Lappeenranta
University of Technology

Maija Hujala

# STRUCTURAL DYNAMICS IN GLOBAL PULP AND PAPER INDUSTRY

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| Supervisor | Professor Kaisu Puumalainen<br>School of Business<br>Lappeenranta University of Technology<br>Finland |
| Reviewers | D.Sc. (For.) Research Scientist Riitta Hänninen<br>The Finnish Forest Research Institute<br>Finland |
| | Professor Runar Brännlund<br>Department of Economics<br>Umeå University<br>Sweden |
| Opponent | D.Sc. (For.) Research Scientist Riitta Hänninen<br>The Finnish Forest Research Institute<br>Finland |

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ABSTRACT

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The pulp and paper industry is currently facing broad structural changes due to global shifts in demand and supply. These changes have significant impacts on national economies worldwide. Planted forests (especially eucalyptus) and recovered paper have quickly increased their importance as raw material for paper and paperboard production. Although advances in information and communication technologies could reduce the demand for communication papers, and the growth of paper consumption has indeed flattened in developed economies, particularly in North America and Western Europe, the consumption is increasing on a global scale. Moreover, the focal point of production and consumption is moving from the Western world to the rapidly growing markets of Southeast Asia.

This study analyzes how the so-called megatrends (globalization, technological development, and increasing environmental awareness) affect the pulp and paper industry's external environment, and seeks reliable ways to incorporate the impact of the megatrends on the models concerning the demand, trade, and use of paper and pulp. The study expands current research in several directions and points of view, for example, by applying and incorporating several quantitative methods and different models. As a result, the thesis makes a significant contribution to better understand and measure the impacts of structural changes on the pulp and paper industry. It also provides some managerial and policy implications.

Keywords: pulp and paper industry, PPI, megatrends, demand, supply, trade, panel data, Hausman-Taylor estimator, gravity model of international trade, system dynamics, input-output analysis, fuzzy linear systems

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Lappeenranta, December 2011

*Maija Hujala*

Abbreviations

| | |
|---|---|
| BHKP | Bleached hardwood kraft pulp |
| BSKP | Bleached softwood kraft pulp |
| FAO | Food and agriculture organization of the United Nation |
| FE | Fixed effects estimation |
| ICT | Information and communication technologies |
| ISO | International organization for standardization |
| PPI | Pulp and paper industry |
| RE | Random effects estimation |
| RISI | Information provider for the global forest products industry |
| RP | Recovered paper |
| RR | Recovery rate |
| UR | Utilization rate |

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PART II - Publications

1. Hujala, Maija (2011) The role of information and communication technologies in paper consumption. *International Journal of Business Information Systems*, Vol. 7, No. 2: 121–135.

2. Hujala, Maija and Hilmola, Olli-Pekka (2009) Forecasting long-term paper demand in emerging markets. *Foresight*, Vol. 11, No. 6: 56 –73.

3. Hujala, Maija, Arminen, Heli, Hill, R. Carter and Puumalainen, Kaisu (2011) Explaining the shifts of international trade in pulp and paper industry. Earlier version of this paper presented in the proceedings of the 16th International Working Seminar on Production Economics, Innsbruck, Austria, March 1–5, 2010. Revised and further submitted version.

4. Hujala, Maija, Puumalainen, Kaisu, Arminen, Heli, Tuppura Anni and Toppinen, Anne (2011) The role of national culture and environmental awareness in recovery and utilization of recovered paper. The first version of this paper 'Trends in the use of recovered fiber – Role of institutional and market factors' published in *Progress in Paper Recycling,* Vol. 19, No. 2: 4-12. Earlier version of this paper presented in the proceedings of the 2010 Biennial Seminar of the Scandinavian Society of Forest Economics, Gilleleje, Denmark, May 19-22, 2010. Revised and further submitted version.

5. Hujala, Maija, Luukka, Pasi, Puumalainen, Kaisu and Mattila, Jorma K. (2010) PPI in traditional and emerging markets – an input-output model based on fuzzy linear systems. In Saranen (Ed.), Quantitative research in industrial management: Proceedings of the scientific writing seminar held in Lappeenranta in June 2010, Lappeenranta University of Technology, Department of Industrial Management, Research Report 226: 61–83.

The contribution of Maija Hujala to the publications:

1. Sole author.

2. Made the research plan, collected the data, and built and tested the models. Interpreted the empirical results together with the co-author and wrote most of the paper.

3. Made the research plan and coordinated the writing of the paper. Collected and analyzed the data in collaboration with the co-authors. Wrote most of the paper.

4. Made the research plan, collected the data, coordinated the writing of the paper, and built and tested the models. Interpreted the empirical results together with the co-authors and wrote most of the paper.

5. Made the research plan, collected the data, and coordinated the writing of the paper. Analyzed the data in collaboration with the co-authors. Wrote most of the paper.

# PART I: OVERVIEW OF THE DISSERTATION

# 1 INTRODUCTION

The input and output markets of the pulp and paper industry (PPI) are currently facing dramatic structural changes. These shifts include, among others, the substitution of printed media for electronic communication technologies, the shift in advertising expenditures from print media to electronic media, innovations in clonal forestry, and the liberalization of trade with formerly closed low-income economies such as China. As a consequence, the focus of pulp and paper production is gradually moving to new areas, closer to the growing markets and the most cost-effective raw materials. In the current situation knowing the key factors affecting the markets of PPI products is important for the industry.

The aim of this research is to shed light on how the so-called megatrends affect the PPI's environment, and to find out ways to incorporate the impact of the megatrends on the models concerning (i) the demand for communication papers, (ii) the international trade of raw materials for paper making, (iii) the recovery and use of recovered fiber, and (iv) inter-industry linkages between the PPI and other industries. This chapter first describes recent trends in the global paper and pulp markets, then shortly discusses the definitions and history of megatrends as well as their role in the PPI, and finally presents research objectives and the outline of the study.

## 1.1 Recent trends in the global markets for paper products and paper making fibers

### *1.1.1 Paper and paperboard*

Recent developments in the production, consumption, and trade of paper products are illustrated in Figures 1–4. As shown in Figure 1, the world's paper and paperboard production has increased almost linearly between 1970 and 2010. Total production has more than tripled since 1970 and was over 394 million tonnes in 2010. The production grows in step with GDP as the level of economic development determines the volume of paper consumption in most

countries. However, there are considerable differences in production and consumption series between regions as well as paper grades (see Figures 2–4).

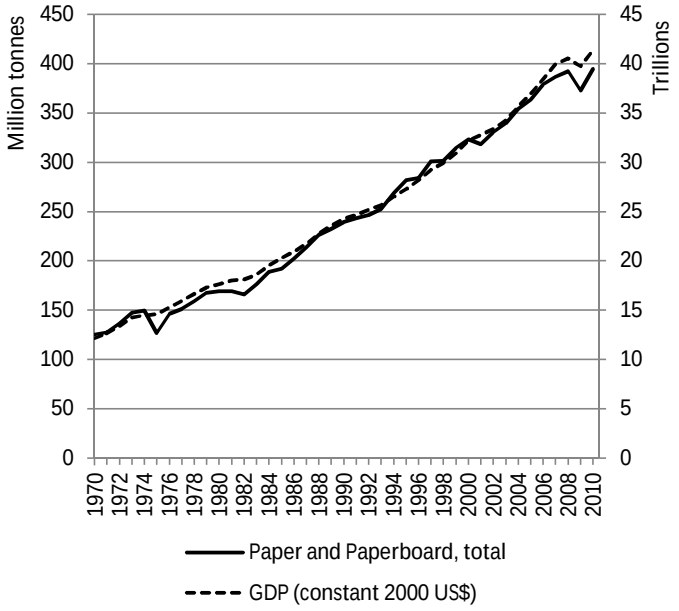


Figure 1 Paper and paperboard production (the left axis) and the world's GDP (the right axis) between 1970 and 2010 (data sources: FAO, 2011; World Bank, 2011)

Figure 2 shows some clear changes in production and consumption series. Europe and North America dominated the paper and paperboard markets until the 1990s. In North America, the markets matured in the early 1990s, and consumption, as well as production, has mainly decreased since 2000. In Europe, the consumption and production reached the maximum in 2007 and then started to decline. However, between 2000 and 2007 the increase in European paper demand was mainly due to the rising demand in Eastern Europe. In Western Europe, paper markets saturated already in 2000 when paper consumption measured as kilograms per capita reached the maximum 210 kg[1]. Between 2001 and 2007 Western European per capita paper consumption stagnated at around 200 kg and then started to decline. FAO's figures for 2010 show that in Europe paper and paperboard production has recovered after the economic recession, but it was still lower than in 2007. Thus, European, or at least Western European, paper markets seem to follow the path of North America when it comes to maturation.

[1] Author's calculations based on RISI's Industry Statistic database (RISI, 2011) and the World Development Indicators database by World Bank (World Bank, 2011).

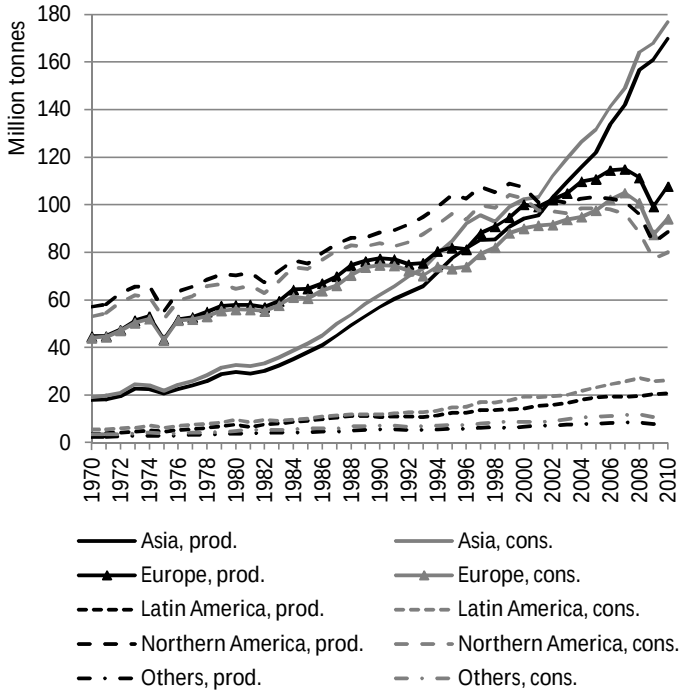


Figure 2 Paper and paperboard production (prod.) and consumption (cons.) by region between 1970 and 2010 (data source: FAO, 2011)

Conversely, in Asia the demand for paper products has grown extremely strongly since the early 1980s and nowadays comprises over 40% of the global paper and paperboard consumption. This is in many respects due to the rapid economic development of China. In 2010, China was the world's largest paper and paperboard consumer/producer (91.7/92.6 million tonnes)[2] and accounted for approximately 56% of Asia's paper and paperboard consumption and 18% of the imports (RISI, 2011). Demand for paper products has rapidly increased in Latin America as well, although it accounts only for about 3% of the global demand due to the small domestic market.

As shown in Figure 2, in Europe and North America the production exceeds the consumption, whereas Asia and Latin America are net importers (consumption exceeds production). In Europe, the gap between production and consumption series started to widen in the early 1990s due to structural overcapacity. The European newsprint and especially magazine paper

[2] United States was the second largest (75.2/75.8 million tonnes) and Japan was the third largest consumer/producer (27.9/27.3 million tonnes) (RISI, 2011).

markets have suffered from an oversupply of million tonnes, and still do despite recent cuts in production capacity (see e.g. Valtonen, 2010).

Figure 3 presents the world's paper and paperboard production by grade, and Figure 4 by grade and by region. According to Figure 3, the impact of the global recession in late 2008 and the first half of 2009 on the production of communication papers is evident as the production of printing and writing papers fell by 9.4% in 2009 compared to 2008 and the production of newsprint shrank by 11.6%. Instead, packaging materials and tissue suffered less than other grades from the downturn: the production of wrapping and packaging paper and board fell only by 1.3% and the production of household and sanitary paper (tissue paper) only by 0.8% compared to 2008. The paper and paperboard markets recovered in 2010, although the production of communication papers was still lower than in 2008.

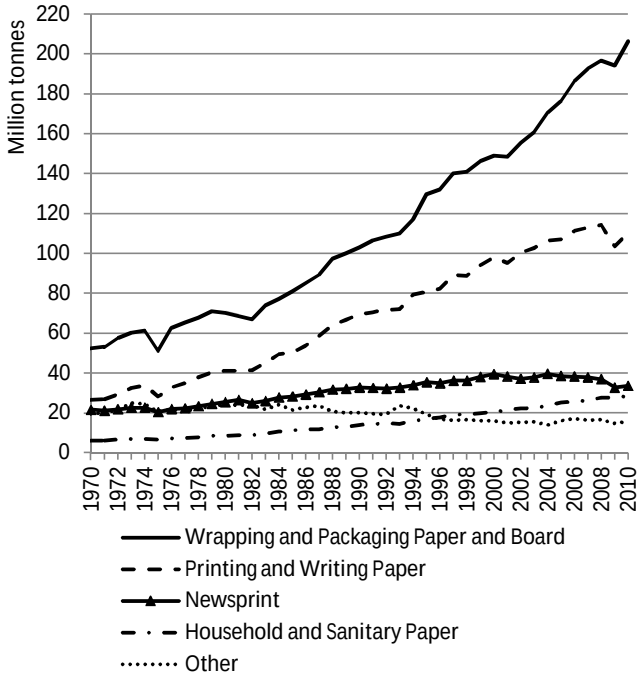


Figure 3 Paper and paperboard production by grade between 1970 and 2010 (data source: FAO, 2011)

As shown in Figure 3, packaging materials are by far the most widely produced type of paper and paperboard: about 206 million tonnes and 52% of the total volume in 2010. The production has grown rapidly and almost quadrupled between 1970 and 2010. However, the production, or consumption, of packaging paper and board is not growing in every region (see Figure 4). In North America, the production and consumption saturated in the late 1990s, and in Western Europe the production has been stagnated since 2007. Instead, in Asia the use and production of packaging materials has grown almost exponentially between 1992 and 2010. According to Diesen (2007), one of the most significant causes for the stagnating demand for paperboard in developed countries is the globalization of the manufacturing industries. In other words, as the manufacturing industries have moved parts of their production from industrialized countries, for example, to China, the need for packaging paper and paperboard has declined in the Western markets.

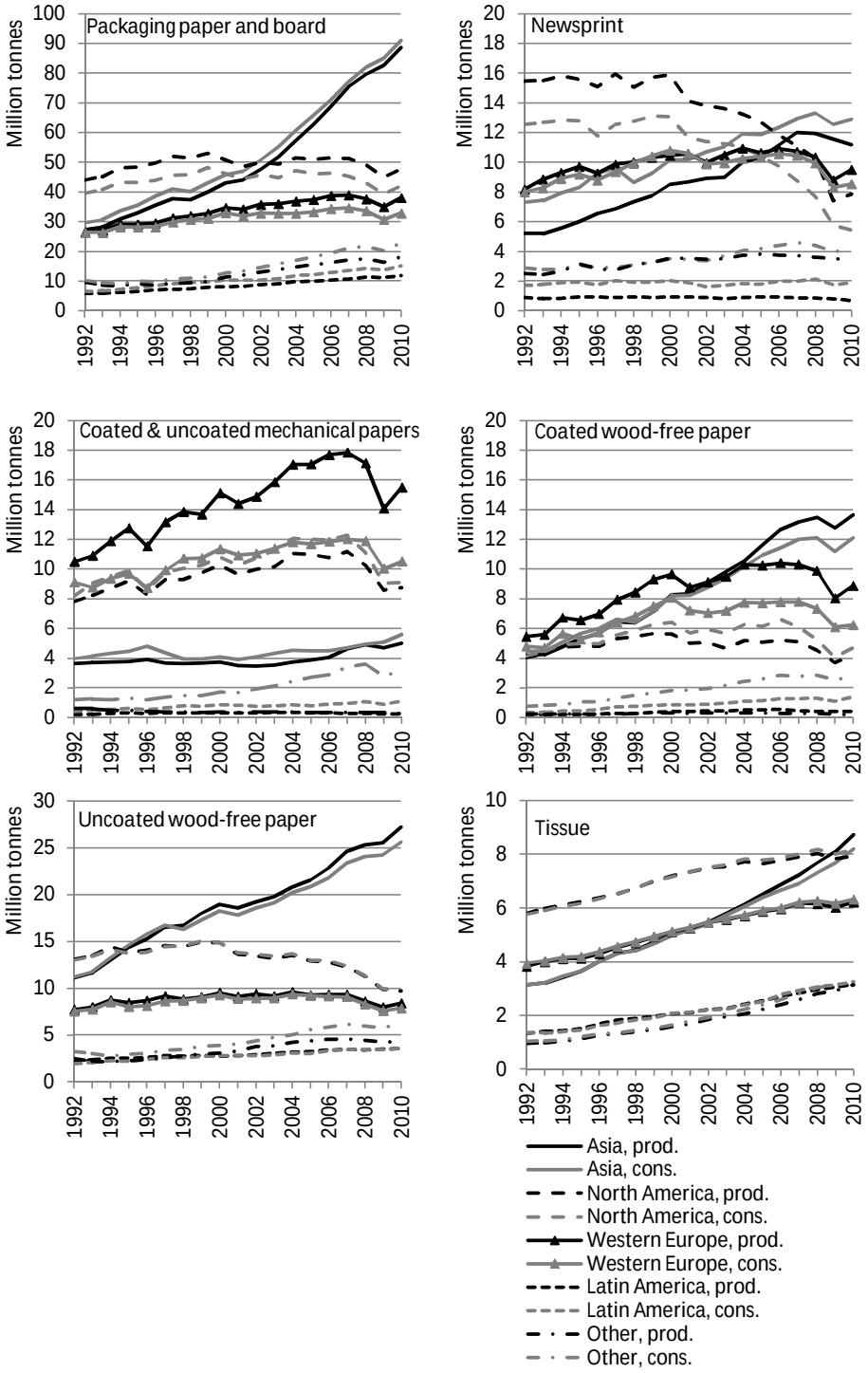


Figure 4 Paper and paperboard production (prod.) and consumption (cons.) by grade and region between 1992 and 2010 (data source: RISI, 2011)

Communication papers (newsprint and printing and writing papers) comprise the second largest group in paper production, that is, about 36% of the total volume in 2010. However, their series are quite different. As shown in Figure 3, the production of printing and writing papers has mainly increased between 1970 and 2010. Instead, the world's newsprint production increased rather slowly from 21.5 million tonnes in 1970 to 39.5 million tonnes in 2000, then stagnated, and started to decline in 2005. According to Figure 4, newsprint production seems to have declined or stagnated in every region in recent years, not only in North America and Western Europe. This tempts to draw the conclusion that newsprint markets are maturing all over the world, not only in advanced economies, but it is still too early to say that this is the case. For example, In China and India the newsprint consumption has grown in step with GDP apart from 2010. One, and probably the most important, reason for the decline in newsprint consumption in developed countries is the substitution effect of electronic media (see for example Hetemäki, 2005; Hetemäki et al., 2010). For example, in the United States, the newsprint consumption has actually sunk. According to RISI's Industry Statistics database (RISI, 2011), the US newsprint consumption was almost 12 million tonnes in 2000 and about 4.5 million tonnes in 2010. Thus, the newsprint consumption was more than halved in just ten years. It is hardly a coincidence that the number of Internet users has increased rapidly and mobile devices allowing access to the Internet anytime anywhere, for example, smart phones and tablet PCs, have become extremely popular during the same period.

Printing and writing papers can be divided further into coated and uncoated mechanical papers and coated and uncoated wood-free papers depending on the finishing techniques and raw materials in paper making. Figure 4 presents their production and consumption series between 1992 and 2009 by region. As shown, Western Europe is the largest producer of mechanical papers[3] followed by North America, and Asia dominates the production of wood-free papers[4].

In Western Europe, the production of magazine paper (mechanical papers) increased strongly until 2007 and then shrunk noticeably. This rapid shrinkage is partly due to the economic

[3] Coated and uncoated mechanical papers are mainly used for magazines and advertising materials such as catalogs (Diesen, 2007).
[4] Coated wood-free papers are used for high quality printing of magazines, catalogs, books, brochures and advertising materials. Uncoated wood-free papers are used, for example, for office papers and offset printing. (Diesen, 2007)

recession, but several closures of machines and mills also occurred in 2008 in Finland and elsewhere to cut overcapacity (Valtonen, 2008). However, Figure 4 still shows some overcapacity in magazine paper production in Western Europe. In North America, the production of mechanical papers increased until 2007, whereas the production of coated wood-free papers was around 5 million tonnes throughout the period. The production of uncoated wood-free papers has decreased since 2000. Thus, it seems that in North America the office paper consumption has decreased noticeably during the past 10 years and also the demand for catalog and magazine papers has started to decline recently. It is very likely that electronic media affect the demand for printing and writing papers, at least in developed countries, although the changes in production series are not as dramatic as with newsprint. For example, according to Hetemäki and Soirinsuo (2008), the decline in the magazine paper consumption in the United States is most likely related to the increasing use of ICTs. They also argue that in the future, a similar trend presumably occurs in other OECD countries and, in the long term, also in the developing economies.

In Asia, the production of wood-free papers, and especially uncoated wood-free paper, has risen strongly during the period (see Figure 4), being over 40 million tonnes in 2010 (coated + uncoated wood-free). The production of mechanical papers was around 3.7 million tonnes until 2004, but has shown a slightly increasing trend since then. The reason for the dominance of wood-free papers in Asia is the limited fiber resources compared to the region's hunger for paper making fibers. Mechanical papers are mechanical pulp[5] dominating (usually about 60–90% of total fiber [Diesen, 2007]) printing and writing paper grades and wood-free papers are made from chemical pulp. The production of mechanical pulp is usually integrated with paper production, whereas chemical pulp can easily be imported overseas.

The world production of tissue (i.e. household and sanitary paper) has steadily increased from 5.9 million tonnes in 1970 to 29.2 million tonnes in 2010 (see Figure 3). Moreover, as shown in Figure 4, tissue production shows an increasing trend in all of the regions.

[5] Mechanical pulp is produced from wood chips or logs by the use of 1) pure mechanical energy, 2) heat and mechanical energy (thermomechanical pulp) or 3) chemicals, heat, and mechanical energy (chemithermomechanical pulp).

### *1.1.2 Paper making fibers*

The paper making fibers of paper and paperboard include recovered paper (RP), wood pulp and pulp from fibrous vegetable materials other than wood. Figure 5 depicts their production between 1970 and 2010.

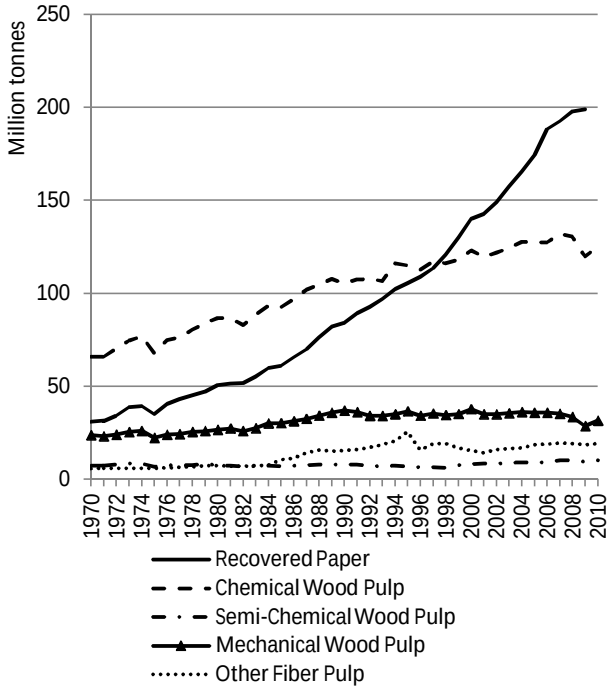


Figure 5 Production of paper making fibers between 1970 and 2010[6] (data source: FAO, 2011)

As shown, the production (i.e. recovery) of RP is skyrocketing, making it the fastest-growing raw material in the paper industry. The world's RP recovery increased by 546% between 1970 (30.8 million tonnes) and 2009 (199 million tonnes). The production of chemical pulp has almost doubled during the same period as well. Instead, the manufacturing of mechanical pulp increased until 1990 but has stagnated since then, amounting to 31.6 million tonnes in 2010 (about one fourth of the production of chemical pulp). There are various reasons for that:

[6] Between 1970 and 2009 for recovered paper. There seems to be an error in FAO's figures for recovered paper production in 2010.

Mechanical pulp is largely used for products like newsprint and mechanical papers, the use of which is declining in North America and Western Europe. Also, as mentioned above, in Asia and China in particular, the majority of printing and writing papers are made of chemical pulp. According to the Mill Project database provided by RISI, several new mechanical pulp lines and pulp mills have been established in China since 2004, but the region's mechanical pulp production capacity still falls short of fulfilling the paper mills' needs. Recycled fiber can be used to make largely the same end products as mechanical pulp, but it is usually impossible to use RP as a substitute for chemical pulp. Therefore, increases in Asia's paper production have required higher RP and chemical pulp imports to the area, because of which the global RP and chemical pulp output has increased.

Semi-chemical pulp and other fiber pulp are less important raw materials on a global scale although the production of other fiber pulp has more than doubled between 1970 (5.8 million tonnes) and 2010 (19 million tonnes). China alone produced over 70% of the world's non-wood pulp in 2010.

Figures 6–10 provide more detailed information about paper making fibers by fiber grade, as well as by region. At first, Figure 6 presents RP production and consumption series by region.

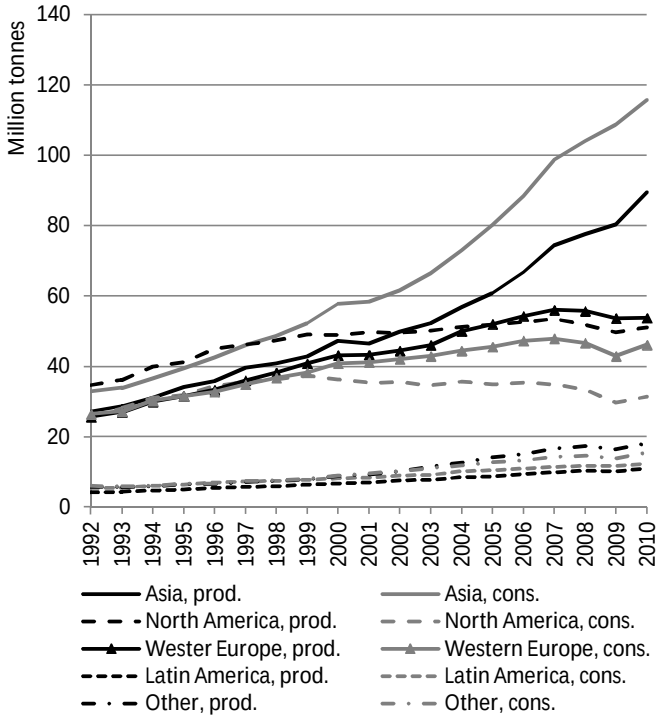


Figure 6 Recovered paper production and consumption between 1992 and 2010 (data source: RISI, 2011)

RP production depicts an increasing trend in every region. Figure 6 clearly shows that by far the largest expansion of RP consumption has taken place in Asia, while the simultaneous increases in the recovery of RP in the region have been far smaller than the rise in consumption, meaning that Asia and China in particular became progressively less self-sufficient in their RP supply. As a consequence, Asia has increasingly come to rely on massive imports of RP from North America and Europe. In 2010 China accounted for 57% of Asia's demand for RP and 75% of the imports. Europe and especially North America are the largest RP exporters. North America's domestic demand for RP has declined together with decreasing demand for newsprint and stagnating demand for packaging materials in the United States. Europe's share of RP production has held at about 30% of the total production, but an increasing share of it is exported, with Asia as the most important export destination. According to the Industry Statistics database (RISI, 2011), RP exports were over 54 million tonnes in 2010 making it the most exported raw material in the PPI.

Market pulp (i.e. pulp sold and bought on the open market) is mainly chemical pulp. Chemical pulp can be further divided into bleached softwood kraft pulp (BSKP), bleached hardwood kraft pulp (BHKP), unbleached kraft pulp (UKP) and sulfite pulp (unbleached and bleached). *Kraft* refers to the sulfate pulping process and *hardwood* and *softwood* to the raw material. Softwood is wood from conifers (for example, pines and spruces) and hardwood comes from broad-leaved trees such as acacia, birch, and eucalyptus. Figure 7 depicts the production series of chemical pulp by grade over the past two decades. In turn, Figure 8 presents the proportions of BHKP, BSKP, UKP, and sulfite pulp in chemical pulp production, as well as in exports.

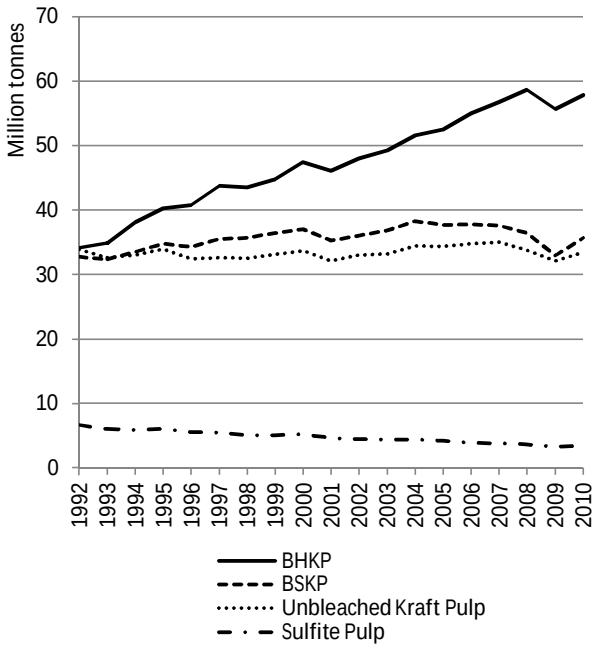


Figure 7 Chemical pulp production by pulp grade between 1992 and 2010 (data source: RISI, 2011)

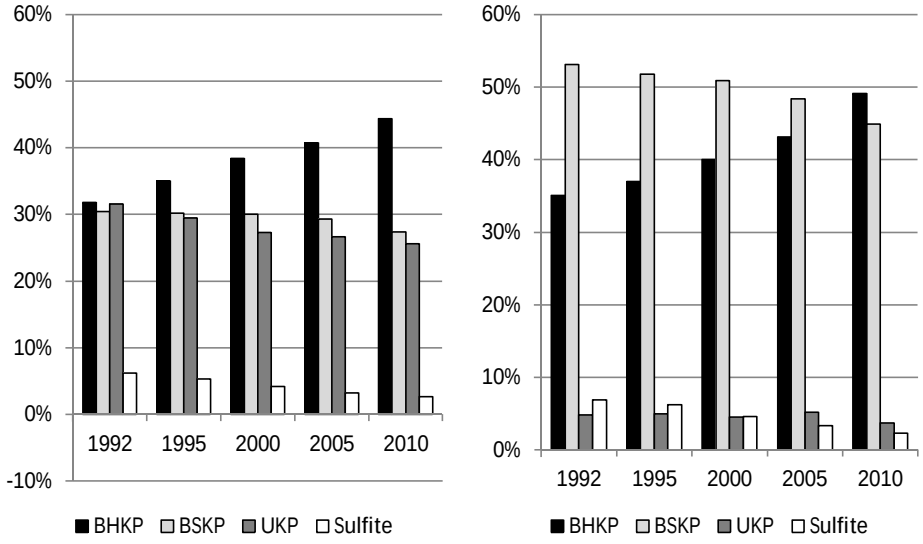


Figure 8 Shares of chemical pulp production (left) and exports (right) by grade between 1992 and 2010 (data source: RISI, 2011)

As shown in Figure 7, nowadays BHKP is the largest and fastest growing grade of chemical pulp. In 2010, almost 58 million tonnes of BHKP were produced, which accounted for about 44% of the total chemical pulp production (see Figure 8). In 1992, the corresponding figures were 34 million tonnes and 32%. Thus, BHKP production increased by over 69% in 18 years (and, as shown in Figure 7, the impact of the economic recession on the production of BHKP is evident in 2009). BSKP is the second largest grade of chemical pulp and UKP the third largest. The production of BSKP has held between 32 and 38 million tonnes throughout the period and that of UKP between 32 and 35 million tonnes. The production of sulfite pulp has declined evenly from 6.7 to 3.4 million tonnes.

Figure 8 illustrates that the world's chemical pulp exports mainly consist of BHKP (19.8 million tonnes and about 49% of the total chemical pulp exports in 2010) and BSKP (18.1 million tonnes and about 45% in 2010). BHKP's share of chemical pulp exports has risen rapidly. In 1992, the corresponding percentages were 35% (BHKP) and 53% (BSKP). The quantity of BHKP exports surpassed those of BSKP in 2007.

Figures 9 and 10 illustrate the production and consumption series of BHKP and BSKP by region. As shown, the production of these pulp grades has decreased over the past years in North America, reflecting the maturity of the paper markets. In addition, the gap between the production and consumption series of BHKP has shrunk close to zero, indicating that North America has lost its position as a major exporter of BHKP. With BSKP, the export supply has remained approximately the same between 1992 and 2010 and North America is still by far its largest exporter. Asia and Western Europe are net importers of both BHKP and BSKP. Western Europe's dependency on imported BHKP has increased in recent years. Instead, the area is nowadays almost self-sufficient in BSKP. In 2010, Asia was the largest producer of BHKP, but the domestic supply is nowhere near to fulfill Asia's and especially China's need for BHKP. Asia is by far the largest importer of BSKP as well.

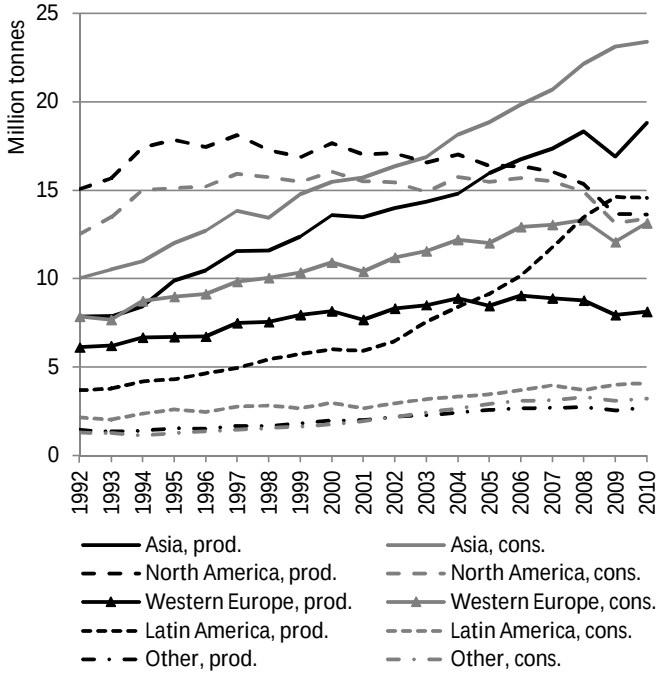


Figure 9 BHKP production and consumption by region between 1992 and 2010 (data source: RISI, 2011)

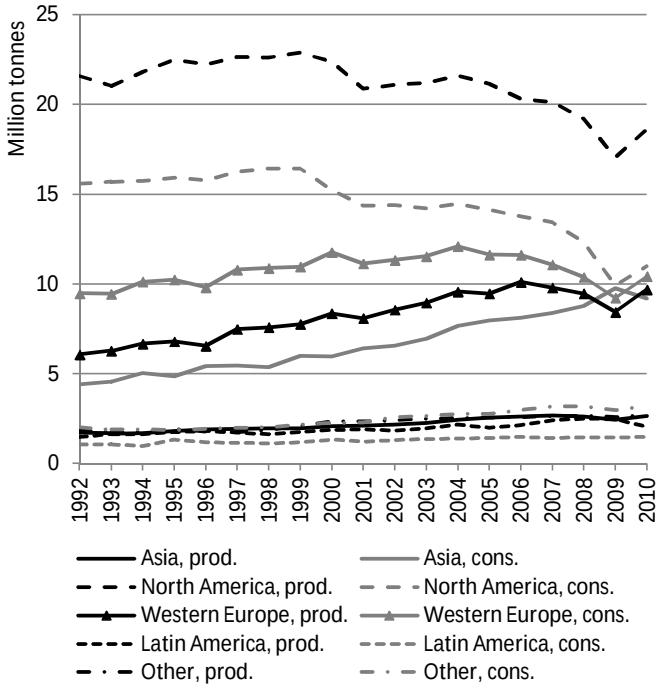


Figure 10 BSKP production and consumption by region between 1992 and 2010 (data source: RISI, 2011)

As shown in Figures 9 and 10, Latin America has rapidly gained a position as a major factor in the global pulp industry. Latin America's recent success in the chemical pulp market is almost entirely due to BHKP. Latin America's BHKP production transcended that of Western Europe in 2004 and that of North America in 2009 and was the second largest after Asia in 2010. In 2010, Latin America accounted for more than half (55%) of the world's total BHKP exports. Brazil is the leading producer of BHKP (mainly from eucalyptus), and there are large manufacturers in Uruguay and Chile as well (Bracelpa, 2010). In 2010, these three countries accounted for about 98% of Latin America's BHKP production and almost 100% of the exports (RISI, 2011). According to Brazilian Pulp and Paper Association, Bracelpa, Europe (39%) and China (31%) were the most important export destinations of Brazilian BHKP in January 2011. In comparison to northern species such as birch and aspen, the cost efficiency of eucalyptus fiber is superior: the trees grow fast and harvesting is relatively inexpensive. For example, in Brazil, the harvest rotation of eucalyptus is about 7 years and the yield is about 44 $m^3$ per hectare in a year, while Scandinavian birches can be harvested after 35–40 years of growth and their annual yield is 4–6

$m^3$/ha (Bracelpa, 2010). Acacia, another commonly planted tree species, e.g. in Indonesia, is almost similar to eucalyptus.

Latin America's, and especially Brazil's, success in the production and trade of BHKP is not just due to optimal growth conditions for eucalyptus, but since the 1950s a great effort has been made in order to create a knowledge base and innovation capability for the eucalyptus based PPI. As a result, Brazilian pulp and paper firms have several patented innovations in clonal forestry as well as in pulp and paper processes and products (Figueiredo, 2010). According to Toppinen et al. (2010), Latin America has some of the lowest wood fiber costs in the world. In addition to favorable conditions for eucalyptus and significant technical capacity, Latin America's advantages include a stable investment climate and low population density (Toppinen et al., 2010).

In sum, there are considerable differences between regions in the phase of the pulp and paper industry life cycle. In North America and Western Europe the PPI is in its maturity, while in Latin America and Asia the market growth is still rapid. Thus, the geographical location of production and consumption has clearly changed over time. Chapter 1.2 considers the role of some megatrends behind these changes.

## 1.2 Megatrends and PPI

### *1.2.1 What is a megatrend?*

The definition of *megatrend* is anything but unambiguous. According to Naisbitt (1984, p. 9), the megatrends "…will affect your life and your business. Trends tell you the direction the country is moving in." The explication given in Singh et al. (2009, p. 14) is almost poetic: "Global megatrends are over arching global forces that stem from the past, are shaped in present and will transform the future," whereas Sultan et al. (2008, p. 29) put it somewhat more engineer-like: "A megatrend is a significant movement, tendency or force that is commencing or occurring in one or more parts of the world, and that expected to continue well into the foreseeable future. Moreover, a megatrend has a profound effect on nearly every aspect of a

society, affecting individuals and businesses." Thus, there is not just one definition of megatrends but many, depending on the author and his or her point of view. Some authors (e.g. Slaughter, 1993) even deny the existence of real megatrends (for more about this, see Section 1.2.2). However, the key words seem to be *big* and *change*. To sum up, megatrends are big global or regional trends that will most probably affect individuals and businesses while evolving.

Conversely, the literature seems to agree that not taking into account the impact of megatrends on the environment in and around the firms can be fatal. According to Sultan et al. (2008), if a company does not anticipate and respond to megatrends, it may end up in trouble with outmoded technologies and products, or missed opportunities. Moreover, a company may find itself doing unnecessary things extremely well if it lacks capability and willingness to change (Bowersox et al., 2000). Larsen (2006) also gives some examples how a company or organization can use megatrends.

### *1.2.2 History of megatrends*

John Naisbitt (1984) was the first one to introduce the concept of "megatrends". The book *Megatrends* presents ten shifts taking place primarily in the US. The methodology used to analyze the American society was the content analysis of newspapers. Naisbitt's company, the Naisbitt Group, measured column inches in thousands of American newspapers to find out increasing and decreasing trends (Naisbitt, 1984). Later, Naisbitt wrote several other books on megatrends (see for example Naisbitt and Aburdene, 1990; Aburdene and Naisbitt, 1992; Naisbitt, 1996; Naisbitt and Naisbitt, 2010).

Slaughter (1993) critically reviewed early books and articles about megatrends and concluded that the area is diffused and the common framework is lacking. Also, many of the studies stay at the empirical level and too little attention is paid, for example, to ideas, traditions, and worldviews. For example, according to Slaughter (1993, p. 831), less than one third of the total 20 megatrends introduced in Naisbitt's first two books can be qualified as major trends and most of the others are "weak, ambiguous, superficial or problematic." Slaughter (1993) shows

some changing ideas that he sees to underlie the empirical landscape, and stresses that these ideas are his preferred point of view of reality. He argues that there can be no megatrends because there is "no single monolithic interpretation of the world" (Slaughter, 1993, p. 845). Instead, he suggests creating a variety of evolving pictures of the near future. However, if it is accepted that no single authoritative account of the world is possible, individuals and organizations would be better to develop their own trend analysis systems and derive their own views of the dynamics of change (Slaughter, 1993).

The latter approach suggested by Slaughter (1993) seems to be dominating, since the majority of the megatrend studies concern individual companies, industries, or areas of businesses. For example, Sultan et al. (2008) introduce a process for identifying megatrends and show the results for Delphi Corporation, Bowersox et al. (2000) and Gordon (2004) present megatrends shaping logistics, Hermans et al. discuss the impact of megatrends on the biotechnology industry in Finland, and Florin et al. (2007) identify megatrends that are critical for marketers to understand. However, there are also some recent studies that are more general in nature. Larsen (2006) presents ten megatrends that are developed by the Copenhagen Institute for Futures Studies. Although Larsen's (2006) megatrends are not related to any particular industry or company, the author stresses that megatrends have different meanings, for example, for different individuals and companies. Hines (2008a and 2008b) analyzes global consumer trends in advanced economies, emerging markets, and developing countries, introducing altogether 20 big trends affecting consumer life around the world. Quite similarly, Singh et al. identify three major global trends and their 14 sub-trends with important implications for global consumer trends. Also, the megatrends indentified by Sultan et al. (2008) are rather general in nature, although, as mentioned above, they show six global and six regional megatrends affecting Delphi's business environment.

Table 1 lists the megatrends introduced in some of the studies above to illustrate a variety of megatrends as well as differences in terminology.

Table 1 Some megatrends or equivalents[7]

| Naisbitt, J. (1984) *Megatrends: Ten new directions transforming our lives*, Warner Books Inc, New York. | Slaughter, R.A. (1993) Looking for the real 'megatrends', *Futures*, 25 (8), 827–849. | Larsen, G. (2006) Why megatrends matter, *FO/futureorientation*, 5, 8–13. | Hines, A. (2008a) Consumer trends in three different "worlds", *Futurist*, 42 (4), 18–23. | Sultan, M.F. et al. (2008) Defogging the crystal ball, *Research – Technology Management*, 51(3), 28–34. |
|---|---|---|---|---|
| From an industrial society to information society | The idea of a sustainable society and qualitative growth | Aging | Aging population | People live longer; a larger and stronger elderly segment |
| From forced technology to high tech/high touch | The notion of a stewardship ethic; the environment as a community | Globalization | Changing families | Increased concern about safety, security, privacy |
| From a national economy to world economy | The notion that the future is deeply implicated in the present | Technological development | Migration | Globalization; socio-economic–political redistribution |
| From short term to long term | The "new science" reflecting an interconnected reality | Prosperity | Population growth | Higher cost of natural resources |
| From centralization to decentralization | The benefits of systematic foresight | Individualization | Urbanization | Increasing environmental awareness/regulations |
| From institutional help to self-help | The rebirth of the sacred | Commercialization | Asia rising | Information explosion; increased volume and dependence on the Internet |
| From a representative democracy to participatory democracy | The conservation and revaluing of native peoples and cultures | Health and environment | Consumerism | |
| From hierarchies to networking | | Acceleration | Middle-class growth | |
| From north to south | | Network organizing | Time pressure | |
| From either/or to multiple option | | Urbanization | Personal outsourcing | |

[7] Slaughter (1993) does not use the term *megatrend* but "changing ideas"

As shown in Table 1, globalization and urbanization are megatrends that are identified more than once. Moreover, both Larsen (2006) and Sultan et al. (2008) identify environmental awareness and technological development, although they use somewhat different names for the same trend. The latter three studies (Larsen, 2006; Hines, 2008a; Sultan et al., 2008) appear to be more consistent with each other than with the earlier ones.

### *1.2.3 Megatrends shaping the PPI*

Based on the analysis in Section 1.1, two megatrends seem to be of high importance in the PPI markets, that is globalization and technological development. Some recent studies (Jansson, 2011; Toppinen et al., 2010; Hetemäki et al., 2010) emphasize the significance of globalization and technological development for the PPI as well. Sideri (1997, p. 38) gives the following definition of *globalization*: "Globalization is essentially a process driven by economic forces. Its immediate causes are, in this order, the spatial reorganization of production, international trade and the integration of financial markets." The regional redistribution of production and consumption of pulp and paper products is obvious. The increased importance of emerging markets as producers and consumers is evident as is the decreased importance of North America and Western Europe. Reorganization in the international trade of chemical pulp has occurred as well due to Latin America's recent success in the BHKP markets and China's insatiable demand for paper making fibers.

According to Larsen (2006), the most important areas in technological development are information technology, biotechnology, nanotechnology, and energy. At least the first two areas are clearly causing structural changes in pulp and paper production and consumption. The production of newsprint has collapsed in the United States most likely due to the substitution effect of electronic media and the shift in advertising expenditures from print media to electronic media, and innovations in cloning eucalyptus have greatly helped Latin America to gain its position as one of the leading chemical pulp producers.

Increasing environmental awareness also has its impacts on the PPI. For example, recovered paper is nowadays the leading raw material in paper production. This development has been

facilitated by technological progress, for example, in the areas of deinking and screening of impurities (Diesen, 2007), the good price competitiveness of recycled fiber, and Asia's need for fiber. However, environmental consciousness—at both the producer and consumer ends—and regulation have also contributed to the increase in the demand for recovered paper (see e.g. Lundmark, 2001; Huhtala and Samakovlis, 2003; Samakovlis, 2003; Berglund et al., 2002; Berglund and Söderholm, 2003). Moreover, according to Kando and Buongiorno (2009), the efficiency in wood and virgin fiber utilization has increased in most of the OECD countries between 1961 and 2005. The results most likely reflect the significance of conserving scarce forest resources since wood utilization efficiency was lower in countries that have vast forest resources. The impact of environmental issues is not limited to production and the use of paper making fibers: according to Toppinen et al. (2010), increasing awareness of environmental and social issues has led corporate social responsibility to become a high profile issue in the forest industry's foreign direct investments, and Jonsson (2011) notes that chemical pulp producers could manufacture new products in integrated bio-refineries and, hence, profit from the growing bio-energy industry.

## 1.3 Research objectives

Why is this thesis important? The reason becomes obvious in Chapter 2. The majority of previous studies concerning the demand and trade of PPI products are either rather old, focused mainly on the US or Western European markets, or they measure the impact of megatrends inefficiently or not at all. However, for a capital intensive industry, accurate demand forecasts are crucial. According to Hetemäki (2005), the traditional paper demand models tend to overestimate the demand of some paper grades especially in North America and Western Europe. For example, if the North American PPI had invested in newsprint production according to FAO's projection (Zhu et al., 1998), it would have led to serious problems because the difference between the projection and the actual consumption in 2004 was 5.4 million tonnes (Hetemäki, 2005). Furthermore, according to Hänninen (2004) there is a growing interest in short-term economic forecasts due to changes in the world's economies. Hänninen (2004) states that the PPI must be aware of alternate future scenarios when making decisions and, thus, there is a need for forecast models and forecasts. According to the recent

literature review of Toppinen and Kuuluvainen (2010) about the forest sector modeling in Europe, it seems that there are only few econometric studies that have attempted to forecast forest sector development.

The aim of this research is to analyze how megatrends affect the PPI's environment, and to find out ways to take into account the impact of these trends when modeling the input and output markets of the PPI. Thus, the main research problem of this dissertation is:

*What kinds of changes are megatrends causing for the PPI, and how could the impact of these trends be taken into account in modeling?*

The research questions are:

1. What is the role of ICT in the demand for communication papers?
2. What will the future demand for paper in Russia be considering the diffusion of ICT?
3. How have dynamic changes in the PPI affected the bilateral trade patterns of raw materials in paper making?
4. Do socio-cultural characteristics and environmental factors affect the recovery of paper and utilization of recovered paper at the country level?
5. What kinds of inter-industry linkages are there between the PPI and other industries, and have these linkages changed in the past decades?
6. What will the structure of inter-industry linkages be between the PPI and other industries in the future?

## 1.4 Outline of the study

Part I of this thesis proceeds from the literature review (Chapter 2) to the empirical part of the study. Chapter 3 introduces the data collection as well as research methods applied in Publications 1–5, and Chapter 4 summarizes their objectives and key findings. Chapter 5 answers the research questions, discusses the results, and offers conclusions.

Part II consists of five peer-reviewed publications that have been published in academic journals, conference proceedings, or in research reports. Publications 1 and 2 explore and discuss the role of the modern information and communication technologies in the consumption of communication papers, which is one of the largest groups of the PPI's end products. Forecasts for future paper demand in Russia taking into account the role of ICTs are calculated in Publication 2. In turn, Publications 3 and 4 focus on the raw materials of the paper industry. Publication 3 analyzes how recent structural changes in the PPI are reflected in the bilateral trade flows of pulp and recovered paper, whereas Publication 4 investigates the role of environmental awareness and cultural factors in waste paper recovery and utilization. Finally, Publication 5 takes a slightly different perspective to the subject when it comes to the research methods and level of analysis. Instead of pure country-level analysis, Publication 5 looks at inter-industry linkages between the PPI and other industries and analyzes their change over time. Table 2 links the research questions presented above to the five publications.

Table 2 Research questions and publications

| Research questions | Publication |
|---|---|
| 1. What is the role of ICT in the demand for communication papers? | Publication 1: The role of information and communication technologies in paper consumption |
| 1. What is the role of ICT in the demand for communication papers?<br>2. What will the future demand for communication papers in Russia be considering the diffusion of ICT? | Publication 2: Forecasting long-term paper demand in emerging markets |
| 3. How have dynamic changes in the PPI affected the bilateral trade patterns of raw materials in paper making? | Publication 3: Explaining the shifts of international trade in the pulp and paper industry |
| 4. Do socio-cultural characteristics and environmental factors affect the recovery of paper and utilization of recovered paper at the country level? | Publication 4: The role of the national culture and environmental awareness in the recovery of paper and utilization of recovered paper |
| 5. What kinds of inter-industry linkages are there between the pulp and paper industry and other industries, and have these linkages changed in the past decades?<br>6. What will the structure of inter-industry linkages be between the PPI and other industries in the future? | Publication 5: PPI in traditional and emerging markets – an input–output model based on fuzzy linear systems |

# 2 MODELING THE DEMAND AND TRADE OF PPI PRODUCTS

This chapter presents some demand and trade models of PPI products and raw materials, and examines how the role of megatrends is taken into account in modeling in the literature. Trade models are limited to the gravity models of international trade. Despite the input–output analysis, this literature review concentrates on national or regional studies.

## 2.1 Models for paper demand

### *2.1.1 Demand models based on Cobb-Douglas production function*

Econometric studies about paper demand have been published regularly over 30 years. One of the first studies, Buongiorno (1977) forecasts the consumption of major forest products in the developed and developing countries. A year later, Buongiorno (1978) investigated income and price elasticities in the world demand for newsprint, printing and writing papers, and paperboard. Buongiorno (1978) was followed by several studies (for example, Wibe, 1984; Baudin and Lundberg, 1987; Brooks et al., 1995; Rasi et al., 1999; Chas-Amil and Buongiorno, 2000; Simangunsong and Buongiorno, 2001; Kangas and Baudin, 2003; Turner and Buongiorno, 2004; Li et al., 2006; McCarthy and Lei, 2010; Michinaka et al., 2011) basically using the same theoretical background.

In most of the studies mentioned above, the demand models for paper are based on derived demand theory. In this framework, paper products are regarded as intermediate goods. In other words, the demand for paper depends on the demand for the end products (such as newspapers and magazines). Paper inputs *y* are combined with other inputs *z* to produce a final output *g*. For given input prices *($p_y$* and $p_z$*)* and the level of output *(g)* there is a level of paper demand *y* that minimizes the production costs of *g* units of output (Chas-Amil and Buongiorno, 2000). Thus, the conditional input demand function for paper is $y(p_y,p_z,g)$. Assuming the production function of the industry that uses a certain paper grade as an input is a Cobb-Douglas production function, the cost minimization problem is defined as follows:

$$\min_{y,z}(p_y\, y + p_z z) \tag{1}$$

subject to

$$g = a y^b z^c,$$

where $p_y$ is the price of paper, $y$ is the amount of paper demanded, $p_z$ is the price of other inputs, $z$ is the amount of other inputs, $g$ is the final output, and $a$, $b$, and $c$ are positive parameters. The derived demand for paper is then (Pindyck and Rubinfeld, 2009, p. 267–269)

$$y = y(p_y, p_z, g) = \alpha_0 g^{\beta_1} \left(\frac{p_y}{p_z}\right)^{\beta_2}, \tag{2}$$

where $\beta_1 = \frac{1}{(b+c)}$ (long-term demand elasticity with respect to output) and $\beta_2 = \frac{-c}{(b+c)}$ (long-term demand elasticity with respect to price $p = \frac{p_y}{p_z}$). In aggregated paper demand (the country level), GDP is typically used as the output $g$ and price of other inputs $p_z$ is proxied by the GDP deflator. After logarithmic transformation to achieve linearity and including an error term $\varepsilon$, the model (2) takes the form

$$\ln y = \alpha_0' + \beta_1 \ln g + \beta_2 \ln p + \varepsilon, \tag{3}$$

where the dependent variable $y$ is the country's paper consumption, and the economic activity (usually GDP) $g$, and the real price of the paper product in question $p$ are used as explanatory variables. Coefficient $\beta_1$ is the income elasticity of the demand and $\beta_2$ is price elasticity. $\beta_1$ and $\beta_2$ give the percentage change in paper demand in response to a one-percent change in economic activity and in the relative price. According to economic theory, income elasticity is expected to be positive and price elasticity negative. For more about this, see, for example, Chas-Amil and Buongiorno (2000), Simangunsong and Buongiorno (2001), Bolkesjø et al. (2003) and Buongiorno et al. (2003).

### *2.1.2 Megatrends and paper demand*

*Technological development*

According to Hetemäki (2008, p. 39), "at the beginning of the 21st century, the paper industry and bulk of industry analysts still considered ICT development to enhance communication paper demand." Thus, it is no wonder that econometric studies about the effects of information and communication technologies on country-level paper demand are rare. Nowadays, the development of ICT is generally seen as a challenge to many paper grades, especially in advanced economies (Hetemäki, 2008). Still, quite few studies have been published in this field compared, for example, to studies concerning individuals' choice between digital and traditional media (e.g., Flavián and Gurrea, 2006, 2008; Ellonen and Kuivalainen, 2008; Klassen et al., 2009).

In one of the first studies about ICT and paper demand (Baudin and Lundberg, 1987), a number of econometric models were developed and evaluated to describe the long-term country-level demand of paper products in all major consuming countries. In one of the models, the effects of changes in other determinants of paper demand than economic activity and prices, for example, the substitution of electronic media for printed media were taken into account by adding time as an additional variable to the classical demand model. Baudin and Lundberg (1987) conclude that these time-variant factors had a positive effect on the demand for printing and writing papers and a negative effect on the newsprint between 1961 and 1981. However, the data used by Baudin and Lundberg (1987) are too old to measure the effects of modern information and communication technologies on paper demand since the Internet and mobile telephones did not exist before the 1980s. Time among the explanatory variables also covers all possible time-variant factors affecting the country level paper consumption, not only the possible substitution of electronic media. In addition, time does not vary between countries and thus does not take into account country differences in the consumption of electronic media. Ten years later, Zhang and Buongiorno (1997) developed a model to estimate the effects of the computer, television, and radio on the demand for printed materials in the US. The results suggest that between 1960 and 1991, electronic media did not have a significant effect on the demand of printing and publishing papers. However, the data used by Zhang and

Buongiorno (1997) also reflect the development before the Internet age and the diffusion of mobile telephones.

The study of Zhang and Buongiorno (1997) was followed by Hetemäki and Obersteiner (2001). Hetemäki and Obersteiner (2001) computed the US newsprint demand forecasts to the year 2020 using three different models: 1) the model based on the Cobb-Douglas production function, 2) its Bayesian variation, and 3) an ad hoc model called *newspaper circulation model*. In the Bayesian variation, the industry experts' scenarios about economic and lifestyle development, the substitution of newspaper by electronic media and future changes in the physical measures (weight, size) of newspapers were incorporated in the estimation. The results indicated that the demand model based on the Cobb-Douglas production function cannot explain or forecast the US newsprint demand. The future projections from the Bayesian approach also indicated only a slight decline in newsprint consumption compared to year 2000. It thus seems that the Bayesian method, i.e. incorporating qualitative data about the impact of electronic media on newsprint demand into quantitative models, is not able to forecast changes in the US newsprint markets since the decline in the consumption has been anything but slight.

Bolkesjø et al. (2003) followed the Bayesian method used by Hetemäki and Obersteiner (2001). They compared the classical model and the Bayesian approach in the newsprint demand by using panel data from Western Europe and Japan. Bolkesjø et al. (2003, p. 1651) concluded that "Bayesian models might have an advantage compared with classical models in cases of unprecedented structural changes, given that sufficient information other than historical data is available."

More recently, Szabó et al. (2009) calculated paper and paperboard demand, energy consumption, and emission scenarios to year 2030 using system dynamics simulation. The authors take into account the possible substitution effect of electronic media but not by using explicit measures of ICT. Instead they use behavioral parameters on the per capita income variable.

Other studies about the ICT and paper markets (e.g., Hetemäki, 2005, 2008; Hetemäki and Soirinsuo, 2008) are more descriptive in nature. Hetemäki (2005, 2008) discusses the structural changes of newsprint, office paper, and magazine paper markets in the US and other OECD countries and also calculates some simple trend forecasts. According to Hetemäki (2005), there is a clear structural break in the US newsprint market due to the impact of electronic media, and it is possible that a similar break will happen in other countries and other paper grades. In Hetemäki and Soirinsuo (2008), the main attention is on describing magazine paper consumption in the USA. According to them, during the last years, the magazine paper consumption has stagnated or even slightly decreased, and the reason is most likely related to the increasing use of ICTs. They also argue that in the future, a similar trend will presumably occur in other OECD countries and in the long term in the developing economies.

*Other megatrends*

Quantitative studies considering the role of other megatrends than technological development in paper demand are very rare. Although calling it simple, Oberstainer and Nilsson (2000) develop a fairly sophisticated and complex scenario model for communication papers. Scenarios for future paper demand are based on population cohorts, characterized by education, age and gender, and their reading intensity and reading habits. For example, economic growth and substitution from paper reading to electronic media are taken into account, and the model allows the inclusion of uncertainty in the scenarios. Thus, in addition to ICTs some other megatrends, such as aging, affecting peoples' lifestyles are taken into account in the model as well. The authors apply their model to newsprint consumption in the US and calculate the so-called "press-imistic" scenario (electronic reading dominated trajectory). As a result, Oberstainer and Nilsson (2000) are able to provide probably one of the most accurate scenarios for newsprint demand in the US: the lower uncertainty limit of the scenario is almost congruent with the realized demand for newsprint between 2000 and 2010.

The most recent study published in this field is that of McCarthy and Lei (2010). They develop and analyze regional per capita dynamic demand models for paper and paperboard, as well as for pulp, newsprint, printing and writing papers, tissue, and packaging materials. Time as well

as urbanization (one of the megatrends listed in Table 1) are among the explanatory variables. The results reveal that urbanization has a positive impact on the demand for pulp, as well as for printing and writing papers. Time has a significant negative impact on the total paper and paperboard consumption in the NAFTA area and Europe, and a significant positive impact on consumption in Asia. In the pulp sector, the time variable has a negative impact on the consumption in NAFTA, Europe, and Asia, and a positive impact in South America. According to the authors, the statistically significant region–time interactions most likely reflect the regional redistribution of production and consumption, in other words, the impacts of globalization. Time also seems to decrease the newsprint consumption in NAFTA and Europe. With newsprint, the time variable is presumably reflecting the increased importance of ICTs (McCarthy and Lei, 2010).

## 2.2 Demand and use of recovered paper and wood pulp

Demand models for paper making fibers are not as common in the existing literature as paper demand models. Especially econometric studies on the demand for wood pulp are rare, but that of McCarthy and Lei (2010), presented in the previous section, is one of them. Moreover, according to Lundmark and Söderholm (2003) the majority of the demand models for recovered paper focus on waste paper use in the production of different paper qualities. Studies on the country-level consumption of recovered paper are scarce and rather old. For example, Turner and Grace (1977) explain and forecast the future demand for waste paper in the UK using linear supply–demand models with GDP as the explanatory variable. Deadman and Turner (1979) forecast recovered paper demand in the UK using three different methods: 1) materials recycling project (MRP) long-term and short-term forecasts, 2) a modification of the MRP approach using exponential smoothing (the Holt-Winters method), and 3) an input–output analysis. In the MRP approach the recovered paper consumption by the mills is a function of either GDP or industrial production. Also, the influence of packaging products output and mechanical pulp prices is taken into consideration. Gill and Lahiri (1980) estimate an econometric model of waste paper consumption in the US using the prices of waste paper, wood pulp, and building paper and paperboard, as well as labor costs and time trend as explanatory variables.

More recently, the country level econometric studies about the demand and use of recovered paper seem to have concentrated on the recovery and use. Van Beukering and Bouman (2001) develop and estimate an empirical model for the recovery and utilization of waste paper and lead. Berglund et al. (2002) as well as Berglund and Söderholm (2003a, 2003b) provide a critical analysis and complementary empirical evidence on the global recycling and trade of recovered paper. They question the earlier finding of Van Beukering and Bouman (2001) that international trade patterns of recovered paper are a major determinant of utilization rates, and focus instead on the availability of recycled fiber. In addition, they include the shares of some paper grades (newsprint, tissue, and liner and fluting board) of the total paper and board production as an explanatory variable. In all of these studies, increasing environmental awareness is expected to affect the recovery and utilization rates, but its impact is measured rather implicitly. For example, Berglund et al. (2002) hypothesize, presumably quite correctly, that national environmental policies are more prevalent in richer countries. Thus, they expect the recovered paper recovery rates to correlate positively with GDP per capita. However, a country's wealth, i.e. GDP per capita, has an influence on many other factors that may also affect the recovery rate.

## 2.3 Gravity models of international trade

The gravity models of international trade predict that the flow of commodities between two countries is positively related to their size and negatively related to their distance (Ghosh and Yamarik 2004). Over time, other explanatory variables have been added to the models to capture the effects of the supply and demand conditions on the exporter and importer. Gravity models have been used extensively in the literature on international trade to evaluate the impacts of trade liberalization and preferential trading agreements, to predict the trade potentials of countries, and to give policy prescriptions. In the simplest form of the model,

$$\ln T_{ij} = \alpha_0 + \beta_1 \ln GDP_i + \beta_2 \ln GDP_j + \beta_3 \ln POP_i + \beta_4 \ln POP_j + \beta_5 \ln D_{ij} + \beta_6 \ln X_i + e_{ij} \quad (4)$$

the volume of trade *T* is defined by the supply conditions in the exporting country *i* (*GDP* and population), the demand conditions in the importing country *j* (*GDP* and population), as well as bilateral trade resistance factors (transport costs approximated by geographical distance *D*) and trade preference factors $X_i$ (e.g. common border and preferential trading agreements). Some authors (e.g. Serlenga and Shin 2007) drop population from Equation (1) to avoid multicollinearity. For aggregate trade the expected signs of the coefficients of exporters' and importers' GDPs and populations are positive (larger countries import and export more). The distance variable is a proxy for transport costs, so that it should reduce the volume of exports. The expected sign of $\beta_5$ is thus negative. Although the bulk of the research analyzes the volume of aggregate trade (or exports or imports), some studies focus on the sectoral level, and single commodity data can be used as well. Analyzing the trade of a single commodity means that it is important to include regressors that impact on the supply and demand of that commodity, therefore affecting its export supply and import demand.

The early contributions to explain the volume of trade by gravity models were criticized for not having a proper theoretical foundation. However, it has later been demonstrated that the predictions of the models can be derived from the models of international trade, including Ricardian, Heckscher-Ohlin, and increasing-returns-to-scale models (see for example Anderson, 1979; Bergstrand 1985; 1989; 1990; Helpman and Krugman, 1985; Deardorff, 1998; Anderson and van Wincoop, 2003). Therefore, the gravity model does not rule out the theory of comparative advantage but can actually be derived from it.

It seems that there is only one previous study focusing on the bilateral trade of paper and pulp, namely that of Karikallio et al., (2011). Karikallio et al. (2011), use the gravity models of international trade to obtain the price elasticities for the export flows of PPI products. According to the authors, they selected this approach to be able to control for factors other than the prices of pulp and paper affecting trade flows. Their control variables include the explanatory variables of the gravity model presented in Equation (4) and no additional variables other than price are included. In addition, Kangas and Niskanen (2003), Polyakov and Teeter (2007), and Zhang and Li (2009) utilize gravity models in the context of forest products trade. Kangas and Niskanen (2003) analyze the aggregate trade flows of forest products among the EU countries and EU access candidates. Polyakov and Teeter (2007) model the interregional trade

of pulpwood in the Southern USA. They use data on the production (supply) and consumption (demand) of pulpwood as the determinants of export supply and import demand. In another recent paper, Zhang and Li (2009) explain China's wood products trade with roundwood production (per capita) and Chinese logging restrictions as the measures of export supply and import demand. Thus, it seems that the study of Zhang and Li (2009) is the only one taking into consideration the role of megatrends, as the logging restrictions most likely measure environmental attitudes in logging.

## 2.4 Input–output models of PPI

Input–output models allow the examination of inter-industry demand and supply. The input–output model is originally developed by Wassily Leontief in 1936. It is an analytical tool that can be used in various economic problems (Miernyk, 1965). It is based on the data organized in the form of a table which illustrates the structure of a nation's (or region's) economy at a given time. The input–output table describes the amount of purchases and sales among industries. Thus, it shows how dependent each industry is on all the others in the economy.

The structure of the input–output table is illustrated in Table 3.

Table 3 An input–output table

| | | industry inputs | | | final demands | | | | | Total final demand | Total gross output |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Industry 1 | Industry 2 | Industry n | HHFC | CHINV | EXP | ... | IMP | | |
| industry outputs | Industry 1 | $x_{11}$ | $x_{12}$ | ... | $HHFC_1$ | ... | ... | ... | $IMP_1$ | $d_1$ | $x_1$ |
| | Industry 2 | $x_{21}$ | ... | ... | $HHFC_2$ | ... | ... | ... | $IMP_2$ | $d_2$ | $x_2$ |
| | Industry n | $x_{n1}$ | ... | $x_{ij}$ | $HHFC_n$ | ... | ... | ... | $IMP_n$ | $d_n$ | $x_n$ |
| | GOS | $GOS_1$ | ... | $GOS_j$ | | | | | | | |
| | LABR | $LABR_1$ | ... | $LABR_j$ | | | | | | | |
| | TAXES | $TAXES_1$ | ... | $TAXES_j$ | | | | | | | |
| | Total input | $x_1$ | $x_2$ | $x_n$ | | | | | | | |

Each row of the input–output table reports the value of the industry's outputs, and the inputs are represented in the columns. Non-industrial inputs, such as the compensation for employees (LABR) and gross operating surplus (GOS) are aligned below the matrix. An array of column

vectors called final demands, such as the household's final consumption (HHFC), changes in inventories (CHINV), and exports (EXP) are on the right hand side of the matrix. The total gross output of the industry *n* equals its total input.

The basic equations of the input–output model can be expressed as follows (Miernyk, 1965): Total gross output $x_i$ is the sum of the intermediate outputs $x_{ij}$ and the final demand $d_i$:

$$x_{i1} + x_{i2} + \cdots + x_{in} + d_i = x_i \,. \tag{1}$$

From Table 1 the so-called technical coefficients are

$$a_{ij} = \frac{x_{ij}}{x_j} \,. \tag{2}$$

These coefficients represent the direct purchases by each industry from every other industry per one unit of output. Substituting (2) in (1) yields

$$a_{i1}x_1 + a_{i2}x_2 + \cdots + a_{in}x_n + d_i = x_i \,. \tag{3}$$

In a matrix form we have

$$\mathbf{A}x + d = x \,, \tag{4}$$

where A = [$a_{ij}$], $x$ = [$x_i$] and $d$ = [$d_i$]. The matrix A is called the input–output, or technological, or consumption, matrix of the economy. Solving for $x$ we obtain

$$x = (\mathbf{I} - \mathbf{A})^{-1} d \,, \tag{5}$$

where $(I-A)^{-1}$ is called the Leontief inverse matrix. If the technological matrix A is known and does not change over the projection period, we can now predict the new total output $x$ and, for example, new inter-industry transactions $x_{ij}$, as a result of changes in final demand vector $d$.

Input–output analysis has been quite popular when analyzing the economic impact of forest resources (e.g. Schallau and Maki, 1983; San Cristóbal, 2007; Dieter, 2009), forestry (e.g. Crowley et al., 2001; Thomson and Psaltopoulos, 2005; Dhubhàin et al., 2009), or the forest industry (e.g. Flick et al., 1980; Munday and Roberts, 2001; Cox and Munn, 2001). However, it seems that the study of Byström and Lönnsted (1995) is one of the rare ones to concentrate on the pulp and paper industry. Byström and Lönnsted (1995) first use input–output matrices to describe the waste paper usage and wood fiber flows in Western Europe in 1990, and then predict and analyze the influence of the increasing recovery and utilization rates on waste paper use and fiber flows in 2000. Thus, the role of increasing environmental awareness is taken into account in the predictions.

## 2.5 Summary of the literature review

In sum, in the existing literature, the influence of technological development on the demand of PPI products is analyzed much more often than the influence of other megatrends although its proxy measures have been rather inefficient or implicit. The impact of increasing environmental awareness has been taken into consideration in some of the studies concerning recovered paper. Instead, the role of globalization in demand and trade is almost neglected. However, the number of quantitative studies considering the role of megatrends in demand and trade seems to have increased in recent years. This dissertation attempts to narrow the gap further.

# 3 RESEARCH DESIGN AND METHODS

This dissertation is part of the project Corporate Social Responsibility and Value Creation Challenges in the Global Forest Industry funded by the Academy of Finland. It is a consortium project of the Lappeenranta University of Technology School of Business and the Helsinki University Department of Forest Economics. More specifically this dissertation contributes to the third work package (WP 3) of the project called "Macro level economic impacts of corporate social responsibility." WP 3 focuses on modeling the international trade of the raw materials and end products of the forest industry in a changing market environment, as well as on changes in production location. The objectives of WP 3 as well as the main research problem of this dissertation, "What kinds of changes are megatrends causing for the PPI, and how could the impact of these trends be taken into account in modeling?", require a quantitative approach in order to achieve valid and reliable results. Thus, the five publications constituting Part II of this dissertation are quantitative in nature.

## 3.1 Overview of the research design

Table 4 summarizes the data sets and analysis methods, and Table 5 summarizes the databases and data sources used, as well as their publishers. As shown in Table 4, several advanced research methods are used in addressing the research questions. Regression models based on panel data are estimated in Publications 1–4, and fuzzy input–output analysis is applied in Publication 5. In addition, Publication 2 constructs a system dynamics model to forecast future paper demand in Russia. In all of the publications there is both the cross-section and time-series dimension. Apart from Publication 5, country-level annual panel data are used. Publication 5 analyzes inter-industry linkages but the differences and similarities between countries are discussed as well.

Table 4 Data and analysis methods

| Title | Data | Research methods |
|---|---|---|
| 1. The role of information and communication technologies in paper consumption | Panel data between 1990 and 2007<br>Number of countries:<br>50 (newsprint), 36 (magazine paper),<br>41 (office paper)<br>Number of observations:<br>607(newsprint), 360 (magazine paper),<br>425 (office paper)<br>Main data sources:<br>Industry Statistics Database, Global Market Information Database, World Telecommunication/ICT Indicators Database | Empirical model for paper demand. Fixed effects (FE) and random effects (RE) estimation. |
| 2. Forecasting long-term paper demand in emerging markets | Panel data between 1990 and 2007<br>Number of countries:<br>22 (newsprint); 11 (magazine paper)<br>(forecasts only for Russia)<br>Number of observations:<br>313 (newsprint), 127 (magazine paper)<br>Main data sources:<br>Industry Statistics Database, Global Market Information Database, World Telecommunication/ICT Indicators Database | Empirical model for paper demand. FE and RE estimations. Scenarios for future paper demand in Russia were forecasted using the system dynamics model with Monte Carlo sensitivity analysis. |
| 3. Explaining the shifts of international trade in pulp and paper industry | Panel data between 1990 and 2008<br>Number of country-pairs:<br>362 (BHKP); 295 (BSKP); 573(RP)<br>Number of observations:<br>3355 (BHKP), 3249 (BSKP), 5084 (RP)<br>Main data sources:<br>Bilateral Trade Data, World Development Indicators, How far is it?, ForesSTAT, Industry Statistics Database | Extended model of bilateral trade. FE, RE and Hausman-Taylor estimations. |
| 4. The role of national culture and environmental awareness in recovery and utilization of recovered paper | Panel data between 1995 and 2008<br>Number of countries: 22<br>Number of observations:<br>308 (RR); 308/289 (UR)<br>Main data sources:<br>Industry Statistics Database, The ISO Surveys, Geert Hofstede Cultural Dimensions, World Development Indicators, Global Market Information Database | Extended models of recovery and the utilization rates of recovered paper. FE, RE and Hausman-Taylor estimations. |
| 5. PPI in traditional and emerging markets – an input–output model based on fuzzy linear systems | Input-output tables for 1995, 2000 and 2005<br>Number of countries:<br>3 (predictions only for Finland)<br>Main data sources:<br>Structural Analysis Database of OECD.Stat, ForesSTAT, Industry Statistics Database | Input–output analysis of PPI in Brazil, Finland and the US. Fuzzy numbers are used in predictions for 2010 input–output structure in Finland. |

Table 5 Data sources

| Database/data source | Publisher/available from |
|---|---|
| *Commercial* | |
| Bilateral Trade Data | RISI<br>- RISI is an information provider for the global forest products industry |
| Country Statistics Database | MarketLine International limited<br>- MarketLine offers a collection of company, industry and country information from over 200 countries and major industries |
| Global Market Information Database (GMID) | Euromonitor International<br>- Euromonitor International is a strategy researcher for consumer markets |
| Industry Statistics Database | RISI |
| World Telecommunication/ICT Indicators Database 2007 | International Telecommunication Union (ITU)<br>- ITU is the United Nation's specialized agency for ICTs. |
| *Free access* | |
| The Finnish Statistical Yearbook of Forestry 2009 | Finnish Forest Research Institute |
| ForesSTAT database | Food and Agriculture Organization of the United Nations (FAO) |
| Geert Hofstede Cultural Dimensions | Geert Hofstede's web pages |
| How far is it? | www.indo.com/distance<br>- How far is it? service uses data from the US Census Bureau and a supplementary list of cities around the world to find the latitude and longitude of two places, and then calculates the distance between them |
| The ISO Surveys of ISO 9001 and ISO 14001 certificates | International Organization for Standardization (ISO) |
| Preliminary Energy Statistics 2009 | Statistics Finland |
| Structural Analysis Database (STAN) of OECD.Stat | OECD |
| World Development Indicators (WDI) database | World Bank |

Special attention is paid to extensive and reliable data collection, as well as to proper estimation methods. Analysis is not limited to advanced economies, but developing countries are included as well. Many of the previous studies mentioned in Chapter 2 use FAO's data when estimating models for paper products demand or trade, but RISI's data are used in this study. RISI's data are more disaggregated when it comes to paper and pulp grades. For example, FAO's ForesSTAT database does not separate BSKP from BHKP or coated wood-free paper from coated mechanical paper. Thus, RISI's data allow a much more detailed analysis. However, FAO data are used when describing changes in the PPI in the past decades due to longer time series.

## 3.2 Data collection and analysis methods

Five sets of data, one for each publication, were gathered from various secondary databases and data sources, many of which are freely available on the Internet. The data in Publication 2 are partly a subsample of data for Publication 1, but otherwise data were recollected for each publication.

*Publication 1*

Publication 1 explores the role of different ICTs in the consumption of communication papers.

Three sets of country level annual panel data for the time period 1990–2007 were used: one for newsprint, one for office paper (uncoated wood-free paper) and one for magazine paper (uncoated + coated mechanical papers). For each country, the annual demand of different paper grades was defined by apparent consumption: production plus imports minus exports. Apparent consumption was further converted to consumption per capita (measured in kilograms) by dividing by population.

Data on production, imports and exports were obtained from the Industry Statistics Database provided by RISI. Apparent consumptions of uncoated and coated mechanical papers were summed together to achieve the demand for magazine paper. In order to reduce measurement errors, countries with annual apparent paper consumption of less than 10,000 tons were excluded from the data. Relatively small countries that are large exporters (such as Finland, Sweden, and Norway) were excluded as well due to unreliable fluctuation in their consumption series. Data on newsprint included 50 countries, data on magazine paper 36 countries and data on office paper 41 countries. Both advanced economies and developing countries were included.

The regressors of the empirical model for paper demand included GDP per capita and four ICT variables: Internet penetration, mobile telephone penetration, penetration of personal computers, and television penetration. Populations and GDPs for all the selected countries and

years were gathered from the Global Market Information Database (GMID) provided by Euromonitor International. GDP was measured at constant US dollars at 2007 prices and fixed 2007 exchange rates, and it was converted to GDP per capita. ICT variables between 1990 and 2007 were obtained from the World Telecommunication/ICT Indicators 2007 Database provided by the International Telecommunication Union (ITU). The parameters of the empirical paper demand models were estimated by using either fixed or random effects estimation. The Hausman specification test (Hausman, 1978) was used to determine which one of the estimators, the fixed or the random, is more appropriate.

*Publication 2*

The second publication analyzes the impact of ICTs on the demand for newsprint and magazine paper in emerging markets, and forecasts future paper demand in Russia considering the diffusion of ICT.

The paper types investigated in Publication 2 were newsprint and magazine paper (coated mechanical paper). The data on newsprint included 22 countries and the data on magazine paper 11 countries for the time period 1990–2007. Countries were chosen by selecting all available countries included in the Morgan Stanley Emerging Market Index. Countries were from Latin America, Europe, Asia, and Africa. Both samples included Brazil, China, and Russia. The main difference between the data sets was the lack of other Asian countries than China in magazine paper data. As in Publication 1, the annual demand for newsprint and magazine paper was defined by apparent consumption per capita. Explanatory variables included GDP per capita, Internet penetration and mobile telephone penetration. The data on paper consumption, GDP, and ICT variables were a subsample of the data for Publication 1. The parameters of the empirical paper demand models were estimated by using fixed and random effects estimation. Estimated regression coefficients were then incorporated into the system dynamics model for scenarios for future paper demand in Russia.

In the system dynamics model, the future Internet and mobile telephone penetrations in Russia were forecasted using the Bass diffusion model (Bass, 1969). The diffusion parameters in Russia

were estimated using SPSS. The GDP variable was exogenous. It was converted into GDP per capita by dividing by population. The Russian population in 2008–2020 was simulated using birth and death rates. Russian GDP as well as birth and death rates between 1990 and 2007 came from GMID. Uncertainty in the system dynamics model was built with sensitivity simulation using the Monte Carlo application of the simulation program. Uniformly distributed randomness was added to the diffusion parameters, as well as to birth and death rates. The scenarios for future newsprint and magazine paper demand in Russia were simulated by varying the growth rate of GDP, death and birth rates, as well as the market potential of Internet penetration.

*Publication 3*

Publication 3 concentrates on paper making fibers and analyzes how the changes in PPI are reflected in raw material trade flows. It first describes the recent trends in global wood pulp and RP markets and then empirically examines the bilateral trade flows of bleached kraft pulp and RP.

The production and consumption series of paper and paperboard, wood pulp, recovered paper, and chemical pulp came from the ForesSTAT database by the UN's Food and Agriculture organization FAO. The data on the production and consumption of BSKP, BHKP, and RP originated from the Industry Statistics database of RISI. Their annual bilateral trade flows (exports from country *i* to country *j*) between 1990 and 2008 were from RISI as well.

The dependent variable was pulp exports (BSKP, BHKP or RP) from country *i* to country *j* in year *t*. The regressors common to all the models included distance, an importer dummy for China, the level of economic development (GDP per capita), population, raw material resources (forest area), the bilateral real exchange rate, a decade dummy, and the interaction of China and decade dummies. In addition, equations for BSKP and RP incorporated exporter dummies for North America, Latin America, and Northern Europe, as well as the interactions of the exporter and decade dummies in the model. In contrast, the equation for BHKP included a dummy for planted forests (eucalyptus and acacia) and the interaction of this variable and the decade

dummy. Dummy variables and their interactions intended to capture the impact of megatrends on bilateral trade flows.

The distances between the capital cities originated from an online tool (www.indo.com/distance), and the other explanatory variables were from the World Development Indicators (WDI) database by the World Bank. As the forest area was only available for 1995, 2000, and 2005, the variable was interpolated and extrapolated for the other years of the sample period.

The parameters of the augmented gravity models were estimated by a fixed effect estimator, random effect estimator, and Hausman-Taylor estimator (Hausman and Taylor, 1981), but only the results for the Hausman-Taylor estimator are reported. Hausman-Taylor method uses the endogenous explanatory variables (that are correlated with country-specific, or bilateral, effects) with their transformations and the exogenous variables already in the model, meaning that the challenging task of finding valid external instruments is avoided. Two sets of instrumented variables were used for BSKP and BHKP and one set for RP. The Hausman specification test (Hausman, 1978) was used to choose the correct set of instrumented variables, as well as to test the consistency of the estimators.

*Publication 4*

The fourth publication extends the econometric models of recovery and utilization rates of RP introduced in Berglund et al. (2002) and Berglund and Söderholm (2003b) by including the variables of environmental awareness and national culture.

The data in Publication 4 were annual country-level panel data for the period 1995–2008. The number of countries included was 22. The most important recovered paper producers and consumers all over the world were included. For each year and country the utilization rate (UR) of recovered paper was calculated by dividing the country's recovered paper consumption by the total paper and board production, and the recovery rate (RR) was recovered paper production (i.e. collection) divided by the total paper and board consumption. The production,

consumption, and trade data of recovered paper, as well as paper and board, were obtained from the RISI's Industry Statistics database.

The regressors of the extended model for *RR* included GDP per capita, urban population, population density, average years of schooling (proxy for environmental awareness), and Hofstede's four cultural dimensions. The explanatory variables of the extended model for *UR* were GDP per capita, forest area, the paper product mix, the structural effect, the recovery rate, and the number of ISO 14001 certificates per million people (proxy for managers' environmental awareness).

GDP, population, urban population, and population density were gathered from the WDI database. GDP was measured at constant US dollars in 2000 and converted to GDP per capita. The forest area data was from the WDI database as well. As the forest area was only available for 1995, 2000, and 2005, the variable was interpolated and extrapolated for the other years of the sample period. Internet penetration was obtained from the GMID. The number of ISO 14001 certificates were from the web site of ISO surveys by ISO, and Hofstede's cultural dimensions came from Geert Hofstede's web page.

The parameters of the extended models were estimated by the fixed effect estimator (UR and RR), random effect estimator (RR only) and Hausman-Taylor estimator (RR only). Two sets of instrumented variables were used for RR, and the Hausman contrast test (Hausman, 1978) was used to test the legitimacy of the instruments used, as well as the consistency of the estimators.

*Publication 5*

Publication 5 analyzes inter-industry linkages between the PPI and other industries in Brazil, Finland, and the US, and predicts Finland's input–output structure for five industry sectors in 2010 using fuzzy numbers.

The production and trade series of pulp and paper used in describing current trends in the PPI were collected from the ForesSTAT database (for Finland and the United States) and from the Industry Statistics Database (for Brazil). The input–output tables were collected from the OECD's Structural Analysis Database (STAN) for all available years (1995, 2000, and 2005). The tables included 37 industries. All nominal monetary values were converted to constant 2005 US dollars by deflating with the GDP deflator.

The PPI is unfortunately aggregated with the printing and publishing industry. Therefore, some more disaggregated input–output tables provided by the Statistics Finland and the Brazilian Institute of Geography and Statistics were carefully examined first to be able to limit the analyses to the industries that are more likely to be linked with the PPI than the printing and publishing industry. Then, a comparative analysis of the OECD's input–output tables was conducted to find out possible differences between Brazil, Finland, and the US in the amount of purchases from other industries by the PPI and in the amount of sales from the PPI to other industries.

Finally, predictions for the input–output structure of Finland's five sectors[8] in 2010 were calculated. The first step was to determine the estimates of the final demand components (private and public consumption, investments, exports, imports, and changes in inventories). The estimations were based on various data sources, such as the Finnish Statistical Yearbook of Forestry by the Finnish Forest Research Institute, ForesSTAT database, Preliminary Energy Statistics 2009 by the Statistics Finland, and the Country Statistics database by MarketLine. The scenarios for final demand were then calculated by subtracting imports from the sum of other final demand components. Two final demand scenarios were proposed, namely pessimistic and optimistic. Fuzziness was added to the final demand scenarios by replacing the crisp values with triangle fuzzy numbers. The technical coefficients of 2010 were also fuzzy numbers with 2005 technical coefficients as the modal values. The uncertainty in the final demand vector and technical coefficients was assumed to be 4%. As an outcome, the predicted total outputs as well as inter-industry linkages in 2010 were fuzzy numbers as well. In order to measure

[8] The sectors are i) agriculture, hunting, forestry and fishing (forestry), ii) wood and products of wood and cork (wood), iii) pulp, paper, paper products, printing, and publishing (PPI), iv) electricity, gas and water supply (electricity), and v) other industries (other).

prediction accuracy, the 2005 total outputs were predicted based on fuzzy 1995 and 2000 technical coefficients and the actual 2005 final demand vector.

# 4 SUMMARY OF THE PUBLICATIONS AND RESULTS

This chapter introduces and summarizes the objectives, main results and contributions of the five publications that constitute the second part of this dissertation. First, Table 6 summarizes the targets of analyses and megatrends taken into account, and Table 7 briefly sets out the objectives, main results, and the contribution of each publication. The publications are then summarized individually in more detail.

Table 6 Pulp and paper grades, target of analysis and megatrends by publication

| | | Target of analysis | | | | Megatrend | | | |
|---|---|---|---|---|---|---|---|---|---|
| Publication | Paper grades | Paper making fibers | Demand | Supply | Trade | Globalization | Technological development | Environmental awareness |
| 1. The role of information and communication technologies in paper consumption | Newsprint, magazine paper, office paper | | x | | | | x | |
| 2. Forecasting long-term paper demand in emerging markets | Newsprint, magazine paper | | x | | | | x | |
| 3. Explaining the shifts of international trade in pulp and paper industry | Total paper and paperboard | BSKP, BHKP, recovered paper | x | x | x | x | x | |
| 4. The role of national culture and environmental awareness in recovery and utilization of recovered paper | | Recovered paper | x | x | | | | x |
| 5. PPI in traditional and emerging markets – an input–output model based on fuzzy linear systems | Total paper and paperboard | Total wood pulp | x | x | | x | x | x |

As shown in Table 6, there is a lot of variation among the publications. Publications 1 and 2 concentrate on communication papers. Technological development equals the diffusion of ICTs, and the penetration rates of different ICTs are included in empirical models for paper demand. The descriptive part of Publication 3 discusses the changes in the demand and production of pulp, recovered paper, as well as paper and paperboard by region, and the empirical part presents extended gravity models for the bilateral trade flows of some paper making fibers. In Publication 3, technological development denotes innovations in clonal forestry that have helped Latin America to become the largest exporter of eucalyptus pulp. The impacts of

technological development and globalization are taken into account in modeling by including a set of dummies in the gravity models. Publication 4 extends the econometric models of paper recovery and recovered paper utilization rates. The recovery rate is one of the determinants of the domestic supply of recovered paper, and the utilization rate equals the demand for recovered paper in paper and paperboard production. The quantitative measures of environmental awareness and cultural dimensions are included in the regression models. In turn, Publication 5 deals with input–output tables and analyzes inter-industry demand and supply linkages. The possible impact of technological development and other megatrends is observable in technical coefficients, i.e. in the "recipe" of PPI that may change over time.

Table 7 The objectives, results, and contribution of the research publications

| Publication | Main objectives | Main results | Main contribution |
|---|---|---|---|
| 1. The role of information and communication technologies in paper consumption | To explore whether different ICTs have a significant role in the consumption of communication papers and whether there are differences in the effects between paper grades. | The Internet is a substitute for newsprint and possibly for magazine paper. The estimation results for newsprint and magazine paper are fairly similar and the results for office paper differ from them. The number of PCs seems to have a positive role in office paper consumption. | Provides a better understanding of the effect of ICTs on the consumption of communication papers by using explicit measures for ICT, three different types of papers, and global scale data. |
| 2. Forecasting long-term paper demand in emerging markets | To explore the effect of ICTs on the consumption of communication papers in emerging markets. To forecast the future newsprint and magazine paper consumption in Russia. | The Internet seems to be a substitute for both newsprint and magazine paper in the emerging markets. System dynamics modeling and sensitivity analysis were found to be useful methods to forecast paper consumption. | Provides empirical evidence that the diffusion of ICTs affects paper demand in emerging markets as well. One of the first studies to produce paper demand forecasts using system dynamics modeling. |
| 3. Explaining the shifts of international trade in pulp and paper industry | To describe recent trends in the global wood pulp and recovered paper markets. To model the bilateral trade patterns of chemical pulp and RP. | The changes in PPI dynamics clearly have affected the bilateral trade flows of BSKP, BHKP, and RP. Asia, particularly China, is the most important driver of chemical pulp and RP trade. Import demand seems to be more important than export supply in determining the volume of exports.§ | Presents extended gravity models that are able to capture various impacts the changes in PPI's input and output markets have had on the trade flows of raw materials. The first study to use the Hausman-Taylor estimation method and a large global data set to analyze the trade flows of PPI products. |
| 4. The role of national culture and environmental awareness in recovery and utilization of recovered paper | To analyze the role of culture and environmental awareness in a country's RP recovery and utilization rates using proper quantitative measures. | Greater environmental awareness increases the recovery and utilization rates. Also, national culture affects paper recycling: cultures with low uncertainty avoidance (UAI) are more willing to recycle paper than cultures with high UAI, and collectivistic cultures recycle more than individualistic ones. | Includes quantitative variables about culture, as well as values and attitudes toward recycling and environmental issues in the recovery and utilization rate models of RP. |
| 5. PPI in traditional and emerging markets – an input–output model based on fuzzy linear systems | To identify and discuss the most important inter-industry linkages between the PPI and other industries in Brazil, Finland, and the United States. To predict the input–output structure of Finland's five sectors in 2010. | The structure of direct purchases from other industries by the PPI has clearly changed from the mid 1990s to 2005. Instead, the sales from the PPI to other industries have remained relatively constant over time. | Input–output tables provide useful information about the role of megatrends in the PPI that cannot be achieved from country level time series data. Further confirms the advantages of fuzzy methods when forecasting the future input–output structure and total output. |

## 4.1 Publication 1: The role of information and communication technologies in paper consumption

*Overall objective*

The first publication addresses the research question of *what the role of information and communication technologies is in the demand for communication papers*. The objective is to explore whether different ICTs have a significant impact on the consumption of communication papers (newsprint, magazine paper, and office paper) and whether there are differences in the effects between paper grades. The impact of ICTs on the consumption of newsprint and other communication papers is an issue that the PPI needs to take into account when calculating paper demand scenarios. According to Hetemäki (2005), the traditional paper demand models tend to overestimate the demand of some paper grades, especially in North America and Western Europe.

*Results and main contribution*

A review of the previous studies reveals that in the conventional paper demand framework, a paper product is regarded as an intermediate good that together with other inputs is used to produce a final output, for example, a magazine (see e.g. Bolkesjø et al., 2003). In these traditional models paper demand is the dependent variable, and economic activity (usually GDP) and the real price of the paper product are used as regressors. Publication 1 constructs an empirical model for paper demand built on traditional models. The main difference between our model and traditional models is that four ICT variables (Internet penetration, mobile telephone penetration, television penetration, and penetration of personal computers) are included as explanatory variables. However, paper price is omitted because country-specific price data are not available for pulp and paper products.

The estimation results of our model for paper demand clearly imply that ICTs have an effect on newsprint and office paper consumption, but the diffusion of ICTs has not yet affected magazine paper consumption significantly. However, the estimated coefficients between

newsprint and magazine paper are almost similar (the estimated coefficients are about the same magnitude and they have similar signs between newsprint and magazine paper). According to the results, the number of Internet users has a negative impact on the newsprint consumption. Internet penetration also has a slight statistically significant impact on magazine paper consumption (p-value 0.175). Thus, the substitution effect of the Internet on newsprint and possibly on magazine paper was clearly seen. With newsprint, the estimated coefficient of the number of mobile telephone subscribers is positive and statistically significant at a 5% level. When it comes to the effects of the diffusion of ICT, office paper differs from newsprint and magazine paper. According to the estimation results, the number of personal computers seems to have a positive impact on office paper consumption, whereas other ICT factors are insignificant.

Publication 1 contributes to the existing literature by including explicit measures for information and communication technologies in the model for paper demand. Moreover, unlike the majority of previous studies, Publication 1 employs global scale data and three different types of papers. As a result, Publication 1 provides a better understanding of the role of ICTs in the consumption of communication papers.

## 4.2 Publication 2: Forecasting long-term paper demand in emerging markets

*Overall objective*

The second publication addresses two research questions: 1) *what the role of information and communication technologies is in the demand for communication papers*, and 2) *what will the future demand for communication papers in Russia be considering the diffusion of ICT?* As stated at the end of Publication 1, the role of information and communication technologies in paper demand may differ between developed and developing countries. Thus, the first objective is to explore the effect of ICTs on the consumption of newsprint and magazine paper in the emerging markets. The second objective is to forecast scenarios for the future demand of these papers in Russia using the system dynamics model.

*Results and main contribution*

Again, an empirical model for paper demand built on traditional models is constructed. However, this time television penetration and the penetration of personal computers are omitted from the model because, according to the results of Publication 1, they do not significantly affect the demand for newsprint or magazine paper. Otherwise the model is similar to that of Publication 1.

The estimation results reveal that ICT penetration rates have an impact on paper consumption in the emerging markets. The Internet seems to be a substitute for both newsprint and magazine paper. Instead, the increasing penetration of mobile telephones seems to increase the consumption of these grades. However, these effects are small compared to the effect of GDP per capita which strongly affects the paper consumption in emerging markets. Estimated parameters are incorporated into the system dynamics model to forecast scenarios for future paper consumption in Russia. According to the simulation results, it seems that the per capita consumption of newsprint and magazine paper will grow rapidly during the period of 2008–2020. The higher Internet penetration rate will clearly result in lower newsprint and magazine paper consumption, but the negative impact is relatively small compared, for example, to the effect of lower annual growth of GDP.

Publication 2 contributes in various ways to the literature. It applies the empirical paper demand model that includes explicit measures for information and communication technologies. It shows that the diffusion of ICTs affects paper demand in the emerging markets and also takes into account the impact of ICT when forecasting future demand scenarios in Russia. To the best of our knowledge, producing paper demand forecasts using system dynamics modeling is rare in the existing literature.

## 4.3 Publication 3: Explaining the shifts of international trade in pulp and paper industry

*Overall objective*

The third publication addresses the research question of *how dynamic changes in the PPI have affected the bilateral trade patterns of raw materials for paper making*. The objective is to model the bilateral trade patterns (exports from country *i* to country *j*) of BSKP, BHKP, and RP. This publication draws from the theories of the gravity model and international trade, and estimates an extended gravity model with measures of import demand and export supply as explanatory variables.

*Results and main contribution*

The descriptive part of the third publication shows that the focal point of paper production and consumption is moving from the Western world to the rapidly growing markets of Southeast Asia. Moreover, recovered paper has become the fastest growing raw material in the PPI, and Latin America has rapidly increased its importance as a supplier of raw material for paper and paperboard production due to huge eucalyptus plantations.

According to our estimation results, some of the most traditional gravity variables had the expected impact on the volume of exports. However, the effects vary between BSKP, BHKP, and RP. This may be caused by the significant differences in the transport cost to product value ratio, which is much higher especially for the lower grades of RP than for BSKP. Differences in the availability of the raw material also create distinctions between the two pulp grades and RP. Despite this, the overall results are in line with the roles played by export supply and import demand, which ultimately dictate the volume of international trade. Interestingly, import demand seems to be more important than export supply in determining the volume of exports. It is evident that Asia, particularly China, is the most important driver of chemical pulp and RP trade. Importantly, China's outstanding rate of growth in chemical pulp and RP imports has been strongly driving the increased importance of planted forests in the exports of BHKP as well.

Publication 3 shows that the changes in PPI dynamics have clearly affected the bilateral trade flows of BSKP, BHKP, and RP. To the best of our knowledge, Publication 3 is the first study to use the gravity models of international trade to analyze the trade of forest product commodities with advanced estimation methods (Hausman-Taylor estimator) and a large global data set.

### 4.4 Publication 4: The role of national culture and environmental awareness in recovery and utilization of recovered paper

*Overall objective*

The fourth publication addresses the research question of *whether socio-cultural characteristics and environmental factors affect the recovery of paper and utilization of recovered paper at the country level.* The objective is to analyze the role of culture and environmental awareness in the country's paper recovery and recovered paper utilization rates using proper quantitative measures. Although the growth of paper consumption has flattened in the Western world, on a global scale the consumption is further increasing. With a limited amount of virgin fiber available the growth in paper demand increases the need to use alternative raw materials in paper production. In many countries the recovery rate is still far from the potential rate, so that there may be need to find ways to increase waste paper collection and recovered paper utilization. This study attempts to gain more precise information on factors affecting the paper recovery and recovered paper utilization rates at the country level.

*Results and main contribution*

The literature review shows that in previous studies, the possible impact of environmental consciousness and socio-cultural factors on the recovery and utilization rates is measured implicitly or not at all. Publication 4 extends the econometric models introduced in Berglund et al. (2002) and Berglund and Söderholm (2003b) by including more explicit indicators for the

"softer" country level characteristics: Hofstede's cultural dimensions, average years of schooling, and the diffusion of ISO 14001 certification for environmental management systems.

According to the estimation results, the environmental awareness and the cultural factors have an influence on the recovery and utilization rates. More specifically, the paper shows that together with urban population and population density, average years of schooling explain the recovery rate. This may indicate greater environmental awareness and consumer concern in areas where the recovery rate is greater. Further, the results indicate that the recovery rate is influenced by two cultural factors: individualism and uncertainty avoidance. The recovery rate seems to be significantly higher in collectivistic cultures compared to individualistic ones. It also seems that people in cultures with a low uncertainty avoidance index (UAI) are more willing to recycle paper compared to countries with a high UAI. In cultures with high uncertainty avoidance, people are reluctant to change their behavior if adopting the new practice contains any risk or uncertainty. Even though the uncertainty about the personal consequences of starting to recycle paper is relatively low, it seems to have a negative impact on the recovery rate.

The utilization rate is highly determined by the demand and supply of recovered paper but the environmental awareness seems to have a direct increasing impact on it as well because the diffusion of ISO 14001 certification explains the use of recovered paper.

Publication 4 contributes to the previous literature by including new variables in the models for RP recovery and utilization. In our extended models, values and attitudes toward recycling and environmental issues are taken into account more explicitly compared to the existing literature about the subject. Along with the previous empirical evidence, our findings about the role of cultural and environmental factors could facilitate the tailoring of national and international policies and incentives for the collection and use of recovered paper.

## 4.5 Publication 5: PPI in traditional and emerging markets – an input–output model based on fuzzy linear systems

*Overall objective*

The fifth publication addresses the research questions of 1) *what kinds of inter-industry linkages there are between the pulp and paper industry and other industries, and whether these linkages have changed in the past decades,* and 2) *what the structure of inter-industry linkages is between the PPI and other industries in the future.* The objective is to describe and analyze the economic impact of the PPI on the other industries in three countries (Brazil, Finland, and the United States) using Leontief's input–output matrices, and to predict Finland's input–output structure for five industry sectors in 2010 using fuzzy numbers.

*Results and main contribution*

According to the comparative analysis of the input–output tables of Brazil, Finland, and the US, there are many differences in the inter-industry linkages across countries and over time but also some similarities. The structure of direct purchases from other industries by the PPI has clearly changed from the mid 1990s to the 2005. Instead, the sales from the PPI to other industries have remained relatively constant over time. The paper also ascertained that the role of the PPI in the total output of other industries is relatively small, at least in Finland. The fuzzy input–output analysis with 4-% uncertainty in technical coefficients and final demand was found to be a useful, and fairly accurate, prediction method.

Publication 5 gives empirical evidence that input–output tables provide information about the role of megatrends in the PPI that cannot be directly achieved from country-level time series data used in Publications 1–4. For example, the increased inputs from forestry to the electricity industry between 1995 and 2005, in other words, the increased use of wood energy, most likely reflects the impact of increased environmental awareness on energy production. In the future, if the demand for biofuels vastly increases, the energy use of wood fiber will further increase, which in turn may have significant impacts on the PPI in Finland.

Publication 5 also shows that the technical coefficients, i.e. the “recipe” of the pulp and paper industry, have changed over time in all of the countries although the aggregation of the pulp and paper industry with the printing and publishing industry slightly disturbed the interpretations (especially with the US). To the best of our knowledge, reporting the predictive accuracy of fuzzy applications in input–output analysis on real data is rare in the existing literature.

# 5 CONCLUSIONS

Globalization, technological development, and increasing environmental awareness are important megatrends shaping the global pulp and paper industry. This study analyzed the effects of these trends on the pulp and paper industry globally, and tested ways to incorporate them into models concerning the demand, trade, and use of the pulp and paper industry's products and raw materials. The results provide evidence that information and communication technologies have an impact on the demand of communication papers. The Internet is evidently a substitute for newsprint and possibly for magazine paper, but the paperless office is still far from reality because the development of the office technology has boosted demand for office paper. ICTs have an impact on the emerging markets as well, although the country's GDP per capita is still the most important driver of demand. Ongoing structural changes have clearly affected the bilateral trade flows of chemical pulp and recovered paper as well. It is evident that Asia, particularly China, is the most important driver of chemical pulp and recovered paper trade: China is hungry for fiber, and must import to satisfy its growing needs. Planted forests (especially eucalyptus) and recovered paper have quickly increased their importance as a raw material for paper and paperboard production. Moreover, the speed of China's growth in chemical pulp and recovered imports has been driving the increased significance of planted forests in the exports of bleached hardwood kraft pulp as well. This study also provides empirical evidence that cultural factors and increasing environmental awareness have a role in paper recovery and recovered paper use at the country level. Empirical results also provide evidence that megatrends have affected the inter-industry linkages between the pulp and paper industry and other industries over time. Combining econometrics with other modeling techniques was found to be a fruitful way to calculate future scenarios for the pulp and paper industry markets.

## 5.1 Contributions

This study contributes to the literature in various ways. Firstly, it makes a significant contribution in that it helps to better measure and understand the structural change and the

impact of megatrends on the pulp and paper industry. The bulk of previous studies concerning the pulp and paper industry implicitly take into account the impact of megatrends through the traditional explanatory variables. Naturally, megatrends directly affect the traditional factors of demand and trade models. For example, the spatial reorganization of production and international trade caused by globalization affect the pulp and paper prices, as well as countries' GDP and, thus, demand for paper and pulp. However, this study provides empirical evidence that it is worth the effort to include explicit measures of megatrends as explanatory variables as well. For example, the estimation results of Publication 3 indicate that the additional dummy variables included in the gravity models of international trade reflect the effects of globalization and technological development on chemical pulp and recovered paper exports. Thus, these variables are able to capture additional variation in the data that traditional regressors cannot reach. This increases the explanatory power of the models.

The second contribution of this study is that it combines various quantitative methods: panel data regression analysis, system dynamic simulation with Monte-Carlo sensitivity analysis, fuzzy linear models, and input–output analysis. Combining different techniques helps to overpower the limitations that individual methods have, for example, when forecasting future scenarios.

The smaller contributions of this study relate to the data sets used. Previous literature mainly relies on FAO's data when estimating models for paper products demand or trade. However, FAO's ForesSTAT database does not separate BSKP from BHKP or coated wood-free paper from coated mechanical paper. RISI's data used here are more disaggregated when it comes to paper and pulp grades. Disaggregated data allow more reliable and detailed analysis, for example, of office paper demand. The results of this study show that the impact of megatrends heavily depends on the pulp and paper grade in question. Thus the demand and trade models should be estimated by using as disaggregated data as possible to obtain more reliable results.

## 5.2 Managerial and policy implications

As stated by Hänninen (2004), the pulp and paper industry must be aware of the alternate future scenarios when making decisions. The findings of this study enhance the understanding

and measuring of the role of megatrends in the pulp and paper industry. The results also further confirm their significance in the demand and trade of paper products. Thus, the findings of this study may help the managers of pulp and paper industry firms when making investment decisions.

Publication 4 provides policy implications as well. As paper consumption is still growing in the world and the paper recovery rate is still far from the potential rate in many countries, it may be necessary to find ways to increase waste paper collection and recovered paper utilization. Cultural determinants and the level of environmental awareness vary across countries. Along with the previous empirical evidence, the findings of Publication 4 about the role of cultural and environmental factors could facilitate the tailoring of national and international policies and incentives for the collection and use of recovered paper.

## 5.3 Limitations and suggestions for future research

This study has some limitations that should be noted. Firstly, the lack of price data is a significant limitation when it comes to Publications 1 and 2. Country-specific price data are not available for pulp and paper products. Previous studies (e.g. McCarthy and Lei, 2010) use, for example, calculated import prices as a proxy for paper product prices. Unfortunately, the import and/or export values of pulp and paper products to calculate proxy variables for prices are not available for RISI's data used in this study. Therefore, price had to be omitted from the models. In future studies, models introduced in Publication 1 and 2 could be estimated with FAO's data to test whether the inclusion of a price variable affects the results significantly.

Another noteworthy limitation in Publications 1 and 2 is the possible multicollinearity problem between ICT variables. In the presence of multicollinearity, it is difficult to analyze the effect of an individual regressor because two (or more) variables measure the same information. The possible consequences of multicollinearity are that the individual p-values may be misleading and confidence intervals may be very wide. In future research, for example, a principal component of the ICT variables could be used to measure the impact of technological development on paper demand. The models in Publications 1, 2 and 4 are rather simple as well

and only include the main effects of the explanatory variables. Thus, the estimated coefficients are expected to be the same among countries and over time. In future studies, interaction terms or non-linear terms could be included in order to enhance the explanatory power. For example, interaction between income and the ICT variable could be included in the paper demand model in order to test if income elasticity is affected by the ICT. Similarly, interaction between income and time could be used to analyze if the income elasticity of paper demand has decreased over time. Paper recovery and recovered paper use could also be estimated simultaneously because the two equations constitute a system: the recovery rate is a regressor for the utilization rate, and, thus, changes in the recovery rate will have an impact on the utilization rate.

The distance variable used in Publication 3 (distance between capital cities) is obviously a rather rough measure for transportation costs especially with geographically large countries. However, it is commonly used in the literature. In the future, for example, the distance between the most significant ports or the geographic centers of the pulp and paper industry could be used instead. Furthermore, in future research, the application of gravity models and panel data estimation methodology in the context of paper and/or paperboard trade would be interesting. Moreover, it would be useful to try to analyze the factors that have played a role in transforming the trade flows of pulp, recovered paper, paper, and paperboard beyond the export–supply and import–demand variables.

There are also some problems with the quality and availability of the data. Relatively small countries that are large exporters of paper (such as Finland and Sweden) had to be excluded from the data set in Publications 1 and 2 due to unreliable fluctuation in their consumption series. Fortunately, RISI's database was updated in 2009 and these errors were corrected so that they are included in Publications 3–5. In the data gathering of input–output tables for Publication 5 it turned out that the PPI is aggregated with the printing and publishing industries in OECD's input–output tables. It proved to be impossible to disaggregate them in a reliable way. The aggregation slightly disturbs the interpretations (especially with the US). Many emerging markets and especially the developing countries also suffer from the lack of pulp and paper data and/or data related to megatrends. However, as many emerging markets and developing countries as possible were included in the analyses in Publications 1–3. The ICT

variables used in this study are also somewhat rough measures of the impact of electronic media. For example, country-specific long time series of the amount of mobile telephone traffic, amount of data transferred or time spent online would have been better variables. Unfortunately, at present such data are not available. The forecasts of Publication 2 are limited to the Russian markets, and in order to have more generalization power, it should be repeated in other emerging economies, such as the former East European countries and China. A more ambitious suggestion for future research is to construct a somewhat more sophisticated system dynamics model, for example by following the ideas presented in Obersteiner and Nilsson (2000), and to forecast scenarios for future paper demand, bilateral trade flows, or paper recovery and recovered paper use.

The techniques used in this study are not limited to the pulp and paper industry but they could also be used to analyze some other industry in transition.

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