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Economic analysis of recyclable papers

Charles O. Njelita
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ABSTRACT

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ECONOMIC ANALYSIS OF RECYCLABLE PAPERS

Advisor: Professor Charlie Carter, Ph.D.

Thesis dated May, 1996

The purpose of this thesis is to trace the effect of the real price of wastepaper on the quantity of wastepaper recycled, under the framework of secondary material market.

A linear demand model of a national market for wastepaper was derived from the industry's production function, and a linear supply function was also derived from past wastes and flows of current waste streams. An equilibrium price that determines the quantity of wastepaper recycled was obtained and illustrated. Two-stage least squares (2SLS) was used to obtain the values of structural parameters in the over-identified equations.

The coefficient of the wastepaper price proved to be inelastic. As hypothesized, the real price of wastepaper has no effect on the quantity recycled. The result supported the argument of the past studies in questioning the effectiveness of current recycling policy of using price as an instrumental variable to adjust the recycling rate.
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ECONOMIC ANALYSIS OF RECYCLABLE PAPERS

A THESIS
SUBMITTED TO THE FACULTY OF CLARK ATLANTA UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF MASTERS OF ARTS

BY
CHARLES OKEY. NJELITA

DEPARTMENT OF ECONOMICS

ATLANTA, GEORGIA
MAY 1996
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CHAPTER I
INTRODUCTION

Humanity has been recycling paper for three hundred years, but never has it been under more pressure to recycle than in recent times. The need to recycle began as solid waste disposal became a costly problem for federal, state, and local governments, and for households. Households pay for waste disposal primarily through their local taxes or by fixed fees paid to local governments and to private collectors.

Faced with rising disposal costs, communities are implementing programs and legislation to encourage recycling activities to reduce solid wastes. These supply side policies are intended to increase the recovery of recyclable products (i.e. wastepaper).

These policies are based on the past research and recommendations of some of the following authors: Quimby 1975; Anderson and Spielgelman 1977; Grace et al 1977; Edward and Pearce 1978; Little 1978; Pluat and Steiker 1978; Deadman and Turner 1980; Turner and Walter 1988; Hong et al 1992; Wieseman 1992; and Dinan 1993.

Most of these studies have produced mountains of knowledge and methodologies to examine the wastepaper market. However, their policy recommendations have been supply sided. Thus, it is appropriate to investigate the demand side of recycling policy.

The thesis of this paper is the proposition that the real price of wastepaper has no influence on the quantity of wastepaper demanded for recycling purposes.
Background and the Problems

Waste management is a pressing problem in the United States. In 1993 alone, America generated about 306.8 million tons of Municipal Solid Waste (MSW), an increase from 291.7 million tons in 1992. According to the Environmental Protection Agency (EPA) estimate, the 1993 figure is about 4.3 pounds of solid waste per person per day, in comparison to 2.7 pounds per person per day in 1960. There is no doubt that as America's population, production and consumption increases, so does the quantity of solid waste generated.

Approximately 71 percent of MSW was disposed in landfills in 1992, and this qualifies landfills as the dominant method of waste disposal in America (Biocycle 1994). The other two methods of waste disposal - incineration (10 percent) and recycling (19 percent) - account for the remaining 29 percent. By the year 2000, 522 million tons of municipal solid waste (MSW) will be generated, and only 49 percent will be discarded in landfills. The rest will be either recycled (25 percent) or incinerated (26 percent), due to the declining volume of landfills (Franklin Associate, 1992).

In 1993, the number of landfills that were operational stood at 4,482 throughout the nation. In 1960, there were 92,384 operational landfills. Imagine the difference. The EPA estimates that by the year 2000, only about 2,200 landfills will be operational at the current rate of utilization, down from 5,500 in 1992 and over 14,000 in 1978 (Biocycle 1994). Landfilling is under pressure from the general public and government for several reasons. First, laxed pollution controls have led to the allowance of open
dumping and resultant poor sanitation. This abuse has raised the public awareness and, hence, the "not in my back yard" (NIMBY) syndrome for landfill sites. This social behavior raises the overall cost of landfilling.

Secondly, geographical location plays a role in the selection of sites for landfills. The Census regions rank as follows in the landfilling of their Municipal Solid Waste: Northeast (36 percent); Mid-Atlantic (57 percent); South (68 percent); and Great Lakes (68 percent). Inverse to regional landfilling is the incineration method: North East (40 percent); Mid-Atlantic (18 percent); South (12 percent); and Great Lakes (10 percent).

In 1993, *The State of Garbage in America* counted 6,678 curbside recycling programs in the U.S., up 24 percent from the 5,404 counted in 1992. This number has risen from 1,042 curbside programs in 1988 to the 1993 level (Biocycle 1994).

The United States Congress Office of Technological Assessment (OTA) considers recycling as the best alternative to any other form of solid waste management. The recycling process begins with separation of a product that otherwise would have become waste and ends when the recovered materials are processed into a new product.

There are three basic steps to recycling. First, reusable products must be separated from other trash (i.e. source separation at Material Recovery Facilities (MRF)). In 1993, there were 776 MRFs nationwide where quality materials were prepared for the end users (Biocycle 1994). The second stage of recycling is processing of the materials by the manufacturers so that they can be used as material inputs. In the final stage, open loop recycling, the recycled materials are returned to commerce usually as a component of
another product. Sometimes the recovered product is made into the same product over again. This is considered closed loop recycling.

The Islip (Long Island, N.Y.) barge incident is seen as the major turning point in public perception about garbage. The New Jersey garbage crisis really set some legislative wheels in motion. New Jersey had closed all but 20 of its landfills by 1984, and no new ones were sited. In 1987, the state passed a law requiring all communities to mandate recycling programs; however, it did not consider where all that additional collected recyclable material was going to be marketed.

Many states followed New Jersey's lead by setting up their recycling systems or by studying such programs. Over 40 states have comprehensive recycling laws that require separation of recyclables or provisions to stimulate recycling (Pulp and Paper 1994). Since 1989, all 50 states have enacted some type of recycling law, and as these recycling programs generate more and more recyclables, it becomes apparent that demand for them is not growing proportionately.

About 82.5 percent of MSW is organic waste (e.g. paper and paperboard, yard waste and food waste), and close to 17.5 percent is inorganic (e.g. metals, plastics, glass, etc.) (Franklin Associates, Ltd 1992). Since paper and paperboard account for almost half of all solid waste, the paper industry inevitably is obligated to recycle more of it. Historically, paper and paperboard have ranged from 29.9 million tons in 1960 to 73.3 million tons in 1990. Recovery of wastepaper has also gone up from 5.4 million tons in 1960 to 20.1 million tons in 1990, nearly 29 percent of total generation. In 1990, American Forest and Paper Association (AF&PA) set a goal to recover 40 percent of all
paper used in the U.S. by the end of 1995. At the end of 1993, the paper industry attained a 39.3 percent recovery rate and established a goal of 50 percent by the year 2000.

Old Newspaper (ONP) and Old Corrugated Containerboard (OCC), comprised a substantial proportion of recovered wastepaper because they made up a substantial proportion of mixed solid waste landfilled in the U.S.. Note that an Old Newspaper that is directly landfilled may be readable in 20 years to come, if it fails to encounter the right combination of moisture, bacteria, chemicals and oxygen (Quimby, 1975).

It is apparent that as recycling programs generate more and more old newspaper, the rate of consumption by the paper company is not matching up to the supply. Hence, there was a market glut of ONP in the early 1980s. Some states, in the interim, paid paper mills to take the excess ONP rather than pay the high tipping fees at landfills or pay to transport the solid waste across the state boundary. Some recycling sites closed as an excess supply of old newspapers depressed prices and lowered profit margins.

In 1988, for example, 3.2 million tons of old newspaper was reused in the U.S. for newsprint, paperboard and other products. That amounted to approximately one quarter of the U.S. newsprint consumption. Therefore, if 12 million tons of old newspapers were to be collected, only 3.2 million tons of it would find markets. Thus, recovery of paper and paperboard grade depends on its marketability.

The Problem and Hypothesis

According to The State of Garbage in America, these supply sided programs and laws continue to push the supply of recyclables upward, and depress prices for many
secondary commodities (i.e. wastepaper). Has the market failed to allocate resources efficiently because prices fail to reflect full social cost? What has happened to the quantity of wastepaper recycled to this point? It is often argued that in the rush to recycle, the demand for recyclables has not always kept pace with burgeoning supplies.

Paper and paperboard industry representatives have argued that the recyclable paper market needs no external manipulation by local, state, or federal government. The market can allocate resources to achieve permanent, expanded markets for recyclable paper. The only support that this industry needs is for local government to focus on recovery of wastepaper grades (AF&PA, 1995). How good is this argument? One only needs to investigate trends in the ONP market to answer this question.

Conservationists and municipalities argue that success of recycling programs depends on the stability of the market for recyclable materials. The mayor of Newark, New Jersey called for an investigation of the paper recycling industry, suggesting collusion and price fixing because the city of Newark was paying the paper stock dealers to take their recovered ONP. The director of the New York Office of Recycling Market Development (ORMD) wrote:

In order to achieve the environmental and solid waste management benefits of recycling you need some basic outcomes driven by business development and the market place.

Historically, the wastepaper market is a volatile market. This price volatility presents a problem for both paper firms and municipalities. Some municipalities include expected profit from recyclable sales as part of budget revenues. The paper and paperboard firms are risk averse and must set up the optimal input mix in their production...
process. The price swings in the recyclable paper market create uncertainties for both economic agents. Let's pose the same question over again: does the price of wastepaper reflect the full social cost of recyclable paper in America? Within the broader scope of the general problems of the wastepaper market, the hypothesis of this study is that the real price of the wastepaper has no measurable effect on the quantity of wastepaper recycled.

Objective of the Study

The primary objective of this thesis is to trace the effect of the real price of wastepaper on the quantity of wastepaper recycled under the framework of the secondary material market.

A secondary objective is to examine the effect of other variables (i.e. price of woodpulp, final output production, minimum wage, export, wastepaper recovery rate, price of energy, and past price) on the quantity of wastepaper recycled.

Limitations of the Study

Factors other than price may influence the quantity of wastepaper recycled. These factors include the primary material market (i.e. demand and supply of woodpulp); the final product market; each individual firm's production function and input mix; market information; government content requirement and procurement policies; industrial organization; (i.e. vertical integration); and demography. The investigation of such factors is beyond the scope this study.
Organization of the Study

The remaining part of this study is divided into four chapters. The second chapter provides a review and overall description of the wastepaper market and is subdivided into thirteen sections. Chapter three presents theoretical and empirical frameworks. Chapter four presents the empirical results. In chapter five the conclusions and recommendations of the study are discussed.
CHAPTER II

DESCRIPTION OF THE WASTEPAPER MARKET

Historical Development of the Paper Industry

The word "paper" was derived from the Greek and Latin words "papurous" and "papyrus" respectively. Papyrus has played an important role in world history since ancient Egyptian civilization. The oldest written rolls date back five thousand years, and papyrus was one of the writing materials to have many of the properties of paper.

Paper is a material made in the form of sheets containing the macerated fibers of rags, cotton, bark, wood, or other cellulose substances. After being beaten into separate fibers, the raw material is mixed with water and lifted from the water with a screen. As the water drains through, the fibers form a mutated sheet on the screen's surface. This sheet is paper.

Around 105 A.D., Ts'ai, an enterprising member of the court of Chinese emperor Ho-ti, created sheets of paper by pounding membranes and other plant fibers, along with lag and hemp waste to a watery pulp and pouring them into a bamboo screen. By the sixteenth century, paper was still being made by hand, one sheet at a time from a rag pulp.

The whole process of making paper changed during the industrial revolution of the seventeenth century. Paper making was mechanized by the invention of a fourdrinier paper machine "for making endless paper." The first paper mill was established in
America in 1690 by William Rittenhouse near Germantown, Pennsylvania. Immigrant paper makers from Europe started the earliest mills, modeled after European designs.

These paper mills had to be located near populated areas that could provide a supply of rags (secondary fiber), the main raw material at that time. The advertisement in contemporary newspapers, pamphlets, and flyers urged the colonists to save rags for their local paper mills. A generous supply of fresh water was a second requirement, both for washing the fibers and providing power for turning the milling machine. Thus, recycling is as old as paper manufacturing in North America.

Most of the colonial paper mills were located near print shops. The craft of printing generally preceded papermaking in most of the settlements in American colonies.

Even before they had a reliable supply of papers, the colonists began to establish newspapers. The first was the Boston News Letter which was first issued in 1705. The second was the Boston Gazette established in 1719.

**Technological Development of Paper Recycling**

As indicated in the above section, the practice of papermaking from waste paper is an old art, dating back to 300 years ago. The term "recycling" encompasses both the recovery of recyclable materials from the waste stream and their conversion into consumer products.

To produce recycled paper, wastepaper is mixed with water and beaten to separate the fibers and form a slurry. Chemicals are added only in deinking mills, where recycled pulp is washed with chemicals to remove inks from the paper fibers. The pulp slurry is
then cleansed of contaminants such as metals (paper clips and staples) and other unwanted materials. Recycled pulp may be combined with varying quantities of wood pulp to manufacture new paper.

The process by which pulp is transformed into paper is similar to that of virgin wood pulp. Fibers are fed into machines that remove the water and then into form sheets that are pressed and dried. In general, mills cannot use virgin and recovered fibers interchangeably because the processing equipment for wastepaper differs from that used to process wood fibers. Most recycling mills are equipped to process recyclable papers only; mills using virgin fibers are typically not equipped to repulp wastepaper, although they obtain recycled pulp from deinking mills that produce and market it.

Of the approximately 600 paper and paperboard mills in the United States, about 200 rely exclusively on wastepaper as their raw material; the remainder may use between 10 to 30 percent of waste paper in their manufacturing process. At least seven recycling newsprint mills are capable of deinking newsprint. Some produce 100-percent recycled newsprint and others combine recycled and virgin pulp (GAO/GGD-3 1989).

In recent years, trade associations such as the American Forest and Paper Associations (AF&PA), the Confederation of European Paper Industries (CEPI), and the Bureau International de la Recuperation (BIR) have dropped the term "wastepaper" in favor of "recovered paper" to avoid an association with solid waste. Other terms used include paper stock, recovered fiber, recyclable paper, scrap paper, and secondary fiber.

The technologies of recycled and virgin paper making are somewhat different. Secondary fibers differ from the virgin ones in that they have already undergone pulping and are often
contaminated with inks, clays or other substances. This repulping system has three basic stages: [a] defibering, [b] cleaning and screening, and [c] washing and thickening. Depending on the final use of the wastepaper stock, additional processing (e.g. bleaching and bleach washing) may be required.

[a] **Defibering**: is performed in a special unit where wastepaper is mixed with water and chemicals and is subjected to violent agitation in a process which may operate on a batch or a continuous method. The consistency of the batch (6 to 8 percent), temperature, chemical concentration and the duration of the process are predetermined. The raw material used determines the chemicals and their concentration.

[b] **Deinking Process**: Wastepaper in many cases must be treated to remove ink, especially in the case of ledger grades, as well as old newspapers and magazines. This process consists generally of centrifugal cleaning to remove contaminants having greater specific gravity than wood pulp fibers. The stock is then screened to remove all particles larger than the size of the screens holes. At this stage, the wastepaper stock must be washed to remove inks, clays, chemicals, or other foreign substances in the stock. This process is called "deinking" and different methods are used, the key parameter being water consumption and efficient treatment. Bleaching may be carried out during the initial defibering or during the deinking.

[c] **Thickening**: is required to provide working consistency to the stock. The wastepaper stock is now ready to be fed directly onto the paper machine or be mixed with virgin pulp. From this point on, the paper making process is as previously described. Besides the differences which exist in the methods of converting virgin pulp and wastepaper, there are
specific characteristics associated with secondary fiber repulping systems. First, the capital investment for such a plant is much less on an absolute and per ton basis than for a virgin pulp plant. In addition, the source of raw materials shifts from rural (virgin pulp) to urban (wastepaper pulp), thus having a direct impact upon the location of the pulp mill (Cardin, 1974).

The major difference between the cost of converting virgin pulp and secondary fiber is in the pulping and stock preparation stages. The capital cost of expanding the papermaking capacity is estimated to average 150,000 dollars to one million dollars if wood pulp is used. The cost of building a new mill is considerably greater than the cost of expanding an existing mill. For example, building a new mill for recycled paperboard can cost 50 percent more and usually takes twice as long as expanding an existing mill. The cost differential for the fibers is much less important in the comparative economics of virgin versus secondary fiber than this capital cost differential (OTA, 1989).

Franklin (1975) reported that the greatest differential is for box board, the cost of a recycled box board mill is about $115,000 per daily ton of capacity (about $40 million for 350 tons per day capacity), compared to a mill producing solid bleached sulfate (about $92 million for 350 tons per day capacity). The differential is less spectacular for other grades, but still sizeable.

For newsprint, the differential investment favorable to recycling mills varies from $10,000 to $40,000 per daily ton of capacity. The composite average is in the range of $40,000 to $50,000 per daily ton.
Characteristics of the Wastepaper Market

The purpose of this section is to provide a general description of the characteristics of the wastepaper market, i.e. (1) the sources and the types of wastepaper, (2) the end products that use wastepaper as an input, (3) the structure of the paper and paperboard industry, and (4) the major factors that encourage and discourage the recycling of wastepaper.

The Sources and Grades of Wastepaper

There are two broad sources of wastepaper supply: (1) waste generated by households, businesses, institutions, and government offices which is any paper or paperboard product that has been discarded by the users, and (2) scrap created in paper-converting operations, such as cuttings and clippings from envelope and corrugated box plants and printing operations.

The latter category is by-products of the manufacturing process called converter wastepaper and the by-products are usually bundled and shipped directly to recycling mills. As a matter of fact, these scraps serve as pulp substitutes and are currently being recovered at a rate close to 100 percent (API 1992).

There are five grades of recyclable paper generated by households, businesses, institutions, and government offices. They are as follows: (1) news (principally old newspapers); (2) corrugated (principally old corrugated containers); (3) mixed papers; (4) high grade deinking papers, and (5) pulp substitutes. The first two categories are called the bulk grades and have the highest recovery rate of about 67 percent.
In 1993 about 7.3 million tons of old newspaper were recovered, and close to 8 million tons estimated to be recovered by 1995. Seventeen million tons of corrugated containers were recovered for recycling. Almost 4.6 million tons of mixed papers were recovered, which included all papers not classified elsewhere. The recovery of high-grade deinking categories was about 3.5 million tons. Close to 3.6 million tons of pulp substitutes were recovered, which includes paper recovered from printing plants, offices and data processing centers (API, 1992).

The Industries that Use Wastepaper as an Input

Wastepaper is consumed mostly by two industries: (1) paper and paperboard, and (2) construction. Wastepaper is used in the manufacturing of newsprint, tissue products, paperboard, printing and writing papers. It should be noted that the recovered paper grades are not interchangeable as a raw material to make new paper products. Different recovered papers lend themselves to making different types of new products. For example, old newspapers are used primarily to make new newsprint and recycled paperboard; old corrugated containers to make liner board, corrugating medium and recycled paperboard; high grade deinking papers and pulp substitutes to make tissue and printing/writing papers.

Over 500 mills in the United States (75 percent) use wastepaper for their raw material requirement. The utilization rate of all grades of wastepaper had increased from 12 million tons in 1970 to 30 million short tons in 1994. A one percent increase was forecasted for 1995, about 31 million short tons.
The percentage of wastepaper grades utilized relative to virgin pulps utilized was as follows: mixed paper 12.2 percent, newspaper 18.8 percent, corrugated 47.6 percent, pulp substitutes 11.6 percent and deinking 9.8 percent (Pulp & Paper, 1994).

Construction paper and paperboard functional groups consist of a number of fibrous materials that are primarily used in the building industry. Little (1976) divided this group into three subcategories: construction, gypsum wallboard, and hardboard/insulation board. Construction paper includes sheeting paper, felts (roofing, floor covering, automotive, sound deadening, industrial, pipe covering, refrigeration, etc.), asbestos and asbestos-filled paper, and flexible wood fiber insulation. Asbestos paper used to be the only material not made entirely of wastepaper, but recent prohibition on the use of asbestos for construction made construction paper almost 100 percent wastepaper. Almost all forms of construction paper are intermediate products. Gypsum Line board, another intermediate product, is the facing material on gypsum wallboard. It is made entirely of wastepaper. Gypsum wallboard is used chiefly for interior wall and ceiling panels and as a base for plaster. Hardboard board is usually made from long-fiber mechanical pulp into a fiberboard that may be treated and/or tampered. This product is used for such applications as cabinet backing and wall paneling. Insulation board is a homogeneous wood fiber panel made from defiberated pulp. The semi-rigid variety is used for insulation purposes, such as ceiling tile and acoustical tile.
The Structure of the Paper and Paperboard Industry

The paper and paperboard industry can be divided into two categories: those firms which utilize primarily virgin woodpulp and those firms using primarily wastepaper as an input. In 1872, individual entrepreneurs and partnerships accounted for over 80 percent of the ownership of pulp and paper mills. By 1934, over 96 percent of the mills were owned by corporations. Consolidation and merger have become common trends in this industry since then. Firms which utilize virgin woodpulp tend to be large, integrated manufacturers that have attained control over their supply of pulpwood and, thus, can obtain a reliable supply of woodpulp at a relatively constant. According to Grace et al, the virgin woodpulp industries tend to be organized along oligopolistic lines with some price and output stability and vertical integration.

On the other hand, secondary material mills which utilize wastepaper tend to be small, poorly capitalized, and labor intensive, often with substandard technology and management skills, and beset with environmental problems. These mills depend on the market for their supply of wastepaper as raw material (Allen and Nelson, 1976).

In general, these large, integrated paper and pulp mills tend to be located in the South and Northwest (near the sources of virgin pulpwood), while secondary material mills (mini-mills) tend to be concentrated in the Northeast and North Central regions (near the highly concentrated population urban centers). These mini-mills depend on paper stock (wastepaper) dealers to supply them with their wastepaper needs. Wastepaper prepared for sale to a paper mill is known as paper stock. Paper stock dealers are divided into three groups-brokers, wholesalers, and retailers. In many instances, wholesalers also
double as brokers. A wholesale paper stock dealer purchases all of the wastepaper stock from large printing facilities; while a retail paper stock dealer purchases relatively small amounts of paper from households and others and sometimes sells their output to the wholesaler. The wastepaper dealer industry is characterized as being extremely fragmented with small, family-operated firms. Thus, the brokers bring buyers and sellers together, and for this service receive one or two dollars per ton (Quimby 1975).

Factors that Encourage and Discourage Wastepaper Recycling

In a report by Franklin Associates, Ltd (1988), four major factors have historically led to the increased use of wood pulp relative to wastepaper in the production. These factors have economic and noneconomic root context. These factors are as follows: [a] current plant design; [b] the effects of contaminants in wastepaper; [c] heterogeneity of wastepaper grades; [d] the consumer demand for the finished product.

[a] Current Plant Design. This factor is more technological than market oriented. A mill designed and constructed to process virgin pulp does not have the proper equipment to process secondary fiber. While the situation can be changed in the long run, it is not reasonable to abandon high capital cost and efficient pulp mill equipment (digester, chemical recovery plants, etc.) and replace it with equipment suitable to process secondary fibers (increased defibering, cleaning, and screening capacity) simply to increase wastepaper recovering rates. Where excess paper mill capacity relative to pulping capacity exists, some wastepaper repulping may be economically sensible through the addition of secondary facilities (Cardin 1974).
Based on a number of economic cost models, Little (1976) found that the profitability of a new secondary-fiber mill is less attractive than that of a new integrated pulp and paper facility (for all products except newspaper). According to the American Paper Institute (1992), it is difficult to say precisely the cost differential, since the cost differential varies widely depending on the size of the mill and the product to be produced. Depending on the end product produced and the number of tons slated to be produced daily, the costs can range from $100,000 to $600,000 per daily ton.

[b] The Effects of Contaminants: The impact of contaminants on the recyclability of wastepaper was discussed in detail in the report by Franklin (1975), “Paper Recycling.” One of the characteristics of wastepaper is that it frequently contains contaminants which make it difficult to be used in the manufacture of paper and paperboard. Contaminants include such materials as adhesives, certain inks, asphalts, plastics, carbon papers, and foils.

The high costs of removing contaminants have severely limited the recyclability of certain grades of wastepaper. This problem of contaminants is largely confined to box board grades, corrugating medium, and deinked newsprint.

[c] Heterogeneity of Wastepaper Grades: The organization, The Paper Stock of America, defines different grades of "regular" secondary fibers plus specialty grades. This wide variety of secondary fibers complicates the recycling process since the wastepaper grades determine the repulping process to be used. Specifically, the wastepaper generated by industrial and commercial sources tends to be much more homogeneous (than household scrap) and thus, much less costly to recycle.
Because of the high costs of cleaning and separating, Little (1976) sees almost no possibility for the increased utilization of mixed paper (mostly household generated).

**[d] Demand for the finished product:** Increased recycling is dependent on the expanded market demand for the finished products that can be made from recovered or recycled fibers. This factor can be subdivided into two parts: noneconomic and economic. Both parts were discussed in detail in the report by Franklin Associate Ltd. (1975), *Economic Incentives and Disincentives for Recycling of Municipal Solid Waste*.

Noneconomic factors include attitudes of manufacturing personnel or of end product consumers; attitudes on quality control; and long-standing policies and procedures. People place value judgements on certain aspects of business decisions which are not obviously economic factors, e.g., there have been some trials conducted by state and federal printing operations where recycled paper was compared to virgin paper. In some of those trials, the recycled paper was more prone to several problems, such as paper-feed jamming and overall appearance of the finished product. In extreme cases, even though currently produced grades of recycled paper have been shown to operate without problems, a prejudice still exists.

Historically, recycled paper products have not been as "bright" as virgin products. Recycled products intended to be white may have a slight gray or brown tint, in some cases, recycled paper has a speckled appearance. Some market researchers claim that consumers will choose the "brighter" appearing products, even though the other products function as well. While recycled products frequently cannot be distinguished from virgin products, prejudices still exist in the marketplace.
The final factor is what simply may be called "inertia". People tend to resist change. Thus, there is a noneconomically motivated resistance to converting virgin operations into recycled operations, or to even install supplemental or incremental recycling capacity at a virgin operation (Franklin, 1988).

The solution to these noneconomic barriers is primarily communication and education. The next barrier to consider is the economic factors that affect recycling markets.

The economic barriers are factors that limit recycling markets through economic forces. The factors are as follows: (1) costs of raw materials, capital, and labor; (2) costs of transportation; (3) new business or capacity expansion decisions; and (4) end product prices. These economic factors can be broadly classified as supply-side or demand-side factors. Franklin (1988) examined the supply-side factors that affect the procurement and processing of raw materials prior to manufacturing. Demand-side factors are those that affect the end consumers of goods -- industrial and commercial businesses or households. Mills are at the pivotal point of the system, being direct participants in both supply-side and demand-side factors.

Each grade of recycled material has a specific set of market factors that affect the degree to which it is used. For example, old newspapers (ONP) are relatively easy to collect, but the two primary end products that use ONP (recycled boxes and newspapers) are sold to limited markets. Hence, ONP is demand-side limited. Franklin (1988) recommends that incentives be applied at that point in the system in order to create markets.
Old corrugated containers (OCC), on the other hand, compete well against products made of virgin materials in many markets. Thus, OCC is supply-limited, and incentives to collectors would likely result in increased use of it.

Finally, procurement guidelines are being used to remove demand-side barriers. On October 20, 1993, Federal Acquisition Recycling, and Waste Prevention, was signed into law by the U.S. President, as amended by the Resource Conservation and Recovery Act (RCRA) of 1979. In order to increase the quantity of recycled paper utilized by the U.S. government, guidelines on the minimum content requirement were set by Dec. 1, 1994. These guidelines state that all printing/writing paper, including high speed copier paper, offset paper, forms bond, computer printout, carbonless, file folders, and white wove envelopes purchased by the federal government must contain at least 20 percent postconsumer fiber, rising to 30 percent by Dec. 1, 1998. For other uncoated printing/writing grades, including writing and office papers, book paper, cotton fiber paper, and cover stock, the Executive Order requires a minimum of 50 percent recovered materials.

Since the Federal Government purchases only about two percent of all paper consumed in the United States, it is expected that this Act will remove some demand-side and economic barriers. There are some similar laws and voluntary agreements that encourage the purchase of recycled paper in 21 states of the United States, including the District of Columbia. For example, in 1989, Connecticut and California enacted legislation requiring all state newsprint manufacturers to increase the level of recycled contents in response to the glut of ONP.
Also, federal regulation protects the spotted owl habitat in the Northwest, thus, restricting logging and increasing the price of wood chips, which causes paper mills to consider recycled production inputs as a way to contain raw material costs (Alexander, 1992).

In summary, the high costs of sorting, cleaning, and transporting of wastepaper tends to discourage recycling. This market characteristic showed that an increase in the price of wastepaper is supposed to increase recovery of wastepaper, and, in turn, induce a higher level of wastepaper usage in paper and board production. But, by how much? This is the primary objective of this paper. Thus, it is important to examine the determinants of the price of wastepaper in the next section.

Trends in Wastepaper Use, Availability, Export, and Prices

This section presents a general overview of the national trends in consumption rate, recovery rate, and prices of wastepaper relative to substitute virgin woodpulp. Examining these trends aids in understanding of how the wastepaper market actually operates.

Consumption, as applied to the paper industry, is "apparent consumption." Apparent consumption is domestic production plus import less exports. Consumption does not take into account inventory adjustments. Recovery is defined as salvage. It also means the acquisition of an energy value from incineration or other chemical conversions. Recoverable resources are materials which retain their useful properties and can be reclaimed after the cycle of production, use, and discard.
Two main indicators are used to measure wastepaper consumption: the utilization rate and the ratio of wastepaper to total fiber furnish. Utilization rate is calculated as a ratio of wastepaper consumed to total paper and paper board produced. Due to loss of fiber in papermaking there is a small differential between the data (figure) collected by the Department of Commerce and the American Forest and Paper Association. AF&PA figures are generally higher than those from the Department of Commerce because AF&PA includes in-plant and intra-plant use of paper machine trim and broke. (Pulp and Paper, 1995).

The percentage of recycled paper used in overall fiber furnish in the U.S. did not change appreciably in the 1970s and 1980s. With only minor setbacks along the way, it grew from 27.4 percent in 1970 to just 33.5 percent in 1989, according to AF&PA figures. However, it increased rapidly in the early 1990s and is expected to grow at a rate of 7.4 percent on average from 1991 through 1996. It is expected to reach 52.3 percent of total fiber consumed by 1996.

Wastepaper Utilization Rates

One of the simplest measures of the recycling rate is the proportion of U.S. paper and paperboard made from wastepaper. Wastepaper utilization denotes the consumption of wastepaper as fiber input in the paper and paperboard industry. Figure 11.1. presents this rate trend from 1939 to 1993. There was a sharp decline in the utilization rate of wastepaper between 1944 and 1965. Since the mid 1960's, the rate of recycling has increased.
Between 1944 and 1945, the total utilization of wastepaper was almost 40 percent which steadily declined to about 23 or 24 percent of the total paper and paperboard production in 1970, despite great fluctuations in the price of wastepaper (Edgren and Moreland 1988). Thus, wastepaper consumption (utilization plus imports) declined from about 40 percent in 1945 to about 23 percent in 1985. However, it seems that since 1985
this decline has ceased, and the utilization rate has crawled up to 29.2 percent in 1991. It was expected to exceed 36 percent in 1994.

The Second World War figure of 40 percent has often been cited by conservation advocates as what benefits society could receive if more emphasis was placed on wastepaper recycling. This figure may also be the answer as to why AF&PA set a 40 percent recovery rate by the mid 1990s as the new recycling target for paper and paperboard industry.

In 1992, the Recycling Advisory Coalition issued its proposed minimum recycled-percentage requirements for government paper procurement. If adopted by EPA, this will boost the utilization rate of almost all grades of wastepaper. In 1993 alone, the utilization of the wastepaper grades was as follows: Mixed papers (12.9%), Newspaper (18.1%), Corrugated (48%), Pulp substitutes (10.7%) and deinking (9.7%).

Wastepaper Recovery Rate

Recovery rate of wastepaper is the measure for the availability of wastepaper from domestic sources and is defined as domestically recovered wastepaper and board relative to apparent consumption of paper and paperboard.

Historically, recovered paper has provided 20 to 25 percent of the total raw material requirement of the U.S. paper industry. The war years 1939-1945 have the highest recovery rates. The waste paper recovery rate has risen beyond the utilization rate, due to an increase in U.S. exports of wastepaper (see Fig 11.3). Overall, the recyclable recovery rate has been climbing for the past two decades. It has hovered
around 26 percent since 1980, but jumped to 28 percent by 1986. This was almost a 13.3 percent rise in exports and a 7.8 percent increase in the amount of paper and paperboard collected for recycling.

Fig 11.2 describes the wastepaper recovery rate from 1939 through 1993. The collection of wastepaper continued to rise in the late 1980s and early 1990s, reaching 33.773 million tons in 1993, which was equivalent to a recovery rate of 39.2 percent (Pulp and Paper, 1995). AF&PA came close to attaining its 1993 target of 40 percent recovery goal. AF&AP estimated that recovery may reach up to 42 percent by 1995, and has set a new goal to recover 50 percent by the year 2000.

According to the projections of Franklin Associates Ltd., the volume of paper and paperboard recovered will increase to 33.6 million tons, a 52 percent increase, from 1996 to 2000. While new supplies will increase by 16.8 percent, recovery of paper could increase by as much as 51.1%, according to the study.
Old Corrugated Container (OCC) continues to account for the single largest grade recovered by weight, but its relative share will decrease to approximately 40 percent of all paper and paperboard recovered in 2000, down from 46 percent in 1992. The relative portion of total recovered paper represented by Old Newspapers and high-grade deinking grades will remain unchanged by the year 2000. (Pulp and Paper, 1995).

Franklin estimated that 7.0 million additional tons of mixed paper will be expected to be recovered by 2000. The recovery sources of paper grades are as follows: 1.0 million
tons will be old magazines (OMG); 1.0 million tons will be office paper; 1.7 million tons will come from residential sources; and 1.0 million tons will come from other commercial sources.

**Export and Import of Wastepaper**

The difference between the U.S. utilization rates and the recovery rates of wastepaper is determined by the quantity of wastepaper exported and imported. The amount of wastepaper exported has been small, accounting for only about 2.5 percent of the total recovery (wastepaper consumption plus exports) during the 1960s. During the 1970s, this figure rose to 3.7 percent; it increased to 9.8 percent in 1974, dropped to 7.7 percent in 1975, and rose again to 10.5 percent in 1976 (Plaut and Steiker). Fig 11.3. depicts the net quantity of wastepaper exported from the U.S. to other countries between 1970 and 1993.
In 1970, the United States imported about 67,000 tons of wastepaper, and ten
years later it imported just 87,000 tons. It increased to 123,000 tons in 1990, and 137,000
in 1993. Most of the U.S. imports of wastepaper are from Canada.

The U.S. is the largest exporter of wastepaper. In 1991, the U.S. exported almost
6.6 million tons - a 1.4 percent increase over 1990 - but fell in 1992, for the first time in
10 years, by 2.3 percent, to 6.4 million tons (Department of Commerce, 1994). This
compares with a 12.8 percent annual growth in the 1985 to 1990 period. In 1993, the
downward trend continued, with exports dropping to 5.9 million tons.
The largest consumers of U.S. wastepaper in 1993 were Republic of Korea (1.212 million short tons); Canada (1.182 million short tons); Taiwan (880,200 tons); Mexico (669,200 tons); Japan (417,000 tons); Indonesia (305,800 tons); China (208,500 tons); Venezuela (177,536 tons); Thailand (137,900 tons); and the Philippines (127,300 tons), according to the U.S. Department of Commerce (Pulp and Paper, 1995). The trend of wastepaper imports is obviously increasing at a decreasing rate. In 1970, the U.S. imported just 67,000 tons of wastepaper, and in 1980 it was just 87,000 tons. And it jumped to 123,000 tons in 1990, increased to 137,000 in 1993, about 83 percent of which came from Canada (Pulp and Paper, 1995).

Mixed paper registered the greatest gain in exports among all grades with 939,000 tons, a growth of 6.5 percent from the year before. Newspaper dropped by 1.3 percent to 1.29 million tons. Corrugated container grades fell by 11.0 percent to 2.5 million tons; and pulp substitutes dropped 12.7 percent to 535,600 tons. Deinking plummeted by 29.9 percent to 639,200 tons.

The American Forest and Paper Association expects that the export market of wastepaper will represent a declining share of total demand for U.S. recovered paper. Total exports are expected to increase only slightly from 6.5 million tons in 1992 to 7.74 million tons by 2000.
**Wastepaper Prices**

Wastepaper is a commodity subject to price fluctuations. Materials prices may be valuable signals of scarcities and surpluses in any commodity market. High prices tend to encourage limited use of a particular material and leads to a search for cost reducing technological changes and cheaper substitutes, whereas low prices tend to encourage expanded use of a particular material instead of more expensive alternatives. Wastepaper is not an exception to this fundamental law. Figure II.4 presents the average national wholesale price index for wastepaper and woodpulp with 1982 as the base year (1982=100). Upon examining this market, it is obvious that the wastepaper

![Graph](image-url)

**Figure II.4. Wastepaper and Woodpulp Price**
price is highly volatile in comparison to woodpulp. For example, there was a 50 percent drop between 1947 and 1952, and a 62 percent drop between 1974 and 1975 with a rise of 60 percent by 1976. Since 1976, the volatility continued, but the downward swings appear to have been larger. By 1985, the real price of wastepaper was half of what it was in 1976 (Edgren and Moreland, 1988).

From 1985 to 1993 there was a steady increase in prices, but not like 1973, and it bottomed out by 1989. Then the wastepaper price took a downward dive from 157.1 dollars in 1989 to 117.7 dollars by 1993, and this had a tremendous impact on the recovery of some wastepaper grades. For example, wastepaper dealers were charging as much as 30 to 40 dollars a ton to some municipalities in the Northeast to take their recovered old news. No. 6 newspaper in 1990 was selling for a negative 12 dollars per short ton at the New York spot market (Pulp and Paper, 1995). The mayor of Newark, New Jersey, called for an investigation of the paper recycling industry, suggesting collusion and price-fixing.

This market remained depressed until 1994 when OCC prices advanced from 23 dollars per short ton in January to 104.63 dollars in July, and this bolstered other grades, especially those which could be used as OCC extenders in contained board manufacture. No. 6 Old news prices increased from a national average of 14.38 dollars per ton in January 1994 to 47.50 dollars per ton in July 1994. During the same time frame, mixed paper advanced from 3 dollars to 45 dollars per ton. No. 8 Old news rose from 28.75 dollars per ton to 65.63 dollars per ton. For the deinking grades, CPO prices averaged 240 dollars per ton for laser-free and 197.50 per ton for laser in July 1994 compared to
200.63 per ton for laser-free and 162.50 per ton for laser six months earlier. Sorted white ledger shot up to 165 dollars in July 1994 from 128.75 per ton in January 1994 (Pulp & Paper, 1995).

Why do wastepaper prices fluctuate so much in comparison to virgin woodpulp? The answer is very important since this swing creates uncertainties for both consuming mills (demanders) and recovering municipalities (suppliers). The suppliers have difficulties making projection for their revenue from period to period; the demanders are risk averse, they must set up the optimal input mix in their production process with certainty. Thus, the large mills tend to be wary about wastepaper, and many rely on virgin woodpulp for their input supply. (Edgren and Moreland, 1988).

In general, markets for all materials are characterized by recurring cycles of tight supplies and perceived shortages, succeeded by periods of ample supplies and accumulating surpluses. The consequence is that prices of materials tend to fluctuate a lot. According to Strauss, in certain material markets, prices are established by producers and are referred to as administered prices. In these instances, price changes tend to be tied primarily to cost factors. For other materials, prices are determined on open markets (i.e. commodity exchanges), heavily influenced by current supply and demand factors. In still another category are negotiated prices, which apply primarily to those bulk commodities sold through long-term contracts (Strauss, 1977).

Strauss concluded that the intermediate influence in price determination may differ in the three categories mentioned, but over a protracted period prices for all materials must reflect the three basic factors of supply, demand and cost. In the long run,
supplies are only available if costs are covered. The next section will look at other empirical research on demand, supply and costs.

Note also that fluctuations in foreign currencies in relation to the U.S. dollar also play a role in the wastepaper price. "If the American dollar strengthens, foreign buyers will find it increasingly more difficult to afford U.S. wastepaper," noted Dan Temple (Garcia, Pulp and Paper, 1995).

The Effect of Prices on the Wastepaper Recycling

Price is most commonly seen as the pivot on which recycling policy turns - a commonly natural enough orientation in the market style economy like U.S. It is expected that like any other sector of the industry that the price of wastepaper reacts to demand and supply fluctuation. The only measure of the policy effect is the price elasticity - defined as the resulting percentage change in quantity (either demanded or supplied) divided by a percentage change in the wastepaper price (at the mean). The demand of wastepaper is defined as the quantity of wastepaper and board used domestically as an input in the paper and paperboard industry. Supply is defined as the quantity of wastepaper and board recovered from domestic sources. And price is defined as the national average of all local spot market prices (NYC, Chicago, Atlanta, and SF-LA).

This section entails reviewing the empirical result of past studies on price elasticity for demand and supply of wastepaper at various periods (i.e. technological) and geographical locations coupled with substitution effect of both input. Generally, most of the previous works listed the factors that affect demand (utilization) as follows:
(1) negatively related to own real price; (2) positively related to the real price of its substitutes, i.e. woodpulp; and (3) positively related to the industry output of paper and paperboard.

Supply is a function of the following: (1) real price of wastepaper; (2) the total domestic production of paper minus exports plus past imports, subject to three kinds of lags: [a] a "distribution lag" for scrap, between the end of the manufacturing process and procurement by final consumers and users - highly variable and product-specific, involving transport, warehousing, inventories, and the like; [b] a "consumption lag" between the initial purchase and the end of a product's life; and [c] a "recovery lag" between the end of a product's useful service and completion of the recycling process for the recovered component of the waste stream; (3) the real minimum wage; and (4) the real price of energy.

These previous works on the wastepaper market took two approaches. One approach developed a two equation model describing the demand and supply for wastepaper. This model was used by Anderson and Spiegelman (1977); Plaut (1978); Gill and Lahiri (1980), and Edgren and Moreland, (1988). The second approach used a single-equation, price-expectations model to estimate the price elasticity of supply. Edwards and Pierce (1978), Edwards (1979), and Deadman and Turner (1981) used variations on this approach.

Anderson and Spiegelman (1975) conducted an extensive econometrics study on the national market for wastepaper. The paper attempted to access the impact of tax subsidies on the mix of material consumption, using the paper and steel industries as case
examples. Using nonseasonal adjusted monthly data, demand and supply curves for wastepaper were estimated using two-stage least squares from January 1962 to December 1974. The authors reported that, "Supply responded positively to the current price (estimated elasticity 0.53) but negatively to past prices which apparently serve to deplete the reservoir of wastepaper such that the long-run price elasticity of supply is about 0.40, (i.e. supply is inelastic with respect to price). Demand is also a function of the price of wastepaper (elasticity 0.08) and the price of woodpulp (elasticity 0.17).

Plaut and Steiker estimated the regional demand and supply wastepaper grade price elasticities using monthly data from 1970 through 1976. Table 1 presents the result of the regional econometrics studies with respect to price elasticity for demand and supply. The demand for wastepaper in all regions and for all grades is completely inelastic (with respect to price). The supply of wastepaper (in all regions and for all grades) is very inelastic (with respect to price). The supply of news appears to be slightly more responsive to price than the supply of corrugated, which, in turn, is much more responsive to price than the supply of mixed paper.
TABLE 1. Regional Price elasticities at the Mean (1970-1976)

<table>
<thead>
<tr>
<th>Price</th>
<th>Demand</th>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrugated</td>
<td>0.21**</td>
<td>0.22**</td>
</tr>
<tr>
<td>News</td>
<td>0</td>
<td>0.29**</td>
</tr>
<tr>
<td>Mixed</td>
<td>0</td>
<td>0.10**</td>
</tr>
<tr>
<td>North</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrugated</td>
<td>0</td>
<td>0.17**</td>
</tr>
<tr>
<td>News</td>
<td>0</td>
<td>0.19*</td>
</tr>
<tr>
<td>Mixed</td>
<td>0.05**</td>
<td>0.10**</td>
</tr>
<tr>
<td>South</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrugated</td>
<td>0</td>
<td>0.19**</td>
</tr>
<tr>
<td>News</td>
<td>0</td>
<td>0.25**</td>
</tr>
<tr>
<td>Mixed</td>
<td>0</td>
<td>0.10a</td>
</tr>
</tbody>
</table>

** Significant at the one percent level.
* Significant percent level.
a Significant at the five percent level.
Note: "0" indicates that the elasticity is not significantly different from zero (at the ten percent level).
Edgren and Moreland estimated an econometrics model of paper and wastepaper markets, and calculated price elasticities to be very small. The authors reported an input substitution elasticity range between 0.0 and 0.17, which is very low (i.e. a 10 percent increase in prices would lead to a more than 0.17 percent increase in input substitution). This implies relatively fixed coefficients in the production process (i.e. paper companies tend to use both inputs in fairly fixed proportions and do not vary those proportions much in response to price incentives). The price elasticities of the market were very small for demand (-0.26798) and supply (0.15716).

Edward and Pierce estimated a single linear supply based on the basis of expected price equations using annual/quarterly data from 1960 - 1974 (USA). The authors’ estimate of the elasticity at mean value was 0.3, implying that a percent increase in price would bring forth a less than 1 percent increase in supply. This shows that price elasticity of supply with respect to expected prices was very low. Consequently, very large changes in the expected price would have to be achieved before the supply of wastepaper would increase significantly. Hence, the changes in the actual price (the policy instrument) do not feed instantaneously or totally into expected prices. So the adjustment process is very slow and imperfect.

The low price elasticity of supply (0.3) was confirmed by Deadman and Turner using the same price expectation model (Edwards, 1978), and using data from the United Kingdom. The only difference between the two sets of the results is that there is more of suspicion of serial correlation in the seasonal adjusted data. But the price elasticity of supply for wastepaper was confirmed inelastic.
A Rational expectation model was tested in this market in comparison to a Rational expectation model by Kinkley and Lahiri (1983). The authors reported, "The rational price and quantity forecast were nearly 25 percent more efficient than their adaptive counterparts in terms of mean squared error criterion expectation. Finally, with REH the price elasticity of supply was estimated to be 0.23, which is nearly twice the value we got using adaptive expectations." Thus, a rational expectations hypothesis is a useful framework to analyze secondary material markets and price based policies designed to stimulate recycling may not be as ineffective as some of the earlier studies have implied.

Summary

The findings that emerge from these studies of the national and regional markets for wastepaper are quite simple. First, the concept of wastepaper and paperboard recycling is not a new phenomenon; it is as old as paper and paperboard industry. The paper and wastepaper industry is divided into two broad groups: those firms primarily using virgin woodpulp as inputs and those firms using wastepaper as an input. The firms using virgin inputs are characterized by a few large firms (i.e. Oligopolistic) that are vertically integrated all the way from the timber resources in the Northwest and the South to the production of the final paper and board products. Those firms which use wastepaper as inputs tend to be fairly small, competitive, labor intensive, often with substandard technology, and located near major urban areas.

Both types of firms have high capital commitments in favor of one type of paper making technology or the other and, thus, the price substitution between woodpulp and
wastepaper in the production process is very small (i.e. 0.27). From 1945 onwards, the utilization of wastepaper had steadily fallen until the early 1990s, and the paper and paperboard industry using virgin inputs has steadily increased its share of the market. Consequently, the wastepaper recycling rate fell after the second World War.

The trend in this market is that of pure volatility. The demand for wastepaper is considered an input demand function that depends on the price of the virgin woodpulp, which presumably sets the upper limit for the price of recyclable paper. The assumption here is that the mills hire both variable inputs (virgin woodpulp and recyclable paper) until each input price equals its marginal product. Hence, the demand for recyclable paper is expected to behave normally as a negative function of price with its elasticity some composite of: [a] the substitutability of the recyclable for the virgin pulp; [b] its substitutability for the competitive material in the same applications; and [c] the elasticity of demand for the final product. The supply of recyclable paper depends on the cost of collection and reprocessing to the extent required for re-use in production.

Another point that needs to be noted in the market is the role of public policy. Subsidies for the extraction of virgin materials, tax depletion allowances, or direct grants tend to depress demand for recyclable materials. On the other hand, pollution control costs imposed upon producers are passed on to consumers and federal regulation protecting owl habitats will tend to stimulate the demand for recyclable papers. Also, governments may also stimulate demand directly by specifying recycled content requirements in its products acquired in its own procurement activities. Due to the low unit of recyclable materials, the relative costs of transportation are very high, so the rate
structures in transport industries may affect demand for recyclable materials. Finally, technical advances developed by or with government assistance may affect both the supply and demand sides of the market. The next chapter will discuss the theoretical framework and the method of analysis for this study.
CHAPTER III
THEORETICAL AND EMPIRICAL MODEL

The theoretical and empirical model presented in this section is a combination of Grace et al (1977), Plaut (1978), and Edgren & Moreland (1988). It should be noted that there is little in the form of original analysis in this model. These models were adopted based on the assumption that the paper and paperboard industry are the principal users of wastepaper. Wastepaper and woodpulp serve as two primary inputs used to produce paper; therefore, they are perfect substitutes.

It is assumed that demand for wastepaper is strongly linked to price of woodpulp, even though that the cross price elasticity between the price of woodpulp and wastepaper is low (Grace et al, 1977). This implies that the higher the relative price of wastepaper, the greater is the tendency for substitution. Thus, price elasticity increases as elasticity of substitution increases.

Note that the following exogenous factors do affect market of wastepaper, thus they are held constant until specified otherwise. First, is the impact of public policy upon the following:

(1) subsidies for the extraction of virgin woodpulp, tax depletion allowances, or direct grants;
(2) pollution control costs imposed upon producers of consumer products;
(3) the government procurement policies;
(4) unit value transportation subsidies;
(5) technical research may also affect this market.

The second point concerns the vertical integration that apparently characterizes the paper industry. These two influences are held constant in the following theoretical argument.

Theoretical Model

The demand for wastepaper paper is derived from the demand for industry's production output, while the supply of wastepaper is derived from the stock of past wastepaper and flows of current wastes stream. The market equilibrium price is invoked, given the demand for and supply functions of wastepaper.

Demand for Wastepaper

The above and following assumptions will be used in deriving the input demand function from the output supply function. The output of the industry is taken to be bulk or wholesale quantities of paper, paperboard, construction paper and paperboard produced, plus wood pulp exported. The producers's input demands are derived from underlying demand for the commodity which the firm produces. The hired inputs were labor (L); capital (K); raw materials; wastepaper (Ws); and wood pulp (Wv).

It is assumed in this study that labor and capital supplies were perfectly elastic at the exogenously given input prices. If estimated, the result is expected to yield price
elasticity of labor, price elasticity of capital, and the cross elasticity of labor and capital. The raw material inputs are comprised of wastepaper and woodpulp; the estimated result is expected to yield own price elasticity of wastepaper, the cross elasticities of wastepaper with respect to woodpulp.

The production function for paper and paperboard, \( Q_x \), can be expressed as:

\[
Q_x = Q(L, K, W_s, W_v) \quad (1.1)
\]

The paper and paperboard firm will maximize profits by maximizing output subject to the following cost constraint:

\[
C_x = wL + rK + P_w W_s + P_v W_v + \Gamma \quad (1.2)
\]

where \((w)\) is the wage rate of labor, \((r)\) is the rental rate of capital, \((P_w)\) is the price of wastepaper, \((P_v)\) is the price of virgin woodpulp, and \((\Gamma)\) is the cost of any fixed inputs. It is assumed that all members of the paper industry are profit maximizing entrepreneurs. Their objective is to maximize profits, defined as the difference between total revenue and total cost. The total revenue of a paper producing firms which operates in a perfectly competitive market is given by the number of units sold multiplied by the unit price \((P_x)\).
Hence profit \( (\pi) \) is defined as:

\[
\pi = P_xQ_x - C_x \tag{1.3}
\]

Thus, the profit function can objectively be expressed as follows after substituting (1.1) and (1.2) into (1.3):

\[
\pi = P_x f(L, K, W_s, W_v) - wL - rK - P_{ws}W_s - P_{vW}W_v - \Gamma \tag{1.4}
\]

Profit is a function of \( L, K, W_s, \) and \( W_v \) and is maximized with respect to these input variables. Taking partial derivatives with respect to \( W_s \) and \( W_v \) and setting them equal to zero,

\[
\frac{\partial \pi}{\partial W_s} = P_x f_1 - P_{ws} = 0 \quad \text{and} \quad \frac{\partial \pi}{\partial W_v} = P_x f_2 - P_{vW} = 0 \tag{1.5}
\]

Moving the input-prices to the right hand side of equation (1.5),

\[
P_x f_1 = P_{ws} \quad \text{and} \quad P_x f_2 = P_{vW} \tag{1.6}
\]

The partial derivatives of the production function with respect to the wastepaper and woodpulp are the marginal products (MPs) of the two inputs. The first-order conditions
for profit maximization (1.6) require that each input be utilized up to a point at which the value of its MP equals its price. That is to say,

\[ \frac{f_1}{f_2} = \frac{P_{ws}}{P_v} = \text{MRTS} \]  

(1.7)

where MRTS is the marginal rate of technical substitution. The rate of substitution (σ) is the measure of the rate of substitution between wastepaper and wood pulp.

Let \( m = \frac{W_s}{W_v} \) and \( \omega = \frac{P_{ws}}{P_v} \), so that

\[ \sigma_{wswv} = \frac{(dm/d\omega)m}{\omega} \]  

(1.8)

The paper firm can increase its profit as long as the addition to its revenue from the employment of an additional unit of Ws exceeds its costs. Wastepaper and wood pulp were assumed to be perfect substitutes, but according to past estimations, it seems that little substitution take place at the stage where intermediate outputs are combined to form final output.

Finally, substituting equation (1.1) into equation (1.5), the first order condition and solve for Ws in terms of \( Q_x \) yields the corresponding input demand functions for wastepaper (1.8). Thus the \( i \)th domestic firm's input demand function of wastepaper is obtained by solving the first order condition (1.5) for the firms input level as a function of inputs and output prices.
\[ Q_{\text{PWs}} = D_1( P_{\text{ws}}, P_v, Q_x, \text{Const}, A) \] 

(1.9)

The above individual input demand curves is assumed to be negatively sloped. It is also assumed that this input demand curve relates the demand for wastepaper as a function of its own price \((P_{\text{ws}})\), which is negatively related to the quantity of wastepaper demanded. The price of the substitute \((P_v)\) is positively related to the quantity of wastepaper demanded; and output supply \((Q_x)\) is positively related to \((Q_{\text{PWs}})\). Some of the wastepaper recovered is used in the construction industry \((\text{Const})\), so it is assumed to be an exogenous variable. Finally, technology \((A)\) is assumed to be efficient, which implies that if an input of wastepaper is increased and all other inputs (i.e., woodpulp) are held constant, output must increase. Otherwise the increased output will be wasted.

**Supply of Wastepaper**

The following assumptions were made so as to facilitate the development of wastepaper supply. First, the supply of wastepaper is derived from past wastes and flows of current wastes stream. It is assumed that the higher the national prices, the larger are the proportions of the current wastes that tend to be recovered and the higher the rate of depletion of accumulated wastepaper stocks.

According to Wiseman (1992) the cycle of paper production and recycling results in fiber breakage and shortening. Consequently, successive recycling of a given stock will yield both a continual decline in recoverable fiber and a decrease in the paper strength.
Under conventional bleaching processes, the fibers tend to become hardened, causing breakage and loss from recycling.

The supply of wastepaper depends on the cost of collection \( (C) \), and the cost of reprocessing to the extent required for reuse in production \( (Mwage) \). \( Mwage \) is the minimum wage at the period, since the job of collection and reprocessing is unskilled. Consequently, the supply of wastepaper in the long run is determined by the equality of price and long-run marginal cost \( (MC) \). Supposedly the cost of collection and processing is equal to the price of wastepaper for the collectors to engage in wastepaper recovering from the waste stream. Thus,

\[
MC = \Phi'(QWs)
\]  

(1.10)

Equation (1.9) implies that the marginal cost of wastepaper recovery is equal to the extra quantity of wastepaper recovered. Setting \( Pws = MC \) and solving for \( QWs = Q^*Ws \), yields,

\[
Q^*Ws = S(Pws)
\]  

(1.11)

Thus, the supply function of the wastepaper collectors is obtained from the individual collectors first order condition for profit maximization by letting \( Pws = MC \).

In order to increase the quantity of wastepaper supplied \( (Q^*Ws) \), collectors will have to search more diverse and composite sources for wastepaper, which increases costs;
therefore, the supply function will be upward sloping. The stock of wastepaper available for recovery can be derived from the changes in the stock of wastepaper \((Q_r)\).

The stock of wastepaper available for recovery will be given by the relationship

\[
Q_{r_t} = Q_{x_{t-1}} - Q_{nr_{t-1}} \tag{1.12}
\]

where \((Q_{r_t})\) represents the stock of wastepaper available for recovery in period \((t)\), \((Q_{x_{t-1}})\) is consumption of paper in period \((t-1)\), and \((Q_{nr_{t-1}})\) denotes losses during consumption (cigarette paper, toilet tissue, and the likes). According to Grace, et al, this single - period lag is quite represented in the wastepaper market due to the short product life. Equation (1.12) implies that at any particular time the quantity of recoverable wastepaper stock \((Q_{r_t})\) is equivalent to the consumption of wastepaper output manufactured a period earlier minus the losses during consumption (i.e., tissue paper, cigarette etc).

Certainly, wastepaper merchants will wish to 'speculate' on price changes, but wastepaper has a high volume to weight ratio and storage costs are substantial. Hence, few paper brokers would speculate on such long forward prices (Edwards, 1977). Therefore, the current price \((P_{ws})\) is the justifiable market price at the period.

The collectors (i.e. municipalities) being risk averse will always take the stand “wait and see” before committing themselves to collection and separation of wastepaper from the waste stream. It is expected that suppliers will not react fully to every price change. Therefore, it is necessary to look at the impact of lagged price a period behind
Finally, the level of technology (A), plays a great role in collection and sorting of wastepaper for supply at a period time. Therefore, the level of technology is assumed to influence the availability of wastepaper.

The $i$th wastepaper collectors final supply function is obtained by combining equations (1.11) and (1.12) which yields,

$$Q^{ws_i} = S_i (P_{ws}, QR, Mwage, P_e, P_{ws}, A) \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ld.o
Equilibrium Condition

It is normal to assume that the world market of wastepaper is in equilibrium when the price of wastepaper is at a level such that domestic supply \((Q^D)\) equals the domestic demand by the paper industry \((Q^P)\), plus net exports of wastepaper. Also assume that potential profits of new entrants must equal zero at the long-run equilibrium. As in any other product market, no economic agent can improve his position by recontracting after equilibrium has been reached. That is,

\[
Q^P = Q^D \quad (1.14)
\]

An \(i\)th paper producing firms optimum raw material input combination satisfies the condition that the price of wastepaper equals the value of its marginal product (MP).

Empirical Model

The empirical demand and supply model of the wastepaper market with constant elasticity can be specified in the double-log form as follows:

\[
\ln Q^D = \alpha_0 + \alpha_1 \ln (Pws) + \alpha_2 \ln (Pv) + \alpha_3 \ln (Qx) + \alpha_4 \ln (\text{Const}) + \epsilon_{it} \quad (1.15)
\]

\[
\ln Q^D = \beta_0 + \beta_1 \ln (Pws) + \beta_2 \ln (Rec) + \beta_3 \ln (Mwage) + \beta_4 \ln (PE) + \\
+ \beta_5 \ln (Pws_i) + \epsilon_{it} \quad (1.16)
\]

\(\alpha_i \leq 0, \alpha_2 > 0, \alpha_3 \geq 0, \alpha_4 \geq 0, \beta_1 > 0, \beta_2 \leq 0, \beta_3 > 0, \beta_4 \leq 0, \text{and } \beta_5 \geq 0\)
where $\alpha$s, $\beta$s are parameters, $\epsilon$s are random disturbances, and $t$ represents a specific period of time, which will serve as a proxy for technology (A). The variables are defined as follows:

$$Q^{\alpha}W_s = \text{Quantity of wastepaper consumed by paper and board firms (thousands of tons)}$$

$$QSW_s = \text{Quantity of wastepaper supplied at any time period (thousands of tons)}$$

$$P_{ws} = \text{National wholesale price of wastepaper (1982 = 100)}$$

$$P_{v_t} = \text{National wholesale price of woodpulp (1982 = 100)}$$

$$Q_{x_t} = \text{Annual production of paper and board (thousands of tons)}$$

$$\text{Const}_t = \text{National production of the construction paperboard (thousands of tons)}$$

$$\text{Rec}_t = \frac{QR}{Q_{x_t}} = \text{Relative recovery rate of wastepaper stock recovered that is available for recycling}$$

$$P_{\epsilon_t} = \text{National price index of energy, (a proxy for energy recovery (BTU) through burning of wastepaper)}$$

$$\text{Mwage}_t = \text{the minimum wage as a cost of collecting and processing recyclables}$$

$$P_{ws_{t-1}} = \text{the national price index of wastepaper lagged a year behind (1982 = 100)}$$

$\epsilon_{1t}$ is the classical error term associated with demand function estimation

$\epsilon_{2t}$ is the error term associated with supply function estimation.

The sources and listing of data will be discussed in the next section. It is necessary to postulate in the above models that domestic demand for wastepaper (i.e., the consumption of wastepaper by recycling mills) is linearly related to four sets of variables. First is the own price of the wastepaper. According to standard economic theory, it is
expected that the coefficient associated with this variable will be negative. The higher the price of wastepaper, the lower its corresponding level of demand.

Second is the national price of market woodpulp. If there is any substitution at all between virgin woodpulp and wastepaper, it is expected that as the price of market woodpulp increases, the demand for all grades of wastepaper would increase (the coefficient associated with this variable is expected to be positive).

The third variable is the quantity of output supplied which determines the amount of wastepaper that will be recycled. It is expected that the coefficient associated with this output level will be positive — since the higher the level of production of final output, the higher the demand for wastepaper as an input.

Finally, it is expected that the coefficient associated with the national production of construction paper will be positive, since the higher the level of production of these products, the higher the demand for wastepaper as an input.

The supply equation (1.13) of wastepaper (measured by the receipts of wastepaper by recycling mills) assumed that the supply of wastepaper is positively related to own price, the recovery rate of recyclable wastepaper, and the price of energy, but negatively related to minimum wage and lagged own price. Therefore the coefficient of the own price, and the price of energy in the structural equation (1.16), is expected to be positive.

While the coefficients of relative recovery rate of wastepaper and lagged own price of wastepaper are expected to be negative, an increase in the quantity of the wastepaper recovery rate will increase the quantity of wastepaper supplied, even though some
proportion is consumed by other activities, such as incineration. Since wastepaper inventories are not held for long periods, few merchants will speculate on such long forward prices. Hence, the coefficient associated with the lagged wastepaper price is postulated to be negative.

**Method of Estimation**

Using the Ordinary Least Square (OLS) method to estimate the structural equations may result in biased and inconsistent parameter estimates. Such simultaneity-bias can be avoided by estimating a single equation model. The best-known single equation estimating method is the two-stage least squares (2SLS). It requires running an OLS method on the reduced-form equations (1.17 and 1.18) for the fitted values of QWs, and Pws, using the fitted values of QWs and PWS from reduced-form regression as instrumental variables to run an OLS on the structural models.

In order to obtain the reduced-form equation, the structural equations (1.15) and (1.16) are solved for Qws, and Pws, as a function of the other predetermined variables. The variables QWs, and Pws, are endogenous; while Pws, and Qr, are predetermined. And Pv, Qx, Const, Pr, Mwage, and Ex are exogenous to the system.

Hypothetically, the structural equation (1.15) and (1.16) can be written as a single equation since both equations are over-identified with two endogenous variables, two predetermined, and five exogenous variables. To avoid confusion, let the predetermined variables be defined to include all the five exogenous variables and the lagged endogenous variables. The demand and supply equation are over identified since the number of
excluded exogenous variables from both equations exceeds the number of endogenous variables in the equation minus one.

This single equation determines equilibrium price - quantity. The equilibrium quantity \( Q_{Ws,t} \) is determined by substituting the equilibrium price \( P_{Ws,t} \) in either the demand or the supply function. Thus, price and quantity are simultaneously determined, but price, one of the endogenous variables, is not on the left side of either structural equation. Since the equilibrium condition forces \( Q_{P} = Q_{S} \), we need only two reduced-form equations:

\[
Q_{Ws,t} = b_0 + a_1(P_{Vt}) + a_2(Cons_t) + a_3(P_{ws,t-1}) + a_4(Mwage_t) + a_5(P_{E_t})
+ a_6(Q_{Rt}) + a_7(Qx_t) + \mu_{it} \tag{1.17}
\]

\[
P_{Ws,t} = A_0 + B_1(Q_{Rt}) + B_2(Mwage_t) + B_3(P_{ws,t-1}) + B_4(P_{E_t}) + B_5(Qx_t) +
+ B_7(Cons_t) + \mu_{st} \tag{1.18}
\]

**Data Types and Sources**

The data series used to fit the models was obtained from the library of the Institute of Paper Science and Technology in Atlanta, Georgia. Most of the actual secondary data were obtained from the American Forest and Paper Association, (annual statistical of paper, paperboard and woodpulp), the Department of Commerce, Bureau of the Census, and the *Statistical Abstract of United States*.

Most of the data had been stratified already by Pulp & Paper in their 1995 North American Fact book, such as the wastepaper price and woodpulp price. Therefore, it was
not necessary to convert the 1967 base price to the 1992 base year.

Edgren and Moreland's (1988), recycling rate computations were used to derive the recycling rate for the model. The consumer price index for energy was obtained from the Statistical Abstract of United States (1982-84 = 100).

The eating and drinking nonsupervisory-worker's average hourly earnings were used as a proxy for minimum wage rate, since this industry's wage rate most reflects the trends in the minimum wage market.
CHAPTER IV

EMPIRICAL RESULTS

The price of wastepaper was assumed to be predetermined by the quantity of wastepaper consumed domestically at the paper mills, hence equations (1.15) and (1.16) were estimated using the Two Stage Least Square (2SLS) method. The variables assumed to be exogenous or predetermined in equation (1.15) are as follows: the price of wood pulp, output supply and production of the construction paperboard. The variables exogenous or predetermined to equation (1.16) are as follows: the recovery rate of wastepaper, the minimum wage rate; the price of energy; and the price of wastepaper lagged one period. The following two-stage least squares (2SLS) regression results were obtained (absolute value of t-statistics are in parentheses) and are as follows:

\[
Q^P_{Ws} = -4.721 - 0.236\ln P_{ws} + 0.0417\ln P_{vw} + 2.274\ln Q_x + 0.251\ln \text{Const} \\
(7.33) \quad (4.77) \quad (1.45) \quad (13.77) \quad (3.73)
\]

\[
n = 24 \quad R^2 = 0.96 \quad \hat{R}^2 = 0.95 \quad D.W. = 1.91
\]

\[
Q^P_{Ws} = 3.468 + 0.052\ln P_{ws} + 0.258\ln \text{Rec} - 2.493\ln M_{wage} + 0.018\ln P_e - 0.085\ln P_{w_{t-1}} \\
(53.14) \quad (2.07) \quad (3.95) \quad (0.13) \quad (0.13) \quad (3.94)
\]

\[
n = 24 \quad R^2 = 0.98 \quad \hat{R}^2 = 0.98 \quad D.W. = 1.61
\]
The empirical results provide substantial support for the a priori expectations of the wastepaper consumption. The coefficients of all the explanatory variables signs are as postulated in equations (1.15) and (1.16), and the Durbin-Watson statistics are acceptable.

The coefficient of own price of wastepaper is negative and significantly different from zero at a 0.05 level of significance. That is to say that a 0.5 percent one-sided test with 19 degrees of freedom, \( t_c = 2.861 \) is less than \( t_k = 4.773 \). Therefore, the coefficient of wastepaper price is statistically significant in the hypothesized direction at the 99.95 percent level of confidence. The significant inverse relationship between the price of wastepaper and the quantity consumed confirms that the fundamental law of demand is applicable to wastepaper market.

Since the demand equation is in double-log form, the price elasticity of demand is not different from the estimated price coefficient (0.24). A one percent increase in the wastepaper price would lead to a mere 0.24 percent increase in consumption of wastepaper domestically. Thus, wastepaper consumption is inelastic with respect to price. This confirms previous findings in the reviewed literatures. The implications of this non-responsiveness of demand for wastepaper are spelled out in the concluding section.

The demand for wastepaper is positively related to the price woodpulp (Pv) as postulated and significantly different from zero at a 10 percent level of significance. The estimated coefficient of the woodpulp price is positive (0.04) as postulated, but the quantity of wastepaper consumed is inelastic. This implies that there seems to be no
substitution between wastepaper and woodpulp as inputs; since the cross-elasticity (0.04) is less than one.

The final output supply coefficient turned out to be positive (13.77) as postulated, and significantly different from zero at the 0.5 percent level of significance. This implies that a one percent increase in consumption of final output supply will increase quantity of wastepaper consumed by 13.7 percent, which is highly elastic.

The production of the construction paper coefficient is positive (3.73) at 0.5 percent level of significance. This implies that a one percent increase in the production of construction paper will increase the consumption of wastepaper by 3.73 percent.

The overall "goodness of fit" of the estimated demand model coefficient is high, \( R^2 = 0.96 \) and the adjusted R - Squared (\( \hat{R}^2 = 0.95 \)). This implies that 95 percent of the variation in wastepaper consumption is explained or associated with the variation in the independent variables (own price of wastepaper, price of woodpulp, level of final output supply, and level of construction paper production domestically). The Durbin-Watson d- statistic first-order serial correlations test at 5 percent one sided level of significance indicates no serial correlation.

The regression result from the supply equation of wastepaper estimates indicate that supply is directly related to the own price of wastepaper as hypothesized. This direct relationship implies that as prices of wastepaper increase more of it will be supplied, but at what rate. Since the regression equation is in double-log form, the elasticity is 0.05, which is equal to the variable coefficient. This implies that a one percent increase in the price of wastepaper increases the quantity of wastepaper supplied by 0.05 percent. This
variation is quite minimal to the wastepaper market movement, just as the literatures suggest. But it is statistically significant from zero at a 5 percent one tail test.

The coefficient of one time period lagged wastepaper price came out negative and is statistically significant from zero at a 0.5 percent level of significance. This implies that wastepaper supply is inversely related to one period lagged own price of wastepaper, which is consistent with the hypothesis. Recall that the coefficients are equal to the elasticities; therefore, the elasticity of the lagged price is 0.08. Thus, a one percent increase in the price of wastepaper a period earlier decreases the quantity supplied by 0.08 percent, holding the current period price and other variables constant. Since this coefficient is less than one, the supply is inelastic to past price change.

Supply of wastepaper reacted positively to the relative recovery rate, and is significantly different from zero at the 0.01 percent level of significance. The significant direct relationship between the supply and relative recovery rate of wastepaper confirms that the fundamental law of supply is applicable to wastepaper. As the recovery rate of wastepaper increases, more of it will be supplied to the mills; but the rate is quite inelastic at 0.26.

A surprising result is the minimum wage rate responsiveness to wastepaper supply, with a coefficient of 2.49. This implies that a one percent decrease in the minimum wage rate will increase the supply of wastepaper by 2.49 percent. This is consistent with the original hypothesis, but it is not statistically significant.
The estimated coefficient of the price of energy indicates that the wastepaper supply is directly related to the energy price, which is not consistent with the hypothesis. The coefficient is 0.01, and it is not statistical significant. This result implies that the energy price is totally inelastic to the wastepaper supply. The sign associated with the energy price is consistent with Edgren and Morelands' but its significance is contrary to this paper's finding.

The overall "goodness of fit" of the estimated supply model coefficients is high, \( R^2 = 0.98 \) and the adjusted \( R^2 \) - Squared (\( \bar{R}^2 = 0.98 \)). This implies that 95 percent of the variation in wastepaper consumption is explained or associated with the variation in the independent variables (own price of wastepaper, one period lagged wastepaper price, price of energy, minimum wage rate, and relative recovery rate). The Durbin-Watson d- statistic test for the first order serial correlation in the residuals indicates some minor serial correlation in the supply model residuals.
CHAPTER V

CONCLUSION AND RECOMMENDATION

The main hypothesis of this study is that price has no effect on the quantity of wastepaper recycled in the United States. This paper argued that the recycling policy as it is today is centered around manipulation of the wastepaper price as an instrumental variable. The results of this study and the following conclusions are consistent with those of the previous studies cited, except the magnitude of some variables on the demand for recyclables.

Conclusion

The major findings that emerge from this economic analysis are simple. They are as follows:

(1) The demand for wastepaper is inelastic, therefore price has no impact on the quantity of wastepaper recycled. This explains why wastepaper prices are so volatile in comparison to equilibrium price and is in accordance with the findings of Plaut & Steiker (1978), Anderson & Spielgelman (1977) and Edgren & Moreland (1988).

(2) The supply of wastepaper is completely inelastic, and this agrees with our hypothesis that price has no effect on the quantity of wastepaper recycled.
This confirms the findings of Edward & Pearce (1978), Little (1978), Deadman & Turner (1980), and Pluat (1978).

(3) Supply responds negatively to past prices as suggested by Anderson & Spiegelman (1977) which also apparently serves to deplete the reservoir of wastepaper. That is one of the reasons the long-run price elasticity of supply is about (0.08).

(4) It appears that demand responds positively to price of woodpulp as suggested by Edgren and Moreland (1988), but cross-elasticity is almost nil. Thus, the elasticity substitution is very low. Past studies that looked at input substitution found little evidence of economies of scale. It is expected that as the price of woodpulp increases, there will be an increase in the consumption of wastepaper relative to virgin woodpulp. It seems that the probability of this substitution is very low.

(5) It is not a surprise to find that demand reacts positively to output supply of finished paper products, and the percentage of responsiveness is quite high in comparison to the other variables. The size of the elasticity deduced in this study is greater than the elasticity found by Edgren and Moreland (1988). This may be attributed to a time period when the content requirement increment was imposed across the paper industry.

(6) The result of this study also suggests that demand reacts positively to the production of other products. But the responsiveness of these variables is not as strong as the demand responsiveness to the final output production.
The implication of this study shows how a limited price adjustment can be used as a policy instrument. Since the price elasticities of both demand and supply are low in this study, we do not recommend a price-based policy mechanism to increase recycling.

This paper recommends that another instrumental variable, such as recycled paper product content requirement, needs to be utilized to increase recycling. This paper also recommends a policy that affects innovation in packaging of paper products in the consumer market in order to increase recycling.

Recommendations for Future Research

Based on the limitations and scope of this research, the following suggestions are offered for future research:

(1) Further studies on the effect of content requirement policies on the quantity of wastepaper recycled in United States.

(2) Future studies are recommended on the impact of procurement policies on the demand and supply of finished paper products.

(3) Future studies are recommended on the cost/benefit analysis of the content requirement.
## APPENDIX A

### Data Used In The Regression Analysis

<table>
<thead>
<tr>
<th>Year</th>
<th>LnQws</th>
<th>LnPws</th>
<th>LnPv</th>
<th>LnQx</th>
<th>LnConst</th>
<th>LnRec</th>
<th>LnPwt-1</th>
<th>LnPE</th>
<th>LnWage</th>
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<tbody>
<tr>
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<td>2.189</td>
<td>3.368</td>
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<td>3.149</td>
<td>2.286</td>
<td>2.149</td>
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<td>2.231</td>
<td>2.156</td>
<td>3.327</td>
<td>2.708</td>
<td>3.127</td>
<td>2.269</td>
<td>2.141</td>
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<td>3.119</td>
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<td>3.072</td>
<td>2.019</td>
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</table>
APPENDIX B

Regression Result: Demand

FILE: LT55, NO. OF VARIABLES: 11, NO. OF CASES: 24 (MISS. CASES: 0)
LABEL: THESIS

TWO STAGE LEAST SQUARES

Dep. Var.: LnQWs
End. Ind. Var's: LnPws
Pred. Ind. Var's: LnPv LnQx LnConst CNST
Excl. Pred. Var's: LnEx LnRec LnPwt-1 LnPE LnWage Ln(Rec/Qx)

MODEL: LnQWs = -0.23617LnPws + 0.0416786LnPv + 2.27422LnQx
       + 0.251218LnConst + -4.72054CNST

<table>
<thead>
<tr>
<th>COEF.</th>
<th>SD. ER.</th>
<th>t(19)</th>
<th>PROB.</th>
<th>PT.</th>
<th>R SQ.</th>
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<td>LnQx</td>
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R SQ. = 0.961552, ADJ. R SQ. = 0.953457, D. W. = 1.91089
SD. ER. EST. = 8.74249E-3, F(4/19) = 124.876 (PROB. = 2.31507E-13)
APPENDIX C

Regression Result: Supply

<table>
<thead>
<tr>
<th>FILE: LT55, NO. OF VARIABLES: 11, NO. OF CASES: 24 (MISS. CASES: 0)</th>
</tr>
</thead>
</table>

**TWO STAGE LEAST SQUARES**

Dep. Var.: LnQWs  
End. Ind. Var's: LnPws  
Pred. Ind. Var's: LnPwt-1 LnPE LnWage Ln(Rec/Qx) CNST  
Excl. Pred. Var's: LnPv LnQx LnConst LnEx LnRec

MODEL:  
\[ \text{LnQWs} = 0.0516817\text{LnPws} - 0.0848235\text{LnPwt-1} + 0.0185245\text{LnPE} 
\quad + -2.4934E-3\text{LnWage} + 0.258362\text{Ln(Rec/Qx)} + 3.46799\text{CNST} \]

<table>
<thead>
<tr>
<th>COEF.</th>
<th>SD. ER.</th>
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<th>PROB.</th>
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<td>LnPE</td>
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<tr>
<td>Ln(Rec/Qx)</td>
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<td>CNST</td>
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R SQ. = 0.984385, ADJ. R SQ. = 0.980047, D. W. = 1.60548  
REFERENCES


