The Economic and Environmental Impacts of the Waste Paper Trade and Recycling in India: a Material Balance Approach

Pieter van Beukering and Anantha Duraiappah

CREED Working Paper Series No 10

November 1996

Drs Pieter van Beukering and Anantha Duraiappah are research economists at the Institute for Environmental Studies (IVM) in the Netherlands. They may be contacted at:

Institute for Environmental Studies (IVM)
Vrije Universiteit
de Boelelaan 1115
1081 HV Amsterdam
the Netherlands

	direct tel	Fax:	Email:
P van Beukering:	(31) 20 444 9524	(31) 20 444 9553	beukering@ivm.vu.nl
A Duraiappah:	(31) 20 444 9564	(31) 20 444 9553	anantha@ivm.vu.nl

The 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), Amsterdam. The Secretariat for CREED is based at IIED in London. A Steering Committee is responsible for overall management and coordination of the CREED Programme.

Environmental Economics Programme, IIED

IIED is an independent, non-profit organisation which seeks to promote sustainable patterns of world development through research, training, policy studies, consensus building and public information. The Environmental Economics Programme is one of seven major programmes of IIED; it conducts economic research and policy analysis for improved management of natural resources and sustainable economic growth in the developing world.

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

Institute for Environmental Studies, (IVM)

IVM is a non-profit research institute, based at Vrije Universiteit, Amsterdam. The Institute's primary objective is to carry out multi- and interdisciplinary research on environmental issues, based on cross-fertilisation of monodisciplinary sciences. Environment and the Third World is one of eight major IVM research programmes.

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

CREED Steering Committee members include:

Acknowledgements

The authors thank G.D. Badrinath, Rupa Banerjee, Prakash Bhat and Kasturi of Intervention (India) Ltd for their full support during the field surveys. We are also grateful to staff at the Indira Gandhi Institute of Development Research in Bombay for their hospitality. We were grateful for the comments of Dr. Ramanathan, Dr. Vijaya Lakshmi, Nandini Hadker, Dr. V.K.Sharma, Dr. K.V. Ramaswamy and Dr. Rajendra Vaidya. Comments from Prof.dr. David Kendrick, Dr. Konrad von Moltke, Prof.dr. N.J. Rao and Huib Jansen were also of great value. We also acknowledge the very useful advice from Dr. Xander Olsthoorn and Michiel van Drunen. The provision of data by Maryanne Grieg-Gran, Jaqueline Bloemhof, Ian Cooper, Jacques Lahaussois and E. Brouwer were greatly appreciated. Finally, we thank all the entrepreneurs in the Indian paper cycle who offered their valuable time to co-operate with the field survey.

Abstract

There have been increasing pressures by some governments and non-governmental organisations to restrict the international trade in waste on the premise that each nation should manage its own waste production. Focusing on the Indian waste paper industry, we develop a Material Balance Flow Model to investigate if free trade in non-toxic waste can contribute to economic development and simultaneously reduce environmental degradation. The model is formulated as a non-linear programming model with an objective function which minimises environmental and economic costs. The model in principle describes the life cycle of Indian paper. Preliminary results suggest that trade in waste paper is both economically and environmentally advantageous. The results also show that domestic and imported waste paper are complementary and that the import of waste paper does not "crowd out" the domestic waste paper sector.

Abrégé

Quelques gouvernements et ONG exercent depuis un certain temps une pression croissante pour la restriction du commerce international des déchets, ayant la conviction qu'il revient à chaque pays de résoudre ses propres problèmes d'élimination des déchets. Nous établissons dans ce document un Modèle de Flux à Équilibre Physique afin d'étudier la possibilité qu'un libre commerce des déchets non-toxiques puisse contribuer au développement économique tout en réduisant simultanément la dégradation de l'environnement. Il s'agit d'un modèle de programmation non-linéaire doté d'une fonction objective qui minimise les coûts environnementaux et économiques. Le modèle décrit, en principe, le cycle de vie du papier en Inde. Les résultats préliminaires semblent indiquer que le commerce du papier de récupération est avantageux aussi bien économiquement qu'au plan de l'environnement. Ils font aussi apparaître la complémentarité du papier de récupération domestique et importé et montrent que les importations de papier de récupération «n'étouffent» pas le secteur domestique de la récupération de papier.

Resumen

A partir de la creencia de que cada país debe responsabilizarse por sus propios problemas de eliminación de desechos, existe una presión creciente por parte de gobiernos y de organizaciones no gubernamentales para restringir el comercio internacional de los mismos. En este ensayo desarrollamos un "Modelo de flujo de equilibrio material" para investigar si el libre comercio de desechos no tóxicos puede contribuir al desarrollo económico y reducir al mismo tiempo el deterioro ambiental. El modelo está concebido como un modelo de programación no lineal cuya función objetiva busca minimizar los costos ambientales y económicos. En principio el modelo describe el ciclo de vida del papel en la India. Los resultados preliminares muestran que el comercio de desechos de papel es beneficioso tanto ambiental como económicamente. Los resultados también sugieren que los desechos domésticos e importados de papel se complementan y que la importación de desechos no elimina de la competencia a la producción doméstica.

Contents

Introduction

Recycling may generally be considered as a key strategy for alleviating the pressures of society on the environment. A variety of environmental justifications for recycling exist: recycling processes reduce demand for energy and finite resources, result in less water pollution and air emissions and mitigate the problem of solid waste disposal. In particular, recycling paper reduces the pressure on natural resources such as forests. Moreover, recycling may be considered economically beneficial in developing countries. First, it provides significant employment opportunities to a large informal sector. The high degree of labour intensity of certain reclamation processes enables numerous people to accrue some kind of income. Second, recycling can reduce the costs for raw materials in the production process and thereby may result in an increase in the supply of cheaper products. Third, it can reduce dependence on foreign resources and thereby saves on expenditure on imports in developing countries. Finally, in Asia particularly, the anticipated high growth in GDP will significantly increase the waste disposal burden in most metropolitan areas. 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.

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 vocabulary, recycling is used as a general term for all activities 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 environmentally motivated and public participation and government involvement play a much more important role (Beukering 1994).

Besides this regional difference in the motivations for recycling, 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; with governments promoting the separation of waste at source, this has led to an over-supply of secondary materials. In developing countries, 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.

Table 1 Direction of Global Trade Flows in the Paper Cycle (1991)

Direction	Wood Fibre	Wood Pulp	Paper and Paperboard	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

These distinctive features of the supply of waste in the North and demand for waste in the South emphasise the potential for international trade in secondary materials. Empirical findings confirm this rationale. A recent study has shown that a not insignificant part of international trade flows consists of secondary materials (Jackson *et al*. 1996). Further investigation reveals that, whereas most other materials and products are transferred between countries in the North, a more than proportional share of secondary materials move from the North to the South. For waste paper this is illustrated in table 1. In fact, the share of recyclable waste which is exported to the South is increasing in time.

In theory, international trade can perform much the same function in the secondary materials sector as it does with virgin materials by matching variations in supply in industrialised countries with demand in developing countries. Through a more efficient allocation, both regions can move to higher levels of social welfare than they otherwise would attain. Nevertheless, the attitude of international organisations, national governments and 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. In this view, secondary materials are considered no different from other intermediary or final goods. The counter argument to this ideology is that secondary materials cannot be considered as normal raw material but as waste 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 in this context is considered a cheap and easy way for countries to dump their waste. Both ideologies tend to oversimplify the issue by generalising across a broad spectrum of secondary materials. It may very well be true that for certain secondary materials, trade liberalisation can produce a more efficient global allocation of resources but it could also be true for other secondary materials that international trade would only facilitate waste dumping by the developed countries.

Several other arguments exist which further confuse the issue of trade liberalisation in secondary materials. First, the precise socio-economic impacts of the increase in recyclable waste are unknown. If imported secondary materials totally substitute domestic recyclable waste materials, the local recovery sector may suffer from free waste trade causing employment and disposal problems. Second, 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.

To address and resolve the arguments raised by the two ideologies, this study focuses on waste paper as the secondary material. Waste paper is selected because of its long tradition at the international market. Moreover it is increasingly being collected in both industrialised and developing countries. India is selected for several reasons. First, India is a large country with a growing demand for raw materials in the rapidly developing domestic industries. Also, India has several metropolitan cities where comprehensive recycling networks already exist and are growing. Thirdly, importing waste paper is not new and at present many paper industries in India are switching from virgin materials to imported waste paper. The main objective of this study is to address the economic and environmental challenges and threats to India which arise from increased international trade in waste paper. 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 the domestic recycling sector in particular. Similarly, the results can support industrialised countries in their decision to prohibit or encourage the trade in waste paper.

The paper is structured as follows. In Section 2 the current Indian paper cycle is described in terms of production, consumption, waste management and international trade. Economic and environmental parameters will be explained and technical coefficients will be set. In Section 3 the material balance flow model is introduced. The economic and environmental assumptions under which optimalisation will occur are elaborated on. The results of the economic and environmental optimalisation are presented in Section 4. Finally, general conclusions and policy implications are provided in Section 5.

The Indian Paper Cycle

The paper industry in India is more than a century old. Commercial production of paper started as early as 1879. Limitations with respect to forest-based raw materials forced the Indian paper industry, in these early stages of the development, to utilise non-conventional materials. India was the first country in the world to have a paper mill which relied entirely on bamboo as its primary fibre. 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 (Rao 1989).

At present, several developments and problems prevail in the Indian paper cycle. First, with the prospect of growing urbanisation, increasing literacy rates and general increasing economic growth, the consumption of paper and paperboard products is expected to grow considerably in the coming years. The Indian citizen on average consumes approximately 3 kg of paper each year. Although low 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 expected to increase over the coming decades (FAO 1993). Moreover, it should be realised that the official statistics do not account for the consumption of re-used paper. Therefore, the actual per capita paper consumption in India is slightly higher.

Second, the lack of foreign currency has forced the Indian government to strive for self-sufficiency in paper production. Throughout the years, dependency on imports of most types of paper and pulp has decreased. Today, only newsprint is still being imported on a substantial scale. On the one hand, this was achieved by imposing import constraints on final paper products as well as raw materials. On the other hand, various incentives were provided to the paper industry to increase production. As a result of these developments, India, after China, accounts for the largest number of paper mills in the world. Paper is produced at all scales, varying from handmade paper units to large scale integrated mills. However, despite government support, the overall performance of the industry is low with a constant decrease in capacity utilisation. In the last decade the Indian government adopted a number of measures to improve efficiency. Not only were foreign producers allowed to enter the Indian consumers' market, they were actually allowed to become established in India itself. Also, various import constraints are now being lifted such as the decrease in import tariffs for pulps, paper and paper board.

Third, the Indian paper industry is traditionally suffering from a lack of raw materials. Forest is not an abundant natural resource in India. In 1993 only 19.5% of the total land surface was covered with forest (FAO 1993a). Due to alternative land-uses such as crop production and hydroelectric projects, the forest in India is declining rapidly at an annual rate of 0.6% (World Resources Institute 1994). Another factor which limits the indigenous supply of wood-fibre is the low productivity of the Indian forest. While forests in Europe and the US increase approximately by 2.5 m^3 per hectare each year, the Indian forests grow no more than 0.5 m^3 per hectare (Rao 1989). This shortage has promoted the utilisation of non-conventional raw materials. The share of wood-pulp based paper has declined from 65 per cent in 1985 to 49 per cent in 1992, while the share of agro- pulp based paper increased from 22 per cent to 29 per cent during the same period. The sharpest rise has taken place in the share of waste paper production which has risen from 13 per cent to 22 per cent over the same period (Khanolkar 1995).

Fourth, the environmental profile of the Indian paper industry is not very positive. Energy consumption is relatively higher than the international standard, due to interruptions in production, the poor quality of fuel and equipment, and the relatively low rate of waste paper utilisation in the production. Even more important is the environmental impact of water pollution and consumption. Pollutant emissions in the 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 has intensified the enforcement of environmental regulations. This has forced many paper mills to switch from the polluting agro-based raw materials to waste paper which causes much less pollution. Alternatively, effluent treatment plants have been installed. Nevertheless, especially the small-scale units lack the funds to improve their environmental performance and therefore are threatened with closure.

Fifth, not only are conventional raw materials becoming increasingly scarce in India, waste paper and agro-residues are also in limited supply. The yield percentage of agro-residues fibres is rather low (33% for bagasse and 38% for straw). The low productivity has to be weighted against the transportation element of this commodity. It is reported that the economic distance for hauling the straw is 50 kilometres from the mill although examples of a radius of 100 km are not uncommon (Roberts 1995). In the case of waste paper, the intensive use and re-use of paper in India often decreases its quality which makes it less suitable for recycling. As a result, international supply in the Indian paper cycle is proving to be more important. While in 1975, only 4% of the Indian paper originated from imported waste paper, this rate had increased to 12% in 1994 (Beukering *et al.* 1996a).

Finally, an important development in the Indian paper cycle is the rapidly increasing problem of waste. Rapid urbanisation and economic growth increase waste and at the same time reduce the available landfill space. Although paper is less important in waste in developing cities than in industrialised countries, it still comprises a significant part of the volume. Because of inefficiencies and limited municipal budgets, a large share of the waste remains uncollected causing sewerage blockage and visual and odour pollution. Inappropriate waste management leads to a number of societal problems, such as increased risks of epidemics, air pollution caused by illegal waste burning and pollution of groundwater. These problems emphasise the importance of the informal waste recovery sector which operates in most Indian cities. In Bangalore, a growing urban centre, it has been estimated that 15% of the municipal waste is diverted from dumpsites because of recycling activities (Baud and Schenk 1994). Despite these positive contributions to urban waste management, waste recovery receives little attention from most municipalities (Beukering *et al.* 1996b). This may be explained possibly by the lack of insight into the socio-economic and environmental benefits of recycling throughout the life cycle of different materials. The development of a material flow model of a secondary material can serve to improve this understanding.

Methodology

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

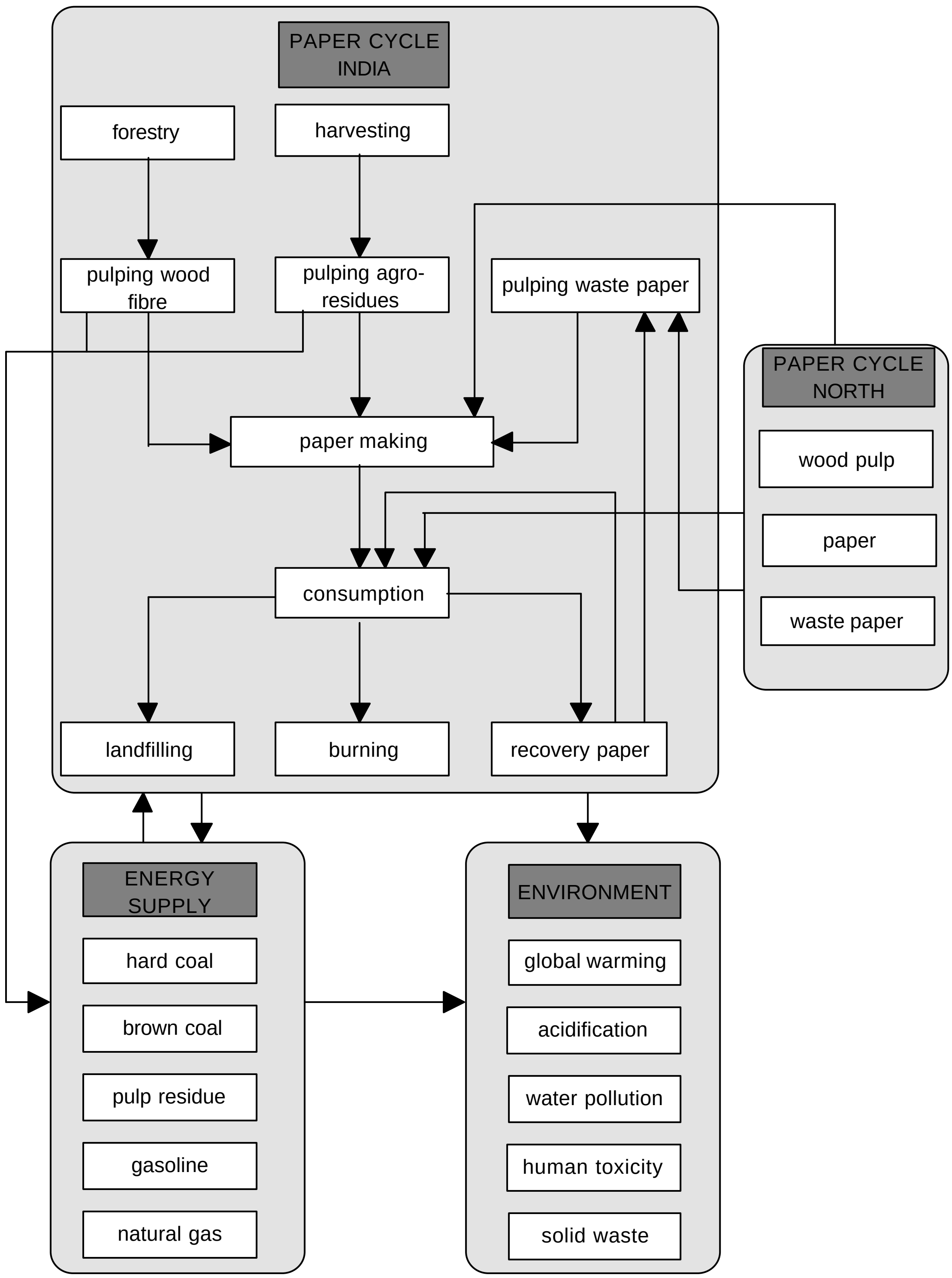
The sectoral model formulated for this study captures in essence the life cycle of paper at each stage of the process, from harvesting the forest to the disposal of the waste paper. By incorporating a life cycle within a sectoral model framework, we are able to: (1) keep track of the use and production of the various materials (life cycle analysis); and to (2) evaluate the trade-offs that occur between economic and environmental impacts at each stage of the paper cycle (sectoral analysis). Moreover, the paper industry is characterised 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 optimisation model.

As the focus of this paper is on the Indian paper cycle, we simplify the analysis 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 liberalisation of trade in waste paper. Figure 1 provides a schematic illustration of the Indian paper cycle. As shown in this figure, we have included the environmental impacts caused by energy use in the paper industry. However, unlike many of the existing studies (Weaver 1995, Virtanen and Nilsson 1993), we allow the decision maker to choose the optimal mix of fuels which are complementary to his objective. We have also included the surplus energy property of some pulping processes. 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 of each energy producing process is tabulated to the cumulative pollutant emission for the paper industry. In this manner, in the optimising process, depending on the objective, 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 scare fuel with high import costs but is considered environmentally friendly.

We have included the six main pulping processes which are presently relevant in India: bleached sulfite, unbleached sulfate, unbleached local waste paper, unbleached imported waste paper, bleached sulfate, and bleached agro. These six processes may be categorised basically 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 sulfate) within the wood fibre category are in turn differentiated by chemical use and intensity, energy intensity, and finally the pollutant emission intensity. Each of these three processes 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 which uses waste paper has two processes, one using local waste paper while the other uses imported waste paper.

As in the case of choice of energy source, 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-offs at this stage is a more complex and involves two layers. At the first layer of analysis, the economic costs of pulp production have 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 are included in the analysis. The second layer of analysis takes into consideration the economic and environmental costs and benefits which are derived from some of the pulping processes which produce surplus energy.

Figure 1 Material Flow Balance of the Indian Paper Cycle



We now turn our attention to the paper making stage. Within the paper category, we identified four main types of paper, differentiated primarily by quality which in turn are characterised by a certain mix of pulps. We formulated the input-output coefficient for this stage as an endogenous variable which is determined by the optimisation process. We model the process in the following way. We begin by fixing the total amount of pulp which is required for each paper type. Next, we specify a pulp combination possibility matrix which in essence specifies the maximum percentage (an upper limit) a particular pulp can be used in the production of 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 optimisation process to choose the optimal mix of the different pulps to make the respective paper types.

The disposal stage is characterised by four different options. First, waste paper collection includes certain economic and environmental costs. 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 characterised by its unique economic and environmental properties.

We identified five major environmental impacts, regional as well as global, for this study:

- Global Warming Potential
- Human Toxicity
- Water Pollution
- Acidification
- Solid Waste.

The mapping from production to environmental impact was undertaken in the following manner. Each stage of production is characterised by a technological input-output matrix. From these technological matrices, we are able to tabulate the emissions of all the pollutants from every activity. 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. We do this with the help of an environmental impact matrix which, similar to an input-output matrix, lists 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, we have two options of modeling the environmental factor in the model. We could either monetize the eco-profiles or specify eco-profile constraints explicitly in the model. We chose the former as this method would allow us to conduct an extended cost-benefit analysis while the latter would allow only a partial cost-benefit analysis. The decision was further prompted by the existence of, albeit crude, damage estimates for the five environmental impact causes. The second method would involve the specification of constraints for each of the five environmental impacts. This method would require us first to identify the upper bounds for each environmental impact at the national or international level, after which we would need to allocate a certain portion of that constraint to the paper industry. We 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 may easily be 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 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 Sustainable Paper Cycle study (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 forest ecosystems at 0.016 dollar per acidification unit. Finally, we adopted a damage estimate 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 incorporating 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 import element in this study, we allow for the possibility of imports at a number of stages. At the pulping stage, the decision maker may choose between producing pulp domestically or importing it. We allow the imports of all pulp except agro-residue as it is highly unlikely that there will be any international trade of this commodity. As there is existing capacity in the different pulping making 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 limit 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 whereby the prices of the primary or "raw" commodities 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 are for all commodities which are sourced from outside India. In the model, these would be all imports irrespective if they are primary, intermediate or final goods.

This brings us to the end of the model description. We next turn our attention to the results from some simulations runs done on the model.

Results

The objective function is the driving factor behind an optimization model. To understand the trade-offs we make between environmental and economic goals, we need to analyse model results when different objectives are specified. For this paper, we identified three strategies with 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 where only environmental costs are minimised;

3. the *sustainable strategy* which implies minimisation of total costs including both economic and environmental costs, and is coterminous with sustainable management.

The 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.

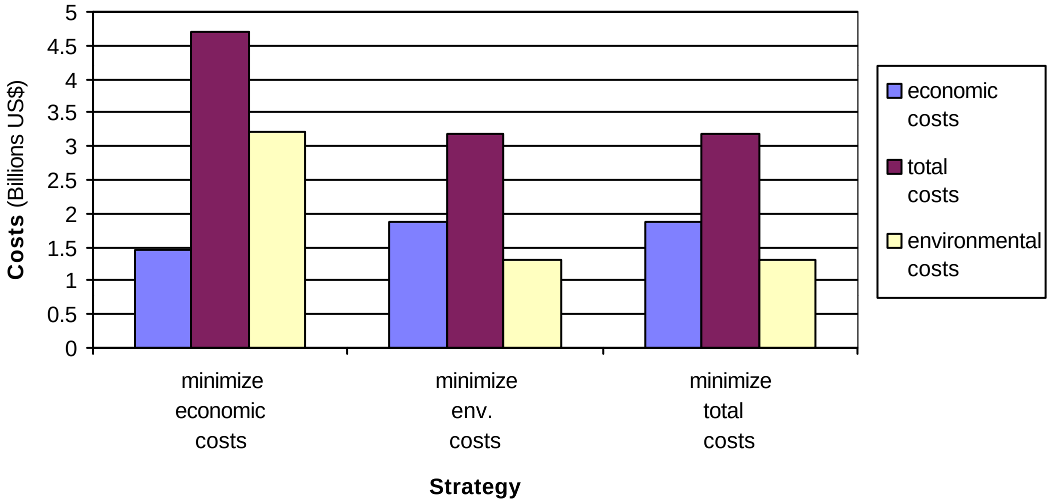
1. The first set of the simulations describes a situation in which *no trade in waste paper* is allowed but trade in wood pulp is allowed;

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 constraint on wood pulps* is introduced.

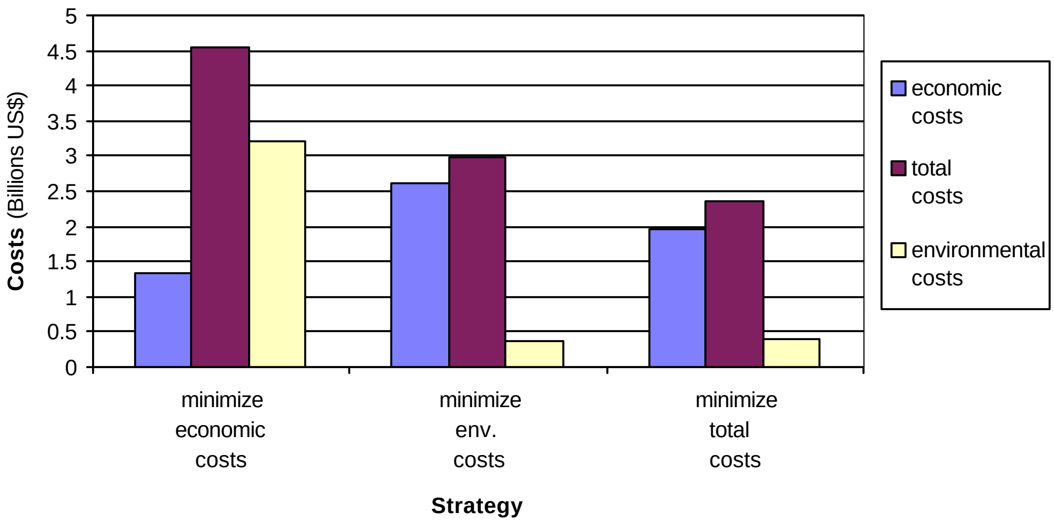
Let us begin by looking at the first set of simulation results in which no trade in waste paper is allowed. As figure 2 below illustrates, in the *economic strategy*, the real cost (the total cost or social cost) is significantly higher than the economic cost. This is because the environmental costs 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. We 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 2 Cost Comparisons with No Import of Waste Paper (Ban)



We now turn our attention to the set of simulations in which free trade in imported waste paper is allowed. As figure 3 below illustrates, a similar trend as in figure 2 is observed but with more significant differences between the environmental and sustainable strategy.

Figure 3 Cost Comparisons with Import of Waste Paper Allowed



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 clearly evident that in both cases, with and without imports, a reduction in environmental costs can be achieved at a relatively low cost.

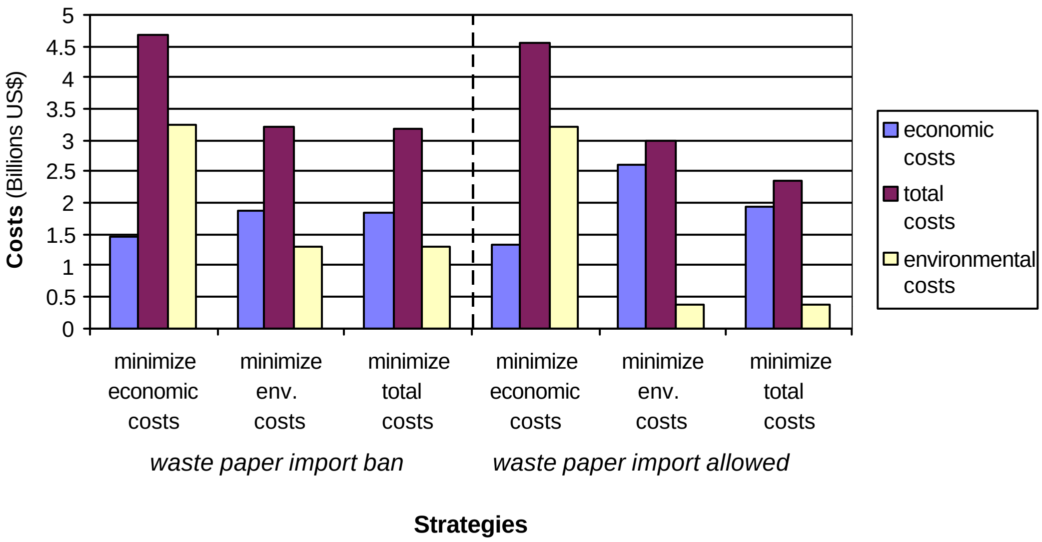
In comparison with the sustainable strategy, the economic costs are further reduced vis a vis the environmental strategy but with environmental costs showing a slight increase. The economic costs decrease by 0.67 billion dollars while the environmental costs increase by 0.03 billion dollars;

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. However, 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. However, the adoption of these processes causes the environmental costs to increase by the 0.03 billion dollars observed above.

We next compare all the strategies from the first two sets of experiments done above. As figure 4 below illustrates, the strategy with the lowest total costs is the sustainable strategy in which imports of waste paper is allowed.

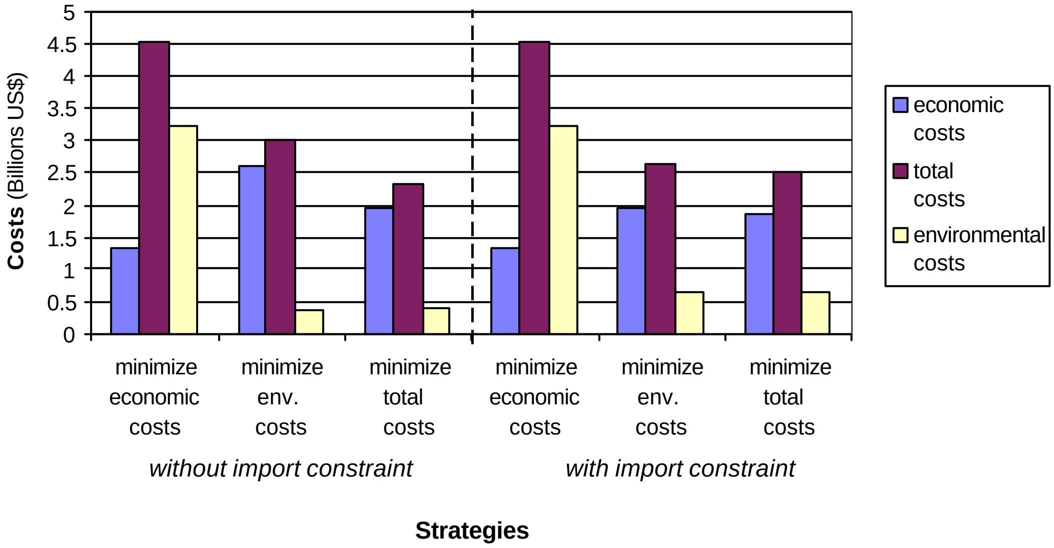
An unexpected result is the higher economic costs that are observed in the sustainable strategy with imports as compared to the simulation without imports under the sustainable strategy. This is explained by the higher import cost. However, the higher economic cost of 0.08 billion dollars is far outweighed by the decrease in environmental costs of 0.9 billion dollars.

Figure 4 Costs Comparisons across all strategies



We next ran a third set of experiments in which we allowed the import of waste paper but with an additional constraint 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 behaviour of the paper sector in India. As we mentioned in the earlier paragraphs, in many instances, the sector had resorted to imported pulp to reduce the environmental impacts. As shown in Figure 5 no differences were observed in the economic strategy with and without an import constraint on pulp.

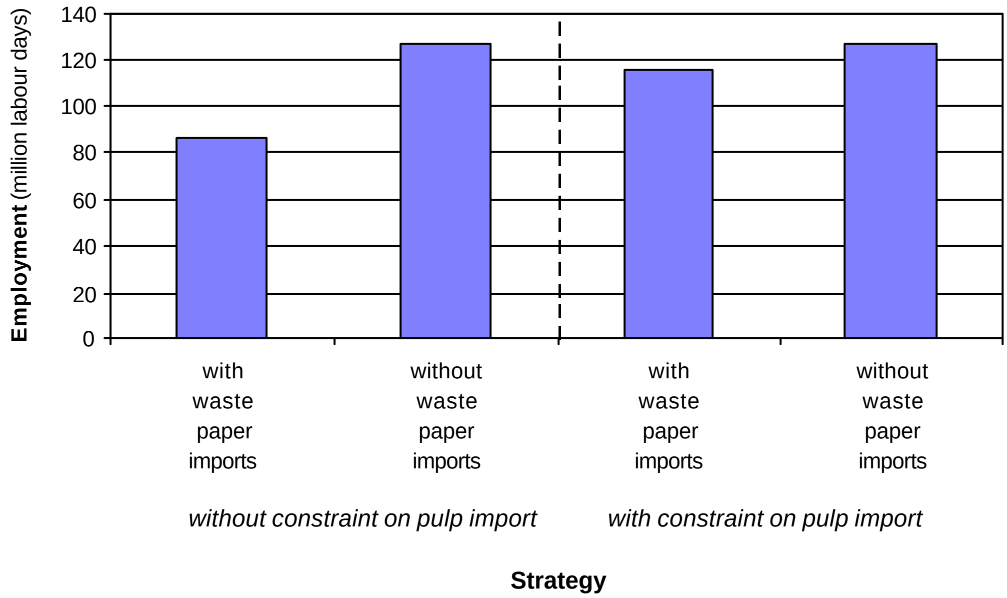
Figure 5 **Cost Comparisons with and without pulp import constraint**



However, in the case of the environmental strategy in which we had observed in the earlier runs a shift to imported pulps to reduce environmental costs, environmental costs are higher in the case when an import constraint on pulps is enforced. Total cost is lower with a pulp import constraint because the import cost component of economic costs 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. Let us assume that we have a pulp import constraint in place to start with and contrast the results when this constraint is removed. T he model results indicate that a 0.09 billion dollar increase in economic costs (primarily import cost) is observed but with 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.

We next turn our attention to employment effects. As we do not internalise the cost of unemployment in the model, it would be useful to know if the first best solution identified above also gives the best employment figures. We limit our comparison of strategies to the sustainable strategies with and without imports of waste paper under regimes with and without a pulp import constraint. We observe from Figure 6 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 **Employment figures under various strategies**

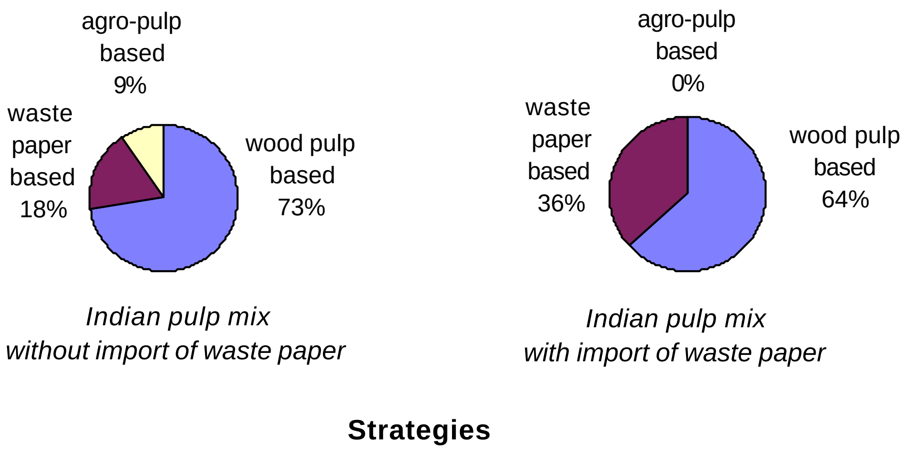


Under the trade regime "with waste paper imports", the main pulping processes in operation are the waste paper based technologies (domestic and imported waste paper). These processes are relatively less labour intensive than the wood and agro based pulping processes, over the whole life cycle. This is 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 in 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 the social cost of unemployment is an important factor. We should highlight 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. We differentiate the final pulp use into three categories: (1) wood fibre pulp (WB); (2) agro-residue pulp (AB); and (3) waste paper pulp (WPB). We limit our analysis to the sustainable strategies with and without waste paper imports under a regime with no wood pulp import constraints, indicated respectively by ITC and NITC.

As Figure 7 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 domestically 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 7 Pulp mix with and without import of waste paper.



The reader 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 from investigating 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. We should like to stress that the actual figures given by the model should not be used as forecast values if certain strategies are implemented. The results however, do provide an indication of how and what would happen if certain policies are adopted. This we believe is the strength of this model.

Conclusions

Does the trade in waste paper provide environmental and economic benefits to the Indian paper sector? The preliminary results from the sectoral model we developed suggests that the answer to the question depends on the objective of the decision maker. If the prime objective is based on environmental criteria, then trade in waste paper is not the best solution. However, if the sole objective is economic, then trade in waste paper is beneficial but only partly. However, if the reduction of both environmental and economic costs is the prime objective, the trade in waste paper is crucial in the sector design process. In other words, if the paper sector is forced to internalise its environmental externalities, then the trade in waste paper becomes a crucial variable in industrial and environmental policies.

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

The last point highlighted in our 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 extremely detrimental to the environment. 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 maximised.

Before we end the paper we should like to point out that the model developed in this paper is still in 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.

1. Appendix

THE MATHEMATICAL MODEL

<u>List of symbols used in the model</u>

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

$\overline{EC}$: Cost per unit of eco-profile

Sets

C: Set of commodities

P: Processes

<u>**1.** Material Balance Constraint on Raw Materials</u>

$$\sum_{p \in PE,PS,PU,PP,PX} a_{cp} Z_p - u_c \le 0 \quad c \in CR$$

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).

<u>**2.** Material Balance Constraint for Fibre and Non-Fibre Materials</u>

$$\sum_{p \in PRE} a_{cp} Z_p \le \sum_{p \in PU} a_{cp} Z_p \quad c \in CB$$

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

<u>**3.** Material Balance for Electricity</u>

$$\sum \sum C_{ip} \geq \sum C_{ip} \; e_{ij}$$

$p \in E \quad p \in D$

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. <u>Material balance for Steam</u>

$$\sum \sum C_{ip} \leq \sum C_{ip} \; e_{ij}$$

$p \in D \quad p \in R$

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

5. <u>Material Balance for Intermediate Tradable Commodities (Pulp)</u>

$$\sum \sum C_{ip} \leq \sum C_{ip} + V \; e$$

$p \in P \quad p \in U$

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. <u>Material Balance for First Stage Intermediate Commodities</u>

$$\sum \sum C_{ip} \leq \sum C_{ip} + V \; e$$

$p \in S \quad p \in X$

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. <u>Material Balance for Waste Paper</u>

$$\sum_{p \in PDW} \ldots \; \sum_{p \in PX} \ldots$$

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

$$\sum_{p \in PU} \ldots$$

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

$$\sum_{c \in CT} b_{cp} = q_{p}, \quad p \in P$$

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

$$\frac{b_{cp}}{q_{p}} \leq B_{cp}, \quad c \in CT, \; p \in P$$

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

$$Z_{p} \le \bar{Z}_{p} \quad p \in PP$$

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

<u>**12.** Material balance for Non-Tradable Intermediate Goods</u>

$$\sum_{p \in P} c_{ip} Z_p \geq \sum_{p \in PP} c_{ip} Z_p \quad i \in NT$$

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

<u>**13.** Material Balance for Final Non-Reusable Goods</u>

$$\sum_{p \in P} c_{ip} Z_p + V_i \geq \bar{D}_i \quad i \in E$$

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

$$\sum_{p \in P} a_{c,p} Z_p + M_c + U_c \ge D_c \qquad c \in R$$

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

$$W = \alpha \sum_{c \in FT} D_c$$

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

$$\sum_{p \in X} a_{wp,p} Z_p = W$$

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

$$U_c \le 0.3\, W$$

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

$$u_c \leq \bar{U}_c \quad c \in RC$$

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

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

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

$$\sum_{p} c_{ip} + \sum_{c} y_{c} = Ad$$

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

$$te_{c} = \ldots E$$

The total emissions of various pollutants caused by transportation.

22. Emissions from Paper Production

$$\sum_{p} c_{ip} z_{p} \quad E$$

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

23. Eco-Profile

$$\sum f_{p} \ldots P$$

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

24. Environmental Costs

$$ec = \sum_{p \in ENP} f_{p} \bar{C}_{p}$$

The total costs caused by all the environmental problems.

25. Raw Material Costs

$$rc = \sum_{c \in rm} u_{c}\, p^{d}_{c}$$

Total costs of raw materials.

26. Domestic Waste Paper Costs

$$ic = \sum_{p \in PU} a\, z\, p^{d}$$

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

$$imc = \sum$$

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

28. Transportation Costs

$$ttc = \sum_{p \in PW}$$

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

29. Waste Disposal Costs

$$wdc = \sum_{p \in PW}$$

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.

References

Baud, I. and Schenk H. (eds.) 1994. *Solid Waste Management: Modes, Assessments, Appraisals and Linkages in Bangalore*. Manohar:. New Delhi.

Beukering, P. van. 1994. “An Economic Analysis of Different Types of Formal and Informal Entrepreneurs, Recovering Urban Solid Waste in Bangalore (India).” *Resources, Conservation and Recycling* 12 (1994) 229-252.

Beukering, P. van, Bennis, M., Hoogeveen, H. and Sharma, V.K. 1996a. *Recycling and International Trade of Waste Paper: a Global Assessment with a Special Focus on India. CREED Programme*. Institute for Environmental Studies: Amsterdam.

Beukering, P. van, Schoon, E. and Mani, A. 1996b. *The Informal Sector and Waste Paper Recovery in Bombay*. CREED Working Paper. No.5. International Institute for Environment and Development: London.

Biermann, J. 1993. *Essentials of Pulping and Paper Making*. Academic Press Inc. New York.

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

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.

CPCB. 1991. *Comprehensive Industry Document for Large Pulp and Paper Industry*. COINDS/36/1991. New Delhi.

Duraiappah, A.K. 1993. “Investing in Clean Technology: an Exercise in Methodology.” *UNEP. Nettlap Publications* No.6 :.87-103.

Food and Agriculture Organisation of the United Nations (FAO). 1993. *Forestry Statistics for Tomorrow.* FAO: Rome.

FAO. 1993a. *Waste Paper Data 1990-1992*. FAO: Rome

FAO. 1993b. *Pulp and Paper Towards 2010: An Executive Summary*. FAO: Rome

FAO. 1993c. *Forestry; Statistics Today for Tomorrow.* FAO: Rome.

FAO. 1994. *Paper Recycling Scenarios*. FO:MISC/94/4. FAO: Rome

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

Grace, R., Turner, R.K. and Walter, I. 1978. “Secondary Materials and International Trade.” *Journal of Environmental Economics and Management* 5:.172-186.

Grace, R., Turner, R.K. and Walter, I. 1979. "Secondary Materials and International Trade: Reply." *Journal of Environmental Economics and Management* 6: 204-207.

Guinée, J.B. 1995. *Development of a Methodology for the Environmental Life Cycle Assessment of Products: with a Case Study of Margarines*. Phd Thesis. Centre of Environmental Science Leiden University: Leiden.

International Institute for Environment and Development (IIED) 1995. *The Sustainable Paper Cycle: Phase 1 Review Report*. IIED: London.

International Labour Organization (ILO) 1992. *Social and Labour Issues in the Pulp and Paper Industry*. ILO. Geneva.

Jackson, S. and van Beukering, P.J.H. 1996. *A Preparatory Study on International Trade and Recycling of Secondary Materials with Special Emphasis on Plastics in the People's Republic of China*. Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam.

Fankhauser, S. 1994. *Evaluating the Social Costs of Greenhouse Gas Emissions*. CSERGE Working Paper GEC 94-1. CSERGE: London.

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 and Future Scenario*. Country paper presented at the Regional Workshop on the 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.

Larssen, S., Gram, F. and Hagen, L.O. 1996. *Urban Air Quality Management Strategy in Asia*. URBAIR. Greater Bombay City Specific Report. OR 56/95. Kjeller.

Lim, B. and Lindeijer, E. 1994. Milieubeoordeling van beglazingssystemen. p.b27. IVAM, Amsterdam.

Markandya, A. 1994. "Economic Valuation: An Impact Pathway Approach." In *Externalities of Fuel Cycles*. European Commission DGXII. Brussels. Vol. 9.

Organisation for Economic Co-operation and Development (OECD) 1993. *Projected Costs of Generating Electricity* - Update 1992. OECD: Paris.

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.

Rao, Y.A. 1989. *The Paper Industry in India - Status and Prospects*. Oxford and IBH Publishing Co.: New Delhi.

Roberts, S. 1995. *Non Wood Fibre Substudy*. Prepared for the project The Sustainable Paper Cycle. IIED: London.

Virtanen, Y. and Nilsson, S. 1993. *Environmental Impact of Waste Paper Recycling,* International Institute for Applied Systems Analysis. Earthscan Publications: London.

Weaver, P.M., Gabel, H.L., Bloemhof-Ruwaard, J.M. and van Wassehove L.N. 1995. *Optimizing Environmental Product Life Cycles: a Case Study of the European Pulp and Paper Industry*. INSEAD: Fontainebleau.

World Resources Institute (WRI). 1994. *World Resources 1994-95*. Oxford.

Yates, P.L. 1959. *Forty Years of Foreign Trade*. London.