry. Instability particularly harms the importing countries, because of the considerable downstream effects caused by the lack of raw materials. It should be realised that increased imports of secondary materials can very well have positive net effects on the balance of trade in developing countries as it may offset the import of virgin materials which are generally more expensive. These theoretical arguments were generally confirmed in the study on waste paper trade to India. Yet, as always, caution is required in generalising these conclusions over other recyclable waste materials. Each material probably has different environmental and economic effects.

7.3.2 National policies

On the national levels, a distinction is made between policies in industrialized and developing countries. In the industrialized countries, the following policy related issues need to be addressed. In the late 1970s, it was concluded that markets without government's interventions fail to recycle waste materials consistent with the maximization of social welfare. A number of countries in the North have chosen to set recycling targets, usually without attempting to determine the economically "optimal" recycling level. This is the level where the marginal costs of recycling equal the marginal benefits. Until recently, increasing recyclable waste collection levels led to increased instability on the markets for secondary materials. This situation has improved as the recycling sector has gradually left the "infant" stage. Demand for secondary materials has developed rapidly, providing a mature balance with the increasing recovery in industrialized countries. This was partly the result of demand side policies, yet more important was the recognition of benefits of recycling by the private sector.

Constrained by the limited funds, government policies on recycling in developing countries are much less profound. Neither in the recovery nor in the utilisation of secondary materials have governments played a decisive role. The recycling sector in developing countries is generally much more driven by private initiatives. Particularly in developing countries, recycling has an important part in the process of increasing industrialization. Primary materials are generally more expensive, require more energy and are more polluting in the production process than secondary materials. Also the technologies used in recycling processes are often less sophisticated. The major constraint for recycling in developing countries is the lack of a stable supply of raw materials. As consumption levels are low, so is the recovery rate of recyclable waste. The gap between domestic supply and demand of secondary materials can very well be met by foreign sources. Not only can waste imports stabilize domestic fluctuations, it can also upgrade the low quality of secondary materials generated by the local market. All these arguments support the elimination of trade barriers on recyclable wastes. Increasing dependency on foreign inputs does not form a significant threat to industrial development because, due to the increasing volume of the international market of recyclable waste, instabilities are bound to reduce in the future.

Besides adapting trade policies, governments in developing countries should also directly promote the recycling industry. An important aspect which has not been discussed very extensively is the technological performance of the recycling industry. For paper production, technological limitations to recycling have largely been overcome in the last decade. As a result, cost-competitiveness between virgin and secondary paper making improved. Due to innovations in deinking technologies, the quality of recycled paper is almost similar to certain type of virgin paper. Also, technologies for chemical recovery in the paper production process have improved. However, as a result of the high capital costs and the relatively less strict enforcement of environmental regulations in developing countries, these "best available technologies" are not yet widely implemented in developing countries. Therefore, recycling policies should receive more attention in developing collaborative projects dealing with technology transfer from the North to the South. Also, policies which are not specifically directed to recycling such as policies affecting the pricing of virgin materials can have important influences on waste recovery.

7.3.3 Local policies

Similar to the policies at the national level, the local policies can be diffrent for the North from those for the South. For industrialized countries, international trade of secondary materials may lead to increase, or at least maintain, their recovery rates. Such policy targets have been under threat recently. The glut in the waste paper markets in North America and Europe dramatically increased the cost of recycling programs. Alternative management options, such as waste paper incineration, were considered by a number of municipalities in the North. This caused considerable distrust among consumers about the usefulness of their voluntary support in separating their waste. Globalization of the market for secondary materials may cause an additional demand for the separated waste in the North.

In developing cities, solid waste is a significant and growing problem. The current system of waste management in most developing cities prove to be very inefficient. Only part of the solid waste is collected by the municipalities. Uncontrolled landfill disposal and illegal waste burning are pervasive problems that cause a range of external costs, such as cost of human health hazards. Most developing cities are serviced by an informal sector which operates parallel with the formal waste disposal authorities. This sector, which is fully driven by market forces, prevents significant quantities of municipal waste going to the dumpsite or lying idle. Still, developing countries are not able to recover at a similar rate as industrialized countries. For waste paper, this can be partly attributed to the relatively high re-use rate of secondary material. It is a very common practice in India to use waste paper for loose and cheaper consumer packagings. However, the major reason for the low recovery rate is inefficiencies in the waste recovery system. The inefficiencies can be overcome by developing policies which build on the existing informal recovery sector. One way of doing this is to have residents pay for the disposed waste collection. Yet, the administrative burden of such a system should not be underestimated. Alternatively, public campaigns for waste seperation at the source could support increased recovery. In doing this, policy makers should be aware that campaigns are particularly succesful if the economic advantages of seperation are highlighted by stressing the existence of the waste networks in most cities. Adoption of the Western recovery system does not seem to be a feasible option in developing countries as this would require tremendous voluntarism of the urban population, which, given the high levels of poverty and illitracy, is rather unlikely to happen.

The advantages of separation at the source are a reduction of the volume of municipal solid waste and the increase in volume of uncontaminated secondary materials of a relatively high quality. The only drawback of this separation at the source is that the waste pickers, who are dependent on the recyclable waste which is disposed by households and institutions, may be affected seriously as they will have either no waste or less waste to pick. However, the increased unemployment among waste pickers can be compensated for by the growth in labour demand by the expanding waste trading network and recycling industries.

7.4 Suggestion for additional research

Although this study focussed on waste paper in India, in general, it provides a framework which may facilitate the analysis of other traded secondary material flows in similar developing countries. Additional research would enable to test the desirability of waste trade in more rigorous manner. There are several aspects which are required to be investigated thoroughly to know whether developing countries really retain a comparative advantage in recycling and what factors underlie such a distinctive property. Some of them are enumerated as follows:

First, based on the current study, conclusions with regard to the sustainability of free trade of recyclable materials are limited to one type of waste i.e. waste paper only. Secondary materials encompass a large range of materials with each having a different impact on the environment and the economy. For example, waste paper is harmless in terms of toxicity. Therefore, waste paper is not subject to the Basel Convention. Many other recyclable materials such as metal scrap and plastics fall under the Basel Convention because of their hazardous image. Such regulatory constraints can have a significant impact on trade. Also, waste paper only comprises one part of the recyclable waste collected in urban areas. Thus its importance for the local recycling sectors in developing countries is not dominant. For example, in India it was found that waste paper provides only 14% of the income of waste pickers, while plastic and metallic wastes contribute 58% and 25% respectively. Also, waste paper can be recycled in a mixed form while for many other waste materials accurate manual sorting is required. This implies a larger impact of the potential of cheap labour on recycling and waste import in the South.

Second, the outcome does not meet the main objective because only one developing country is studied in detail. Developing countries are not a homogenous group. Large differences in their factor endowments exist with variations in natural resources, availability of fossil fuels, population density, etc. They have several factors in common; income is low, credit markets are relatively underdeveloped, information on the latest technologies is difficult to acquire and market imperfections are a common feature of international technology market. On the one hand, this implies low consumption and investment levels, which has a negative impact on the opportunities to support a full grown recycling industry. On the other hand, these characteristics can also provide a comparative advantage for recycling in developing countries. Labour intensity in recycling industry is higher than in other industries. Capital requirements are generally low as technologies are relatively simple compared to many primary production processes. At the final demand side, the impressionistic conclusion is that a significant market exists for relatively cheap recycled products. The bottleneck for a full grown recycling industry in developing countries therefore seems to be the lack of raw materials. Whether this common characteristic holds for most developing countries, is unknown and requires further investigation.

Third, in this study environmental and social effects of trade and recycling have been quantified physically. Only in chapter 6, these effects generated by a kind of life cycle assessment (LCA) were valued economically. Yet, this necessary step in the analysis lacks a rigorous valuation method. Average values were taken from the literature without taking full account of the underlying assumption of these values. For example, variations in human exposure and dispersion of emissions were ignored. In order to become a suitable tool for decision making, LCA has to be supplemented by an appropriate method for valuation of the various social and environmental effects of recycling and international trade.

Finally, technological developments have not received much attention in this project. Yet, given the novelty of many recycling processes, technological developments can still play an important role. For example, many recycling technologies increasingly enable the production of goods of similar quality as from virgin production processes. Also, comprehensive sorting techniques allow the recovery of more materials from solid waste. Such developments may have a significant impact on the supply of secondary materials on the international market.

8. References

Ahluwalia, I.J. 1991, Productivity growth in Indian manufacturing. Oxford University Press, New Delhi

Ali, S.M., Cotton, A. and Coad, A. 1993; Informal sector waste recycling. Paper presented at the 19th WEDC Conference on Water, Sanitation, Environment and Development. Accra, Ghana. p.153-155

Ali, S.M., Cotton, A. and Coad, A. 1996; Municipal and informal systems in solid waste management. In: Educating for Real by Nabeel Hamdi and Emy Al-Sherif . Intermediate Technology (IT) Publications, London.

Argawal, A. & Narain, S. 1995; A wider perspective on political economy of forest resources in India. Prepared for the project The Sustainable Paper Cycle. Centre for Science and Environment (CSE). Delhi.

Bartone, C., Leith, L., Triche, T. and Schertenleid, R. 1991; Private sector participation in municipal solid waste service: experiences in Latin America. In: Waste Management and Research 9 (1991). p.495-509.

Baud, I. and Schenk H. (eds.) 1994; Solid Waste Management: Modes, assessments, appraisals and linkages in Bangalore. Manohar. New Delhi.

Beers, C. van & Bergh, J.C.J.M. van den 1995, International trade and environment. Tinbergen Institute Discussion Paper TI 95-56. Tinbergen Institute, Regional and Environmental Economics, Amsterdam.

Beinaut, E. 1996; Multiattribute value functions for environmental management. Ph.D thesis. Tinbergen Institute Research Series Nr. 103. Amsterdam.

Bernard, A.B. and Chang P.H. 1995; Trade in waste among developed countries; Evidence and origins. Wellesley College Working Paper No.95-06. Wellesly.

Berndt R.E. and Field C.B. eds 1981; Modeling and Measuring Natural Resource Substitution. Cambridge, MIT Press.

Bertolini, G. 1994; Waste cycle management: incentives and product chain pressure point of 'leverage point' analysis. In: H. Opschoor and R.K. Turner (eds); Economic incentives and environmental policies. Kluwer Academic Publishers. Amsterdam. p.229-249.

Beukering, P. van 1994; An economic analysis of different types of formal and informal entrepreneurs, recovering urban solid waste in Bangalore (India). Resources, Conversation and Recycling 12 (1994). p.229-252.

Beukering, P. van and Duraiappah 1996; An environmental impact assessment of international trade of waste paper to India: a material balance flow model. CREED Working Paper. Amsterdam. Forthcoming.

Biermann, J. 1993; Essentials of pulping and paper making, Academic Press Inc. New York.

Binswanger H.P. 1974; "A Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution" *American Journal of Agricultural Economics* Vol. 56 No. 2 pp 377-386.

Brown S.R. and Christensen L.R. 1981; "Estimating Elasticities of Substitution in a Model of Partial Static Equilibrium: An Application to U.S. Agriculture, 1947-1974" in Berndt R.E. and Field C.B. ed *Modeling and Measuring Natural Resource Substitution* Cambridge, MIT Press.

Bureau of Industrial Costs and Prices (BCIP) 1987; Report on Energy Audit of Paper Industry, July, Ministry of Industry, Delhi.

Capital Market 1994; The paper industry; *sailing out of troubled waters. Capital* Market, Sept. 12-25

Central Board for the Prevention and Control of Water Pollution (CBP & CWP) 1986; Small Paper and Pulp Industry, Comprehensive Industry Document, New Delhi.

Central Pollution Control Board (CPCB) 1986; Comprehensive Document on Pulp and Paper Industry, COINDS/22/1986, New Delhi, India.

Central Pollution Control Board (CPCB) 1991; Comprehensive Industry Document for Large Pulp and Paper Industry, COINDS/36/1991, New Delhi.

Central Pollution Control Board (CPCB) 1995; Standards for liquid effluents, gaseous emissions, automobile exhaust, noise and ambient quality. PCL/4/1995-96. New Delhi.

Centre for Monitoring the Indian Economy (CMIE) 1993; Shape of Things to Come, Bombay

Centre for Monitoring the Indian Economy (CMIE) 1983-1993; Markets and Market Shares; Bombay

Chambers G.C. 1988; *Applied Production Analysis: A Dual Approach* Cambridge, Cambridge University Press.

Chung, S.S. and Poon, C.S. 1994; Recycling behaviour and attitude: the case of Hong Kong people and commercial and household wastes. In: International Journal of Sustainable Development and World Ecology Vol.1. p.130-145

Clean Washington Center 1993. The economics of recycling and recycled materials. *Prepared by Sound Resource Management Group.* Report No. D-2. Seattle.

CML 1992; Environmental Life Cycle Assessment of Products; I: Guide, II: Backgrounds, ed. R. Heijungs, Center of Environmental Science No. 9266, Leiden.

Cointreau-Levine, S.J. 1989; Solid waste recycling: case studies in developing countries. In: Regional Development Dialogue. 10-3.

Cointreau-Levine, S.J. 1996; Private sector participation in solid waste management in developing countries. World Bank. Washington D.C.

Cointreau-Levine, S.J. and de Kadt, M. 1991; Living with Garbage: Cities learn to recycle. In: Development Forum, Jan-Febr, p.12-13.

Deadman, D. and Turner. R.K. 1981; Modelling the supply of wastepaper. Journal of Environmental Economics and Management 8, p.100-103.

Edwards, R. 1979; Price expectations and the supply of waste paper. Journal of Environmental Economics and Management 6, p.332-340.

Ewing, J.A. 1985; " Energy Efficiency in the Pulp and Paper Industry with Emphasis on developing Countries", Technical Paper Number 34, The World Bank, Washington D.C.

Fankhauser, S. 1994; Evaluating the social costs of greenhouse gas emissions, CSERGE Working Paper GEC 94-1, London.

Food and Agriculture Organisation (FAO) 1993; Forestry statistics for tomorrow. Rome.

Food and Agriculture Organization of the United Nations (FAO) 1994; Paper recycling scenarios. FO:MISC/94/4. Rome

Food and Agriculture Organization of the United Nations (FAO) 1993a; Waste paper data 1990-1992. Rome

Food and Agriculture Organization of the United Nations (FAO) 1993b; Pulp and paper towards 2010; An executive summary. Rome

Food and Agriculture Organization of the United Nations (FAO) 1993c; Forestry; Statistics today for tomorrow. Rome.

Food and Agriculture Organization of the United Nations (FAO) 1994; Paper recycling scenarios. FO:MISC/94/4. Rome

Furedy, C. 1990; Social aspects of solid waste recovery in Asian cities. In: Environmental Sanitations Review, No.30. p.2-52.

Furedy, C. 1994; One world of waste: Should countries like India deal with solid waste problems through source seperation?. In: E.L. Tepper and J.R. Wood (eds.); Enriched by South Asia: Celabrating 25 years of South Asian Studies in Canada. Vol 2. Canadian Asian Studies Association, Montreal. p.87-108.

Gandhy, M. 1994; Recycling and the politics of urban waste. Earthscan Publications Ltd., London.

General Agreement on Tariffs and Trade (GATT) 1992; International trade 1990-1991, p.25.

Gilhuis, H. 1988; Scavengers between self-employment and wage work, the recycling business in Curitiba - Brazil. Free University, Amsterdam.

Gillis, M., Perkins, D.H., Roemer M., Snodgrass, D.R. 1987; Economics of development. 2nd edition. Norton & Company. New York.

Grace, R., Turner, R.K. and Walter, I. 1978; Secondary materials and international trade. Journal of Environmental Economics and Management 5, p.172-186.

Grace, R., Turner, R.K. and Walter, I. 1979; Secondary materials and international trade: Reply. Journal of Environmental Economics and Management 6, p.204-207.

Greenpeace 1990; The Greenpeace guide to paper, Vancouver.

Guinée, J.B. 1995; Development of a methodology for the environmental life cycle assessment of products: with a case study on margarines. Phd Thesis. Centre of Environmental Science Leiden University, Leiden.

Hadker, N. 1995; Solid waste management in Bombay: a study of the formal and informal sectors contributions, and economic and environmental linkages. Indira Gandhi Institute of Development Studies (IGIDR), Bombay.

Hadker, N. 1995; Accounting for informal sectors: a case study of solid waste management systems in Mumbai. Prepared for the ESCAP project: Environmental accounting for India. Indira Gandhi Institute of Development Research. Mumbai.

Hadker, N., Sharma, V.K., David A., Muraleedharan, T.R., Geetha, S. and Babu, P.G. 1995; Are people in devloping countries willing to pay for natural reserve preservation?: Evidence from a CV of the Borivli National Park, Mumbai. Indira Gandhi Institute of Development Research, Discussion Paper No. 121. Mumbai.

Hagen, Oskar von dem 1994; Is recycling bad? Waste paper and the forest. Institut fur Volkswirtschaftslehre, Universitat Oldenburg. Discussion Paper No. V-144-94.

Hardoy, J.E., Mitlin, D. and Satterwaite D. 1992; Environmental problems in Third World cities. Earthscan Publications Ltd, London.

Huisman, M. 1994; The position of waste pickers in solid waste management. In: I. Baud and H. Schenk (eds.); Solid Waste Management: Modes, assessments, appriasals and linkages in Bangalore. Manohar, New Delhi. p.46-104.

Ince, P. 1995, What won't get harvested where and when: the effects of increased paper recycling on timber harvest. School of Forestry and Envrionmental Studies, Yale University, Working Paper #3. Connecticut.

International Institute for Environment and Development (IIED) 1995; The sustainable paper cycle; phase 1 review report, London.

International Labour Organization (ILO) 1992; Social and Labour Issues in the Pulp and Paper Industry. ILO. Geneva.

Johnston J. 1984; *Econometric Methods* New York, McGraw-Hill.

Kang H.and Brown G.M. 1981; "Partial Elasticities of Substitution and the Energy Capital Complimentarity Controversy" in Berndt R.E. and Field C.B. ed *Modeling and Measuring Natural Resource Substitution* Cambridge, MIT Press.

Keeney, R.L. 1992; Value-focused thinking. Harvard University Press, Cambridge.

Kendrick, D.A. and Stoutjesdijk, A.J. 1978; The planning of industrial investment programmes; a methodology. John Hopkins University Press. Baltimore.

Khanolkar, V.D. 1995; Indian Pulp & Paper Industry: past performance & future scenario. Country paper presented at the Regional Workshop on Sustainable Paper Cycle, 21-22 February *1995, Bangkok.*

Kirkpatrick, N. 1994; The contribution of life cycle assessment (LCA) to responsible waste management. Pira International. Surrey.

Kopp R.J. and Smith K.V. 1981; "Measuring the Prospects for Resource Substitution under Input and Technology Aggregations" in Berndt R.E. and Field C.B. ed *Modeling and Measuring Natural Resource Substitution* Cambridge, MIT Press.

Larssen, S., Gram, F., Hagen, O., Jansen, H., Olsthoorn, X., Aundhe, Uhlas, J., Metha, K.H., Hahashoor, A.A. 1996; Urban Air Quality: Management strategy in Asia (URBAIR): Greater Bombay City Specific Report. Kjeller.

Linder, S.B. 1961; An Essay on Trade and Transformation. Almquist & Wiksell, Upsala.

Mani S. 1992; New industrial policy: New barriers to entry, foreign investments and privitaziation. The Economic and Political Weekly. August 29 1992, pp. m86-m94.

Markandya, A. 1994; Economic Valuation: An impact pathway approach. In: Externalities of fuel cycles. European Commission DGXII. Brussels. Vol. 9.

Metro 1994; Market Profiles for various types of waste paper. Solid Waste Department, Portland.

National Environmental Engineering Research Institute (NEERI) 1994; Solid waste management in Greater Mumbai, Phase I Report, Metropoplitan Environmental Improvement Program, A World Bank project. Nagpur.

National Productivity Council (NPC) 1986; Study on technology forecasting / assessment based on long range quantitative modelling for Indiain paper industry: Summary of findings and recommendations, Report I, Bangalore

Ogilvie, S.M. 1995; Opportunities and barriers to waste paper recycling. Prepared by the Recycling Advisory Unit of the National Environmental Technology Centre (AEA). Oxfordshire.

Organisation for Economic Co-operation and Development (OECD) 1993; Projected costs of generating electricity - Update 1992. Paris.

Pearce, D. and Turner, R.K. 1994; Economics and solid waste management in the developing world. CSERGE Working Paper WM 95-05. London.

Pethig, R. 1977. International markets for secondary materials. In: D.W. Pearce and I. Walter; Resource Conservation; social and economic dimension of recycling. Longman Group. London. p.191-207.

Powell, J.C., Craighill, A.L., Parfitt, J.P. and Turner R.K. 1995. A lifecycle assessment and economic valuation of recycling. CSERGE, University of East Anglia. Norwich.

Pulp and Paper International (PPI) 1994; International Fact and Price Book. Compiled and edited by Heide Matussek, William Salvesen and John Pearson. Brussels.

Ramaswamy, K.V., Vaidya, R., Hoogeveen, H. & Bennis, M. 1996; Input substitution in the Indian paper industry: a variable cost function approach. CREED Working Paper. Amsterdam. Forthcoming.

Rao, Y.A. 1989; The paper Industry in India - Status and Prospects, Oxford and IBH Publishing Co., New Delhi.

Rao, Y.A. 1995; Pulp and paper production in Asia; economic, social and environmental issues. Paper presented at the Regional Workshop on Sustainable Paper Cycle, 21-22 February 1995, Bangkok.

Roberts, S. 1995; Non wood fibre substudy. Prepared for the project The Sustainable Paper Cycle. International Institute for Environment and Development (IIED). London.

Sargent, C. and Bass, S. (eds.) 1992;Plantation Politics. Earthscan Publications, London.

Savage, G.M. and Diaz, L.F. 1995; Future trends in solid waste management. In: International Directory of Solid Waste Management 1995/96: The ISWA Yearbook. London. p.22-28.

Schall, J. 1995; Does the Solid Waste Hierarchy Make Sense? A technical, economic and emnvironmental justification for the priority of source reduction and recycling. Yale University. New Haven.

Singh, Neelam, Kochak, K.Anjani and Malhotra J.Neelam 1990; "Paper and paper Board Industry: Productivity, Structure and Related issues", Productivity, Vol. 31, No.3, October-December.

Society of Toxicology and Chemistry (SETAC) 1991; Code of Practice. Brussels.

Subramanian. T.N. & A. 1987; Small is not Beautiful: Study of the Paper Industry, Economic and Political Weekly, August 9.

Thomson P. and Taylor G.T. 1995; "The Capital Energy Substitutability Debate: A New Look", Review of Economics and Statistics,pp 565-569

Vernon, R. 1966;International Investment and Trade in the Product Cycle. Quarterly *Journal of Economics, May*.

Virtanen, Y. and Nilsson, S. 1993; Environmental impacts of waste paper recycling. International Institute for Applied Systems Analysis. Earthscan Publications Ltd, London.

Waas, E. and Diop, O. 1991; Waste recycling as a economic activity in Dakar. In: African Environment. Vol.VIII, 1-2, No.29-30. p.111-132.

Walter, I. 1975; Secondary materials, environment, and the international economy. *Discussion Paper* 75-72. *Graduate* School of Business Administration. New York University.

Warmer Bulletin February 1995a; European Packaging Levies. p.21.

Warmer Bulletin February 1995b; Assessing Society's Attitudes to Environmental Issues. Europeans and the Environment in 1992. p.6-7.

Weaver, P.M., Gabel, H.L., Bloemhof-Ruwaard, J.M. and Van Wassenhove, L.N. 1995; Optimising environmental product life cycles: a case study of the *European pulp and paper sector.* Working Paper, INSEAD, Fontainebleau.

World Bank 1995; World Development Report 1995; Workers in an integrated world. Oxford University Press, New York.

World Resources Institute (WRI) 1994; World Resources 1994-95, Oxford

Yates, P.L. 1959; Forty years of foreign trade. London, 1959.

Yohe, G.W. 1979; Secondary materials and international trade: A comment on the domestic market. Journal of Environmental Economics and Management 6, p.199-203.

Young, J.E. 1995; The sudden new strength of recycling. World Watch. July/August 1995. p.20-25.

A programme of Collaborative Research in the Economics of Environment and Development (CREED) was established in 1993 as a joint initiative of the International Institute for Environment and Development (IIED), London, and the Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam.

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