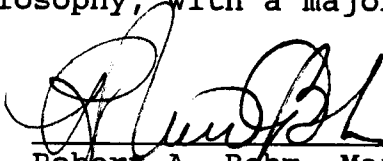
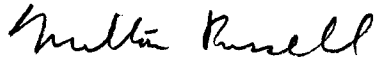


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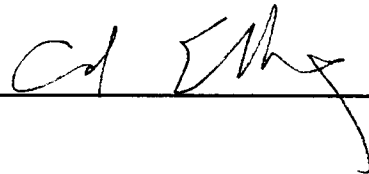
I am submitting herewith a dissertation written by Deborah Vaughn Nestor entitled "Increasing the Rate of Recycling When Demand is Price-Inelastic: A Case Study of the Market for Old Newspapers." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Economics.


Robert A. Bohm, Major Professor

We have read this thesis
and recommend its acceptance:







Accepted for the Council:



Vice Provost
and Dean of The Graduate School

INCREASING THE RATE OF RECYCLING WHEN DEMAND IS
PRICE-INELASTIC: A CASE STUDY OF THE
MARKET FOR OLD NEWSPAPERS

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Deborah Vaughn Nestor

August 1991

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ABSTRACT

The demand for old newspapers (ONP) as an input in newsprint production is an example of a market where policies that aimed to encourage recycling by shifting the supply of ONP (and thus, lowering price) have not resulted in a large and immediate increase in recycling. One reason these policies have not effectively stimulated recycling in the newsprint industry is that the ONP input demand schedule is highly price-inelastic. This hypothesis is tested by developing and estimating a model of the demand for ONP as an input in newsprint production.

Econometric analysis of the derived demand for ONP reveals that the demand for ONP by newsprint producers is price-inelastic in both the short- and long-run. Thus, under current conditions, the application of supply-side policies alone, which attempt to increase recycling by lowering the relative price of ONP, will not significantly boost the rate of recycling in the U.S. newsprint industry even in the long-run.

Further, because the ONP demand schedule has been estimated as a system of five input demand equations, the relative efficacy of other policies that have been suggested for increasing the rate of ONP recycling can be assessed. Tax policy has been criticized for discouraging recycling for a number of secondary materials. In the case of ONP, it is found that fiscal biases in favor of virgin materials

probably have not been a major hindrance to recycling in the newsprint industry. A slightly more effective policy may be tax preferences that alter the price of capital and create an incentive to expand newsprint capacity.

The major finding of the study is that ONP recycling in the newsprint industry is more dependent upon the parameters of the final output market than it is on relative input prices. Growth in ONP consumption has historically arisen as a consequence of output expansion in the U.S. newsprint industry. In sum, expansion in output requires investment in new newsprint capacity and this investment has been biased toward ONP-based mills.

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CHAPTER I

INTRODUCTION

1. THE PROBLEM

Many states and localities have recently adopted aggressive policies to promote recycling of solid waste. These policies generally encourage recycling by removing materials from the solid waste stream; that is, by shifting the supply schedule in secondary markets. At the same time, states and localities have neglected to implement policies to stimulate demand. This unbalanced approach to recycling is often thought to result in a surplus of secondary materials or a glut in secondary markets. From the perspective of economic theory, of course, concerns of a glut are unfounded since demand-side measures are not necessary for markets to clear, in the absence of a constraint to prevent price from adjusting.

However, concern regarding the unbalanced approach to recycling may be warranted in the sense that the market-clearing solution may not imply a large increase in the rate of waste recycling. Any increase in recycling ultimately will be a function of the price-elasticity of demand for secondary materials. If demand is highly inelastic, then the shifts in supply caused by policies to remove materials from the solid waste stream will not result in a substantially higher market-clearing level of recycling.

The demand for old newspapers (ONP) as an input in newsprint production is an example of a market where policies to shift the supply schedule of ONP have not been very effective at increasing recycling. Descriptively, supply-side programs have resulted only in lower ONP prices, not greater use of ONP in the newsprint industry. The hypothesis is that the primary reason supply-side policies have not been very effective lies in the relative inelasticity of the ONP input demand schedule. This hypothesis can be tested by first examining the structure of the newsprint industry and the production processes for virgin versus recycled newsprint. In this regard, analysis of the industry structure and production technology reveals that there are special circumstances in the industry that cause the demand for ONP to be highly price-inelastic. The hypothesis that the derived demand for ONP is price-inelastic is then tested by developing and estimating a model of the demand for ONP as an input in newsprint production.

2. PURPOSE AND CONTRIBUTION OF THE ANALYSIS

The primary purpose of this study is to evaluate current recycling policy from the perspective of the demand side of secondary materials markets. This evaluation is conducted within the context of a specific case study, namely, the market for old newspapers (ONP) as an input in

newsprint production. In this case study, the overall efficacy of several policy alternatives that have been suggested as means for increasing the use of ONP in newsprint production will be assessed.

The analysis of this market will be based on the assumption that the policy goal is to increase ONP recycling. No judgment will be made about the validity of this goal. Also, the the relative "effectiveness" of different policies will be judged on the basis of which achieves the largest increase in ONP recycling. Hence, the study will not be concerned with weighing the relative social benefits versus the social costs of alternative courses of action. Finally, the focus of the analysis will be the on the aggregate U.S. newsprint industry.

The primary contribution of the study is in the estimation of a model of the demand for ONP as an input in newsprint production. The theoretical tools to accomplish this task are well known. However, the specific application of these tools is new.

3. OUTLINE OF THE STUDY

Chapter II starts by setting the issue of recycling in the context of a perceived solid waste crisis. One purpose of Chapter II is to establish that increased recycling has become a social goal in the United States. A second purpose is to outline the policy responses to achieve this goal.

This illustrates that, although there are a number of motives behind the drive to recycle, policy has dealt with recycling as an issue of solid waste management, for the most part.

The characteristics of secondary material markets that determine the type of policy that will result in the maximum increase in recycling are also discussed. More specifically, if the demand for secondary materials is highly price-elastic, then policies aimed at shifting the supply schedule will result in a substantial increase in recycling. In contrast, in the case of a secondary market characterized by a highly inelastic demand schedule, policies designed to shift demand will lead to the largest increase.

In the development of policies to shift the demand for secondary materials, secondary markets must be viewed from the perspective of the potential consumer of the waste material, which is the firm that uses secondary materials as a substitute for virgin materials in a production process. In the case of secondary markets where demand is highly inelastic, then, pursuing the goal of increased recycling will require a departure from the perspective that recycling is an issue of solid waste management. Rather, recycling becomes an issue of resource use or substitution.

Chapter III starts with a brief review of the literature on recycling. This review of the literature

shows that researchers have found that, from both the perspective of the supplier of the secondary material and the user of the secondary material, there are constraints to recycling. These constraints prevent secondary material prices from being the most important determinant of either the supply or the demand functions for secondary materials. Further, these studies have shown that through explicit modelling of the production process, other key questions regarding the ultimate determinants of recycling can be answered.

For the purposes of this study, it has been assumed current policy will remove the supply-side constraints. Hence, the focus of this study is on determining the constraints on the demand for secondary materials.

The second task of Chapter III, then, is to develop a theoretical model of the demand for secondary materials as inputs in production. It will be shown that recycling depends on a number of forces and relative prices may not be the most important consideration. Any of these forces can constrain the firm's response to the lower recycled input prices generated by supply-side dominated policies. This model is a straightforward application of input demand theory. However, it forms the foundation upon which the empirical analysis of the demand for ONP as an input in newsprint production is built.

Chapter IV provides the institutional background for

the case study of the market for old newspapers as an input in newsprint production. Descriptively, this market is characterized by a price-inelastic demand schedule. The rationale for the inelasticity of the ONP demand schedule in both the short- and long-run is given within the context of economic theory as well as within the context of the history of the U.S. newsprint industry and the technical aspects of the processes for virgin versus recycled newsprint production.

In the short-run, the primary reason for the inelasticity of the ONP demand schedule is the unadaptability of existing capital. In the long run, the possible reasons for the inelasticity of the ONP demand schedule are 1) the existence of adjustment costs associated with switching production technology, 2) the manner in which ONP is tied to the cooperating input, capital, 3) the relatively small percentage of total production costs accounted for by the virgin input, woodpulp, 4) oligopolistic inertia created by a well-developed price leadership system, and 5) the low price elasticity of demand for the final product, newsprint.

In Chapter V, an econometric model of the derived demand for ONP is estimated. The objective of the econometric analysis is to test the hypothesis that the demand for old newspapers as an input in newsprint production is relatively price-inelastic. Further, since

the demand for ONP is estimated as a system of five input demand equations, a number of hypotheses regarding the forces that drive the rate of recycling in the U.S. newsprint industry can be tested. Finally, the empirical model is used to simulate the impacts of various policy scenarios for the years 1990-2000.

Econometric analysis of the derived demand for ONP reveals that the demand for ONP by newsprint producers is price-inelastic in the short- and long-run. Thus, supply-side policies, which lower the relative price of ONP, will not be effective at stimulating the rate of recycling in the U.S. newsprint industry even in the long run.

Further, the relative efficacy of other policies that have been suggested for increasing the rate of ONP recycling could be assessed. Tax policy has been criticized for discouraging recycling for a number of secondary materials. In the case of ONP, it was found that fiscal biases in favor of virgin materials probably should not be a major hindrance to recycling in the newsprint industry. A potentially more effective policy might be tax preferences that alter the price of capital and create an incentive to expand recycled newsprint capacity.

The major finding of the study is that ONP recycling in the newsprint industry is more dependent upon the parameters of the final output market than it is on relative input prices. Growth in ONP consumption has historically arisen

as a consequence of output expansion in the U.S. newsprint industry. In sum, expansion in output requires investment in new newsprint capacity and this investment has been biased toward ONP-based mills.

Chapter VI summarizes the results of this study. These results will be generalized, where possible. Also, while the study provides some important insights into the factors that must be considered in the formation of recycling policy, a number of questions remain unanswered. Thus, the limitations of the study and reservations of the analysis warrant explicit discussion. Finally, possible extensions to address the study's limitations are outlined.

CHAPTER II

BACKGROUND

1. THE SOLID WASTE CRISIS

The so-called "solid waste crisis" has become a pressing social and political issue in the U.S.¹ According to Environmental Protection Agency (EPA) estimates, the U.S. discarded 160 million tons of waste materials in 1986. EPA projects that the municipal solid waste (MSW) stream will not only increase to 200 million tons by the year 2000 but will become more toxic as well (EPA, 1988).

While at least 80 percent of all MSW historically has been landfilled, only five states estimate sufficient landfill capacity for the next 20 years. More than half of the landfills in the U.S. will reach capacity within eight years, according to the EPA. In New York, 230 landfills have closed and only one new site has opened. All of Connecticut's landfills are projected to fill within two years. In Illinois, landfill capacity is expected to be exhausted by 1993 (Darcey, 1987). Table II-1 summarizes the

¹It can be argued that the issues surrounding solid waste management (discussed below) do not constitute a crisis. However, the existence or nonexistence of a solid waste crisis is not pertinent to this study. The perception that there is a crisis, whether real or not, is what is relevant to this study since, as discussed below, this has been an important force in shaping recycling policy.

Table II-1
U.S. Landfill Capacity (1986)
(in Years)

Capacity (Years)	Number of Landfills	Percent
0	535	9
1-5	2,167	36
6-10	612	10
11-15	1,126	19
16-20	360	6
more than 20	1,235	20
Total	6,034	100

Source: National Solid Wastes Management
Association, 1988

status of landfill capacity in the U.S. as of the end of 1986.

Escalating landfill costs are a partial indication that MSW capacity may be dwindling. According to Waste Age's annual tipping fee survey, from 1986 to 1987, the average landfill tipping fee rose 51.6 percent. From 1987 to 1988, the average tipping fee rose 32.3 percent. As a comparison, the average tipping fee remained constant from 1982 to 1983 and actually declined 1.9 percent from 1983 to 1984 (NSWMA, 1990).

One response to this perceived landfill capacity crisis has been a renewed interest in incineration. Incinerators reduce waste volume by 70-90 percent and may generate

electricity or steam as a by-product.

However, efforts to expand MSW capacity by building new landfills and incinerators have been unsuccessful, for the most part. Environmental concerns regarding MSW management have prompted a NIMBY ("Not In My Backyard") syndrome, which has caused siting to become the major obstacle to expanding MSW capacity. Fears of environmental degradation have emerged because landfills have contributed to ground and surface water contamination and have emitted methane gas in the past. Questions have been raised about incinerator emissions and what to do with the residual toxic ash.

A National Solid Wastes Management Association (NSWMA) survey indicates that the general public's attitude toward MSW facilities, while improving, is still largely negative. In 1990, 59 percent of the general public said that they would object to having a landfill placed in their community. This percentage is down from 65 percent in 1989 (NSWMA, 1990). Public attitudes have created pressure to consider alternatives to landfills and incinerators.

Another factor that has added to this pressure is the regulatory environment. The EPA and the states are in varying stages of revising performance and technical standards for landfills and incinerators. One effect of these new regulations will be an increase in costs of operation. For existing facilities, the outcome may be closure rather than compliance. Increased costs also will

act as disincentives to building new facilities. Thus, the regulatory environment potentially reduces available MSW capacity and adds to the pressure to seek alternatives to MSW disposal. At the same time, these new regulations lower the relative cost of other waste management alternatives.

An alternative to expanding landfill and incinerator capacity is to reduce the volume of materials entering the MSW stream. MSW can be reduced by: 1) reducing the amount of waste generated prior to consumption, commonly called source reduction and 2) removing materials from the waste stream following consumption, commonly called recycling.

Source reduction and recycling, as well as expanded landfill and incinerator capacity, are all elements of the EPA's proposed integrated MSW management strategy (EPA, 1988). The focus of the following discussion, however, will be on how the solid waste crisis has generated interest in recycling as a MSW management option.

Other key reasons for the increased interest in recycling will be outlined in Section 2. The purpose of Section 2 is to establish that increased recycling has become a social goal. The discussion will include both the rational and not-so-rational reasons often given for the growing interest in recycling as well give evidence for the case that the level of recycling in the U.S. may not be socially optimal. Section 3 will describe the manner in which the increased interest in recycling has been

translated into legislation. This discussion will show that, although there are a number of motives behind the drive to recycle, policy has dealt with recycling primarily as an issue of solid waste management. Section 4 notes the characteristics of secondary material markets that determine the type of policy that will most effectively achieve the goal of increased recycling. This discussion will indicate that, for some secondary materials, pursuing the goal of increased recycling may require a departure from the perspective that recycling is an issue of solid waste management.

2. RECYCLING AS A WASTE MANAGEMENT OPTION

The solid waste crisis has been an important force in generating interest in recycling as an option for managing solid waste. Difficulty in siting new MSW facilities coupled with a decline in available MSW capacity and rising costs of solid waste disposal, the key characteristics of the solid crisis, have caused many localities to turn to recycling as an alternative to disposing of waste in landfills and incinerators. However, this is only part of the reason for the recent increased interest in recycling.

Some proponents argue the U.S. should pursue a goal of maximum recycling for ethical reasons. The argument is that affluence and the convenience of disposability have created a "throw-away" society, which some find morally distasteful.

This is another important element of the drive to recycle.

Also adding to the growing popularity of recycling is the perception among the general public that the rate of recycling in the U.S. is less than optimal. A NSWMA survey found that about 92 percent of Americans believe that a major commitment to recycling will partially alleviate the solid waste problem. In the 1990 survey, it was found that 74 percent of the general public believe that more than 25 percent of MSW can be recycled and 35 percent believe that more than 50 percent can be recycled. Only nine percent believe that one to 25 percent of MSW can be recycled (NSWMA, 1990). While the amount of waste that people believe can be recycled varies widely, one point is clear: the public believes that more recycling can be done than is currently being done. Further, there is some validity to this belief. It has been estimated that about 80-88 percent of the solid waste stream is technically recyclable (EDF, 1988).

There is a gap between the rate that is technically possible and the rate that is practically achievable. However, there is evidence that the U.S. has not approached the practical maximum. The aggregate rate of recycling for post-consumer material in the U.S. has been estimated to be about 10 percent, not including industrial scrap or materials that are recycled in manufacturing processes. For Japan, the second largest generator of MSW (the U.S. is the

first), the recycling rate has been estimated as high as 50 percent. Because these two figures were not directly comparable, the U.S. Office of Technology Assessment (OTA) re-calculated Japan's recycling rate using data published by the Clean Japan Center and found it to be much lower, 26-39 percent (OTA, 1989).² Even if the lower figure is more accurate, it indicates that the U.S. recycles considerably less than Japan. Whether valid or not, advocates of recycling often use Japan's relative success in recycling as a guide for determining the realistically achievable rate of recycling in the U.S.

The relatively lower rate of recycling for the U.S. is often attributed to two major forces. First, waste disposal services, landfills in particular, have historically been cheap. This is due, for one, to an abundance of land in the U.S. The shortage of land in countries like Japan has helped to create a natural economic incentive to seek alternatives to landfilling waste, which may partially explain the higher rate of recycling for Japan. Japan, of

²Proponents of recycling often compare the rate of recycling in the U.S. to the rates reported in other countries. Another example that has been commonly cited is that the (former) country of West Germany reached a recycling rate in excess of 40 percent. These comparisons must be done with caution since the recycling rates may be measured differently (e.g., the rates may include pre-consumer scrap). As was seen in the case of Japan, reconciling the differences in measurement results in considerably lower estimates for recycling. At the time this study was undertaken, the recycling rates reported in other countries had not been re-estimated to make them directly comparable with the figures reported in the U.S.

course, has a higher rate of incineration than the U.S. as well.

Landfills have also been under-priced in an economic sense since they have not been priced at their full social cost. The costs of landfilling wastes traditionally have not included potential environmental damage or the depletion of older landfills and higher costs of replacement associated with newer, more environmentally sound designs. Also, municipal landfill costs are subsidized in many local communities. Operation and maintenance costs for municipal landfills are shared with other local agencies. Households typically pay a flat monthly fee for refuse disposal regardless of the quantity of waste generated. Because the private costs of waste disposal have not been equated with the social costs, overuse of landfill services has been encouraged. Further, the underpricing of waste disposal services increases the opportunity cost of recycling and reduces the incentive to recycle.

Second, recycling has not only had to compete with artificially low cost landfills but under-priced natural resources as well. Oil and mining depletion allowances, accelerated depreciation of capital equipment for extractive industries, timber capital gains, and subsidized exploration were adopted as policies to encourage the development of new industries and promote U.S. economic growth. Such policies also subsidize the use of virgin raw materials (OTA, 1989).

These subsidies have kept prices for virgin materials low relative to their recycled counterparts. Lower relative prices for virgin materials are also cited as an impediment to recycling on a large scale. Table II-2 gives estimates of the magnitude of the federal subsidies that have resulted from preferential tax treatment for nonfuel minerals, timber, and energy for the years 1980-1989.

Finally, the perceived benefits of recycling have added to its popularity. To proponents, recycling is an attractive alternative to incineration and landfilling from the perspective of both the local community and the nation. From the local perspective, recycling extends the life of landfills by removing materials from the solid waste stream. Further, recycling is consistent with national conservation goals (OTA, 1989). Large volumes of raw materials are made available to industry for use as substitutes for virgin raw materials. The use of secondary materials may save energy costs and conserve resources. Increased recycling could help to alleviate U.S. dependence on foreign sources of virgin inputs. These benefits are foregone when recycling is not integrated into the solid waste management system.

Table II-2

Estimated Federal Subsidies Through Special Tax
Treatment for Virgin Materials Production
(Millions of 1987 dollars)

Year	Nonfuel Minerals	Timber	Energy
1980	548	740	5,021
1981	563	756	6,075
1982	519	820	6,095
1983	638	864	4,582
1984	698	1,046	3,750
1985	610	663	2,178
1986	618	747	2,575
1987	455	630	355
1988	352	468	343
1989	330	474	446

Source: OTA, 1989

3. LEGISLATION TO PROMOTE RECYCLING

Federal Policy

Under the Resource Conservation and Recovery Act of 1976 (RCRA), the federal government has authority to address the MSW problem. In the several years following the passage of RCRA, toxic waste sites were given priority and the support for solid waste planning was minimal. More recently, the federal government has begun to take a more active role in solid waste management.

Under subtitle D of RCRA, the EPA is in the process of developing new regulations for landfills. Pertaining directly to recycling, RCRA directs the EPA to promulgate

guidelines for federal, state, and local government purchases of items with recycled content. As of June 1990, procurement guidelines had been issued for paper, tires, oil, insulation, cement, and concrete. Further, the EPA has set a goal of 25 percent source reduction and recycling by 1992. To implement this goal, the agency will provide technical assistance to state and local governments in developing solid waste management programs and develop guidelines for reducing and recycling various components of the solid waste stream (Wiseman, 1990).

State and Local Policy: General

While the situation is gradually changing, solid waste policy historically has been largely a function of state and local governments. Further, the most aggressive recycling legislation has come from the state and local levels. The following discussion will classify state and local programs according to how they intend to increase recycling. The first type of program aims to promote recycling by increasing the supply of materials by removing materials from the solid waste stream. The second type of policy is intended to shift the demand for secondary materials.

State and Local Policy: Policies Intended to Increase the Supply of Secondary Materials

One of the most popular types of recycling legislation is mandatory source separation, which has been put into

effect at both state and local levels. With mandatory source separation, the generator of solid waste must separate designated recyclable materials from the rest of the solid waste stream. The legislation usually involves a numerical target (e.g., 25 percent) for reducing MSW by increased recycling. Table II-3 summarizes the status of these types of programs (at the state level) in the U.S. as of May 1989. Because a detailed discussion of all state plans would be lengthy, only three will be discussed for illustrative purposes.

Rhode Island was the originator of mandatory source separation legislation with the passage of its Solid Waste Management Act Amendments of 1986-1987. According to the legislation, the generator of solid waste must separate recyclable materials from the rest of the solid waste stream. The statewide goal is a 15 percent recycling rate by 1992. The amendments also provide funds to build state owned recycling facilities. The legislation encourages the involvement of the private sector, if it can collect and process materials at a lower cost than the state government can.

In 1987, New Jersey passed the Statewide Mandatory Source Separation and Recycling Act. Each county in the state designates three materials that households are required to separate from the rest of the MSW stream. All counties are required to reach a recycling rate of 25

Table II-3

Status of Source Separation Legislation
(As of May, 1989)

State	Recycling Goal	Mandatory	Deadline for Reaching Goal**
California	20%	No	N/A
Connecticut	35%	Yes	Jan. 1991
Washington, D.C.	45%	Yes	1994
Florida	30%*	Yes	1994
Georgia	25%	No	1994
Louisiana	25%	No	1991
Maine	25%*	Yes	1994
Massachusetts	35%	No	2000
Michigan	28-32%	No	2005
New Jersey	25%	Yes	1990
New York	40-42%	Yes	1997
Pennsylvania	25%	Yes	1997
Rhode Island	15%	Yes	1990
Vermont	40%	No	2000
Wisconsin	20%	No	2000
Illinois	25%	No	1995
Maryland	15-20%	Yes	1990
Virginia	25%	No	1994

*includes source reduction

**as stated in original legislation

Source: Glenn and Riggle, 1989

percent by 1990. On paper, the New Jersey program gives priority consideration to the private sector for collecting and processing the designated materials. Several communities, however, have developed plans without considering private sector recycling efforts.

Connecticut established a \$10 million fund for its recycling program, which was enacted in July 1987. The fund is to be used for planning, promoting, and constructing regional waste processing centers. Connecticut's goal is to increase its recycling rate to 35 percent by 1991. As with Rhode Island and New Jersey, the legislation provides the private sector with only a limited role.

Mandatory recycling programs have generally been successful at removing potentially recyclable materials from the solid waste stream, even in communities where compliance with the law has not been strictly enforced. Fifty-nine percent of these communities have reported household participation rates of 50 percent or more. The actual amount of waste removed from the solid waste stream varies across communities in the states where mandatory programs have been adopted, depending on the materials targeted (different materials comprise different percentages of the waste stream) and the level of participation (EDF, 1989).

Other recycling policies use economic incentives to reduce the flow of potentially recyclable materials to landfills and incinerators. One example is variable

landfill fees. In Lane County, Oregon, waste haulers that offer a recycling option receive a \$2/ton discount on their disposal fees. In Brunswick, Maine waste haulers that bring a load of recyclables to a recycling center are allowed to dump one load of waste for free (EDF, 1989). Similarly, other localities have turned to surcharges on all disposal of waste in landfills and incinerators, which raises the cost of disposal and hence, encourages the removal of recyclables from the MSW stream.

Finally, some states and localities have banned the disposal of recyclable materials. Delaware County, Pennsylvania has adopted an ordinance that prohibits the delivery of newspapers as well as other recyclables to the county's disposal facilities. The ban is enforced by spot inspections of trucks hauling MSW. If the truck load contains an "unacceptable" percentage of recyclable materials, the hauler receives a letter of warning. Subsequent violations result in penalties and ultimate suspension of dumping privileges (EDF, 1989).

State and Local Policy: Policies Intended to Increase
the Demand for Secondary Materials

Some, but not equivalent, effort to increase the demand for secondary materials has been made. These efforts have been aimed at creating incentives for expanding recycling capacity and stimulating purchases of recycled goods. Oregon allows companies to write off 35 percent of the cost

of equipment used solely for recycling over a period of five years. Since the primary recipients of this tax deduction have been garbage haulers and supermarkets, the effect on recycling has been low (OTA, 1989). Essentially, this tax deduction has benefitted the collectors of secondary materials, not the industry that uses secondary materials to produce its output. Because the tax deduction has been a measure to boost collection, it has ended up being another policy to increase the supply of secondary materials and not a policy to augment demand.

At least 23 states have enacted legislation that encourages the government purchase of recycled goods. These programs target the consumer of the final product, not the consumer of the waste material, which is the industry that uses secondary materials to produce goods with recycled content. Ultimate success will depend on how this "encouragement to purchase" is translated into increased demand for products with recycled content and, in turn, is transmitted to the producer of the final product.

4. THE IMPLEMENTATION OF RECYCLING LEGISLATION: SOME CONSIDERATIONS

The approaches to legislation to stimulate the rate of solid waste recycling are varied. However, the focus of recycling has essentially been the same. The legislation aims to encourage recycling by diverting potentially recyclable materials from the rest of the solid

waste stream. While some attempts to stimulate the demand for secondary materials has been made, these efforts have not been as widespread as supply-side legislation. Further, many of the demand-side policies that have been implemented encourage collection of separated materials and hence, ultimately end up affecting secondary materials supply schedules.

Concentration on the supply side stems from two forces. First is the common misconception that separation and collection alone constitute recycling. Separation and collection are only pre-requisites to recycling and do not guarantee that the rate of recycling for all secondary materials will increase. Closing the "cycle" requires that the separated and collected materials are substituted for virgin raw materials in a production process.

To discuss the second reason, assume that the purpose of recycling policy is to remove a constraint to recycling. If competition from landfills is perceived to be the primary constraint to recycling, then the logical focus of policy to increase recycling would be to reduce the flow of materials to landfills. Also, the fact that these programs came online at the same time as pressures from decreasing landfill capacity and rising costs of waste disposal were being felt in many communities (the communities where mandatory separation and collection has been adopted are often the same communities where the most acute rise in

disposal costs has been experienced) is a partial indication that recycling has been viewed as a choice among competing waste management alternatives and as an alternative to disposing of waste, in particular.

This approach to recycling policy has been charged with being "unbalanced" since it emphasizes policies that shift the supply schedule for secondary materials but neglects to stimulate demand simultaneously. The concern is that increasing the quantities of materials collected without increasing the demand for them will result in a surplus of materials or a general glut in secondary markets (OTA, 1989; Kovacs, 1988).

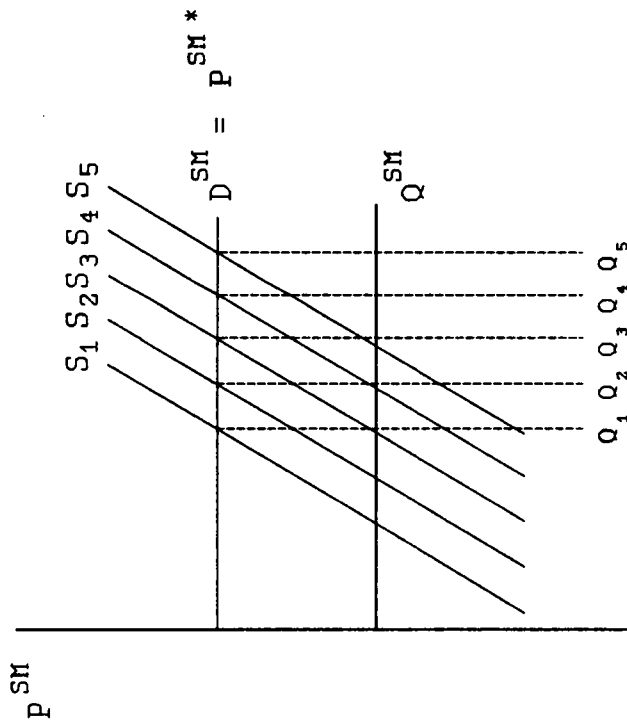
As Wiseman (1990) points out, from the standpoint of economic theory, demand-side measures are not necessary to avoid a surplus in markets for recyclables. Secondary markets will clear, even if a community has to pay to get rid of the materials collected. Equivalently, the market for a given waste material will clear even when prices become negative, unless there is a constraint on the market that does not allow price to adjust fully. Clearly, in the absence of a constraint that does not allow price to adjust, the concerns regarding a surplus in secondary markets are unfounded.

But is market-clearing sufficient for achieving the goal of increased recycling? The answer to this question depends on the shape of the demand curve for any given

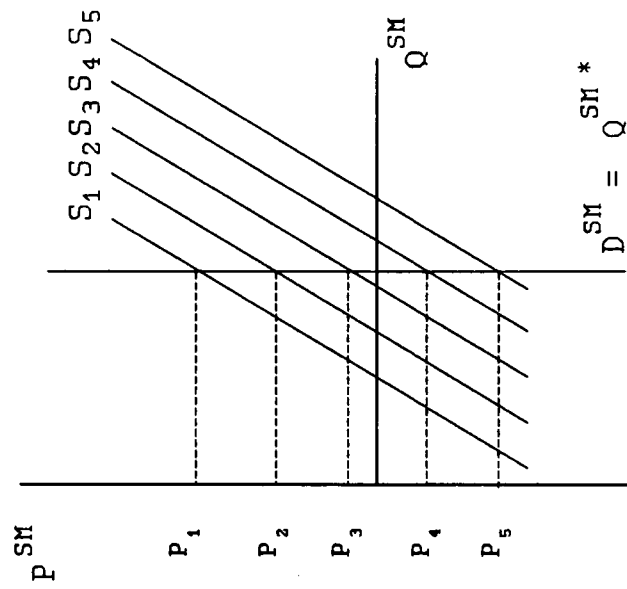
secondary material. As long as the demand for secondary materials is downward-sloping, policies that shift the supply schedule lower prices and evoke the desired response on the part the consuming industry. When the demand curve is price inelastic, however, supply side legislation results only in lower secondary material prices, at least in the short run.

Figure II-1 illustrates the two extreme cases of secondary markets. In panel (a), increases in the supply of the material (S) elicit the maximum possible response on the part of the secondary material consumer. In (a), the demand for the secondary material is perfectly elastic and shifts in supply (depicted by S_1 through S_5) automatically increase the market-clearing level of recycling (Q^{SM}) without affecting price. In panel (b), on the other hand, shifts in supply only lower prices (shown by P_1 through P_5) and the market-clearing rate of recycling remains constant at Q^{SM*} . For the secondary market characterized by (b), even though demand-side measures are not necessary to assure market-clearing, market-clearing does not imply more recycling.

In practice, of course, the demand curve will lie somewhere between the demand curves depicted by (a) and (b). Depending on which of these two demand curves most closely approximates the actual demand curve for the secondary material determines whether supply policies or demand policies will be most effective at achieving the goal of



(a)



(b)

Figure II-1
Two Types of Secondary Markets

increased recycling. If the demand schedule is most closely approximated by (b), concerns for the unbalanced approach to recycling policy are valid, but not because of a potential surplus created by supply-side policies. Rather, the concerns are valid because supply-side measures will not be very effective at increasing the rate of recycling.

5. IMPLICATIONS FOR RECYCLING POLICY

For secondary markets characterized by a relatively price-inelastic demand curve, policies that shift the supply schedule by reducing the flow of recyclables to waste disposal facilities will not be very effective at achieving the goal of increased recycling. In contrast, a more effective strategy will be to implement policies that change the location of the demand curve, or cause it to shift.

To develop such demand-oriented policies, secondary markets must be viewed from the perspective of the industry that uses secondary materials as a substitute for virgin raw materials in a production process. This implies a much different definition of recycling than the one supply-side policies appear to be based upon. From the perspective of the consumer of waste materials, recycling is not just the removal of materials from the solid waste stream. In contrast, recycling is defined to be the substitution of secondary materials for virgin materials in production since

closing the "cycle" requires that this substitution takes place.

Further, from the perspective of policy to promote waste recycling by increasing the demand for secondary materials, the primary constraint to recycling cannot be seen to be competition from landfills. In contrast, the constraints to recycling are the forces that cause the demand curve be price-inelastic and hence, are constraints at the firm-level that prevent the substitution of secondary for virgin raw materials. In this sense, recycling cannot be thought of as an issue of solid waste disposal. Rather, in the formation of policies to increase recycling in markets characterized by a highly inelastic demand for secondary materials, recycling becomes an issue of resource use or substitution.

CHAPTER III

A THEORETICAL FRAMEWORK FOR ANALYZING THE DEMAND FOR SECONDARY MATERIALS

1. INTRODUCTION

As was discussed in Chapter II, there are two types of recycling policies. The first type increases the supply of secondary materials by reducing the flow of these materials to landfills and incinerators. The second type shifts the secondary material demand schedule. The relative efficacy of each type of recycling policy at achieving the goal of increased recycling depends on the shape of the demand curve for the secondary material.

In order to determine which of the two types of policies will be most effective, the factors that determine the shape of the demand curve must be assessed. More specifically, because the ultimate consumer of secondary materials is an industry, the nature of the demand is derived, or is an input demand. One of the key determinants of the elasticity of the derived demand for secondary materials is the relative ease at which the secondary material can be substituted for virgin materials in production. Other considerations include: the elasticity of demand for the final product produced with recycled or virgin inputs, the share of virgin materials in total costs and the level of incentive to switch to the recycled input

generated by savings in production costs, and the structure of the output market. These are theoretical issues and ones that will be discussed in detail in Section 3. Before the theoretical issues are addressed, it will be helpful to review the insights regarding the determinants of recycling provided by previous studies.

2. THE ECONOMICS LITERATURE ON RECYCLING

In October of 1970, the U.S. Congress enacted the Resource Recovery Act of 1970, which provided for the construction of resource recovery systems. Expectations of the impacts on recycling were initially quite optimistic. One enthusiast wrote, "recycling will soon become an increasingly important phase of economic activity. It represents the solution to both the problems of increasing solid waste with its attendant insatiable demands on land and those associated with the growing scarcity of natural resources."¹ Several years later, expansion of recycling was still proceeding slowly and the Resource Recovery Act was falling short of these expectations. Consequently, the failure to achieve the expected rate of recycling spawned the majority of economics literature on recycling.

While most of the literature was directed at

¹Eric Carlsen, "The Economics of Recycling" Environmental Affairs, Spring 1973, pp. 653-666 (quoted in Albrecht, et. al., 1981).

identifying additional policy measures to increase recycling, some economists argued that the "inducement of recycling" was not necessarily desirable. Baumol (1977) argued that, in competitive equilibrium without externalities, the free market left to its own devices will assure an optimal level of recycling, as with any other economic activity. Garbage dumps, of course, are a source of externalities, but recycling processes generate their fair share of externalities as well. For example, the reuse of oil in road maintenance can lead to the same poisonous seepage into waterways that result from disposing of the oil in landfills. Also, drawing an analogy to the case of solar heating, Baumol stated that it was not clear whether recycling would conserve natural resources. Widespread use of solar heating can actually result in reduction of a society's energy supply because the production of the equipment may use up more energy than it is capable of generating over its lifetime. Thus, Baumol concludes that, "in competitive equilibrium without externalities induced expansion of recycling is never beneficial; and . . . in the presence of externalities, the matter requires further investigation." (Baumol, p. 87)

Other economists approached the issue of recycling from a purely theoretical standpoint (Smith, 1972; Schultz, 1970). Interesting results regarding the optimal time paths for waste recycling versus disposal have been derived using

optimal control theory. The impacts of different assumptions regarding the environmental effects of recycling, incentive structures, and market structures on this optimal time path were also studied. As an example, Smith shows the optimal time path of recycling decreases as the accumulated stock of waste in the environment decreases and as the rate at which the waste decomposes in nature increases. However, the results obtained in these studies were criticized for being qualitative (Slade, 1980). That is, the studies were capable of assessing the direction of the impacts, but not the magnitudes. Also, in order to maintain mathematical tractability, extremely restrictive assumptions must be made. Smith, for example, assumes that the reprocessing of waste materials into new commodities can be accomplished with one productive input, labor. These models were not capable of capturing many of the relevant recycling issues, namely, the key constraints that prevent firms from substituting recycled inputs for virgin inputs in production.

Several empirical studies have yielded important insights into the factors that must be considered in the formation of recycling policy. These studies can be classified in two categories. In the first category, a single secondary material supply equation is estimated. In these studies, recycling is defined as an increase in the supply of secondary materials. In other words, the studies

are often based on the assumption that increases in supply are automatically translated into increased recycling. As was shown in Chapter II, the truth of this assumption depends upon the elasticity of the demand curve, which was not estimated in these studies. In the second category, two equations, the supply and demand equations for the secondary material, are typically estimated as a simultaneous system. Slade (1980), however, criticizes the results of these studies because the estimated secondary material equations do not rest on sound microeconomic foundations. Since the estimated equations are not based on theory, they do not accurately capture the important determinants of recycling.

Edwards (1979), focusing on modelling the determinants of the supply of wastepaper in an adaptive expectations framework, estimated a single supply equation. Edwards finds that 1) the supply of wastepaper is not very responsive to changes in price expectations and 2) price expectations are slow to adjust to changes in actual prices. Edwards concludes that price-based policies alone will not effectively boost recycling since lowering prices does not provoke a large quantity response on the part of the supplier of the secondary material. Kinkley and Lahiri (1984) criticize the hypothesis of adaptive expectations and "improve" upon Edward's study by using a rational expectations framework. The authors find that the estimated supply elasticity is larger in this alternative

specification for expectations, but it is still extremely small. Likewise, Kinkley and Lahiri conclude that pricing policies will not effectively stimulate recycling.

Other studies provide important insights into demand-side considerations. Andersen and Spiegelman (1977) estimated both a supply and demand equation in their study of the impacts of removing tax preferences for virgin materials on recycling. These authors find that removal of tax subsidies would have only minimal impacts on wastepaper and steel recycling. Also, a direct subsidy that lowered the price of wastepaper and scrap steel was studied. Andersen and Spiegelman find that subsidy policies would yield benefits in excess of costs only if the social costs of the unrecovered waste material exceeded its market value by several hundred percent. One limitation of the Anderson-Spiegelman study is that the estimated equations were not derived from explicit modelling of the production processes for steel and paper. Hence, the only question that could be directly answered is whether or not prices were an important determinant of recycling. The significance of the Andersen-Spiegelman study, however, is that it acknowledges the importance of demand-side considerations and recognizes that the nature of the demand for secondary materials is derived.

Gill and Lahiri (1980) also estimated both supply and demand equations in their analysis of U.S. wastepaper

markets. In their study, it was found that the derived demand for wastepaper is more responsive to the parameters of the final goods market (paper) than it is to the price of wastepaper. The important conceptual contribution of this study was that it incorporated other variables into the estimated wastepaper demand equation and attempted to explain why relative prices may not be the most important determinant of recycling. However, Gill and Lahiri fall short when they explain their major empirical result. The authors justify their finding that wastepaper recycling is more dependent upon the attributes of the final output market than on secondary versus virgin price by describing wastepaper as an "inferior" input. Wastepaper is used only to fill shortfalls in the supply of woodpulp. The fact that installed paper technologies pose a constraint to the degree to which this explanation can be true is not considered. This shortfall stems from inaccurate modelling of paper technology, which, in turn, stems from not developing a complete microeconomic model of the derived demand for wastepaper.

Slade (1980) was the first to incorporate the microeconomic theories of production and cost into the analysis of secondary material markets. In this study, the primary and secondary copper industries are modelled independently and recycling is defined to be an increase in market share of copper produced with secondary materials

relative to copper produced with virgin ore. Similar to the other empirical studies, Slade finds that pricing policies will not boost the rate of copper recycling. However, there are other forces in motion, namely the declining yield of ore mines, that will assure copper recycling will proceed in response to the declining availability of natural resources. The significance of this study is that it is based on microeconomic theory and was capable of determining, through explicit modelling of the production processes, the key factors that drive the rate of copper recycling. Because "other" variables were incorporated into the estimated secondary supply equation, questions besides whether or not prices are most important determinant of recycling were answered. While Slade's model may accurately portray copper recycling technology, however, this may not be the way to model all secondary markets. In many cases, the producers of the final product, which can be produced from either secondary or virgin material, do not represent distinct industries. In the copper industry, the secondary and virgin copper producers are two different industries with distinct market structures (the primary industry has an oligopolistic structure while the secondary industry has a competitive structure). In contrast, in the newsprint industry, which is the industry that is the object of this study, the producers operate in the same output market.

Finally, other types of studies discuss the barriers to

recycling that remained after the passage of the Resource Recovery Act of 1970. Henstock (1980) describes how the low quality of materials recovered from solid waste places technical constraints on recycling and limits the prospect for increased recycling activity. Henstock's study is important since the role of recyclables as a substitute for virgin materials is acknowledged. However, the study is purely descriptive and no formal attempt to assess the magnitude of these technical constraints to recycling is made. Curlee (1986) focuses on identifying the numerous economic and institutional incentives and barriers that affect the decision to recycle or dispose of plastics wastes. Curlee's study is unique in that he pinpoints the reasons that disposal may be chosen over recycling. However, recycling is viewed as a problem of choice among waste management alternatives. In design of policies to reduce the flow of waste to waste disposal facilities, this view of the constraints to recycling is perfectly valid. But from the perspective of the consumer of the secondary material, the issue is one of choice between competing inputs.

This review of the economics literature on recycling shows that researchers have found, from both the perspective of the supplier of the secondary material and the user of the secondary material, there are constraints to recycling. These constraints prevent secondary material prices from

being the most important determinant of either the supply of or the demand for secondary materials. Also, these studies have given evidence that policies directed at simply altering the price of the secondary material will not be very effective at stimulating the rate of recycling.

For the purposes of this study, it will be assumed that state and local policy (mandatory separation and collection programs, in particular) has removed a majority of the constraints on the supply of secondary materials. As was discussed in Chapter II, these programs have achieved a high participation rate and have demonstrated an ability to shift the supply schedule for secondary materials. This study, then, will focus on determining the constraints on the demand for secondary materials, or equivalently, the factors that potentially discourage firms from substituting secondary materials for virgin raw materials in the production process.

Other studies, Slade's in particular, have shown that through explicit modelling of the production process, insights regarding the determinants of recycling can be determined. If the production process is modelled, other key questions besides whether or not prices are the most important determinant of recycling can be answered. While Slade's model was useful for isolating the factors that ultimately drive the rate of copper recycling, the model may not be equally applicable to other industries. In some

industries, the newsprint industry in particular, the users of virgin versus recycled inputs operate in the same market, and the key recycling issue facing these firms is the choice among competing inputs, recycled or virgin, for producing the same output. The task of Section 3 will be to present an alternative perspective for viewing the firm's recycling problem.

3. RECYCLING FROM THE DEMAND SIDE: A RESOURCE USE PERSPECTIVE

The Profit Maximizing Firm's Input Decision

Because the nature of the demand for secondary materials is derived, an analysis of the forces that can cause the demand schedule for some secondary materials to be price-inelastic is a straightforward application of input demand theory. A complete review of the input demand literature will not be necessary to understand the forces that drive the firm's decision to use recycled or virgin inputs and only the portions of the theory that pertain directly to recycling will be outlined. The purpose of this section is to work through the theoretical tools that will be applied to the analysis of recycling in the newsprint industry in Chapters IV and V.

First, the general case of the profit-maximizing firm's input decision will be discussed. Second, a comparative statics analysis will be used to investigate the impacts of

price changes on the usage rate of a recycled input in the two input, perfectly competitive case. These results will be generalized to the n input case and the implications of relaxing the assumption of perfect competition in the output market will be discussed briefly. Finally, the effects of exogenously induced output changes will be analyzed.

Consider the case of the firm that produces a single output under the conditions given by the production function

$$(III-1) \quad Q = f(x_1, x_2, \dots, x_n) .$$

Q represents the quantity of output while the x_i represent the quantities of the inputs employed ($i = 1, \dots, n$). The production function f possesses all the usual properties (i.e., $f_i > 0$ and $f_{ii} < 0$)². Further, the firm purchases its inputs at market determined prices $p_1, p_2, \dots, p_n$.

The firm markets its output according to the demand curve

$$(III-2) \quad Q = D(P), \quad \frac{\partial D}{\partial P} = D' \leq 0 ,$$

where P represents commodity price.

Under these conditions, the firm's problem is to select the input quantities to maximize total profits (π), which is the excess of total revenue (TR) over total cost (TC)

²In the following discussion, f_i will be used to denote the first-order partial derivatives of f while f_{ij} will denote the second-order partial derivative.

$$(III-3) \quad \pi = TR - TC = PD(P) - \sum_i p_i x_i \quad (i = 1, \dots, n)$$

The first-order conditions for maximization are

$$(III-4) \quad \frac{\partial \pi}{\partial x_i} = \left(\frac{D}{D'} + P \right) f_i - p_i = 0 \rightarrow \left(\frac{D}{D'} + P \right) f_i = p_i .$$

Equations III-4 are the jointly derived input demand equations.³ The profit-maximizing firm will employ each input until the point where the addition to total revenue (marginal revenue product) is just equal to the addition to total cost (marginal resource cost), which is just a simple variation of the marginal revenue equals marginal cost rule.

Price Changes and the Demand for Recycled Inputs: The Two Input, Perfectly Competitive Case

To analyze the impacts of price changes on recycled input usage, let us start with the simple case where the firm uses only two variable inputs, x_r and x_v . x_r will represent a recycled input while x_v will represent its virgin counterpart. Also, assume that the firm operates under conditions of perfect competition in the factor and output markets.

Applying equations III-4, the firm's jointly derived input demand equations will be

³We are assuming, of course, that the second order conditions are satisfied. Also, note that under conditions of perfect competition in the output market, $D' = -\infty$ so that the term in parentheses in III-4 collapses to P .

$$(III-5) \quad \begin{aligned} Pf_r - p_r &= 0 \\ Pf_v - p_v &= 0 \end{aligned} .$$

To perform the comparative static analysis, we will need to make use of the condition for equilibrium in the output market. Equilibrium requires that the quantity sold is equal to the quantity produced or

$$(III-6) \quad Q = D(P) = f(x_r, x_v) .$$

Now let us consider the case of an exogenous change in the price of the recycled input, p_r . Partial differentiation of equations III-5 and III-6 with respect to p_r yields

$$(III-7) \quad \begin{aligned} -D'(P) \frac{\partial P}{\partial p_r} + f_r \frac{\partial x_r}{\partial p_r} + f_v \frac{\partial x_v}{\partial p_r} &= 0 \\ f_r \frac{\partial P}{\partial p_r} + Pf_{rr} \frac{\partial x_r}{\partial p_r} + Pf_{rv} \frac{\partial x_v}{\partial p_r} &= 1 \\ f_v \frac{\partial P}{\partial p_r} + Pf_{rv} \frac{\partial x_r}{\partial p_r} + Pf_{vv} \frac{\partial x_v}{\partial p_r} &= 0 \end{aligned}$$

To simplify the analysis, let us assume that the firm operates under conditions of long-run constant-returns-to-scale or, equivalently, the firm's production technology is linearly homogeneous. If the production process is linearly homogenous,⁴ it has been shown that

⁴For a complete discussion of the properties of homogeneous functions, consult Allen (1938), pp. 315-9 and 481-2 and Ferguson (1971), chapter 5.

$$f_{rr} = -\frac{x_v}{x_r} f_{rv} \text{ and } f_{vv} = -\frac{x_r}{x_v} f_{rv} .$$

At this point, it will be noted that the (market) elasticity of demand in the output market (ϵ) and the elasticity of substitution of x_r for x_v (σ) are given by

$$\epsilon = |D'(P)| \frac{P}{Q} \text{ and } \sigma = \frac{f_r f_v}{Q f_{rv}} .$$

Using the linear homogeneity conditions, the conditions given by III-5, and the definitions for the demand and substitution elasticities, equations III-7 can be rewritten as

$$\begin{aligned} (III-8) \quad Q\epsilon \frac{\partial P}{\partial p_r} + p_r \frac{\partial x_r}{\partial p_r} + p_v \frac{\partial x_v}{\partial p_r} &= 0 \\ Q\sigma \frac{\partial P}{\partial p_r} - \frac{x_v}{x_r} \frac{\partial x_r}{\partial p_r} + p_v \frac{\partial x_v}{\partial p_r} &= 1 \\ Q\sigma \frac{\partial P}{\partial p_r} + p_r \frac{\partial x_r}{\partial p_r} - \frac{x_r}{x_v} \frac{\partial x_v}{\partial p_r} &= 0 \end{aligned}$$

Solving III-8 algebraically, we find that

$$(III-9) \quad \frac{\partial x_r}{\partial p_r} = -\frac{x_r}{p_r} \left(\frac{p_r x_r}{PQ} \epsilon + \frac{p_v x_v}{PQ} \sigma \right) .$$

Now introduce the notation

$$S_i = \frac{p_i x_i}{PQ}, \quad \epsilon_{xi, pj} = \frac{p_j}{x_i} \frac{\partial x_i}{\partial p_j}, \quad i, j = r, v .$$

S_i is, of course, the proportion of total receipts going to the each of the factors, or the share of the i th factor in

total cost. $\epsilon_{xi, pj}$ are the own and cross-price elasticities of demand for the factors.

Using this notation, III-9 is more conveniently written

$$(III-10) \quad \epsilon_{xr, pr} = -(S_v \sigma + S_r \epsilon) .$$

The elasticity of the demand for the virgin input with respect to the price of the recycled input analogously can be derived

$$(III-11) \quad \epsilon_{xv, pr} = S_r (\sigma - \epsilon) .$$

The interpretation of these results is straightforward. When the price of a recycled input declines, production costs are lowered and more Q is produced. Since ϵ is positive, more Q is purchased. When more Q is produced, there is an increase in the demand for both the recycled and the virgin input.⁵ This is shown by the term $-S_r \epsilon$ in III-10 and III-11. This increase in the demand for both inputs is the output effect of a price decrease. Also, when the price of the recycled input decreases, it elicits a substitution effect. That is, a decline in p_r causes x_r to be relatively cheaper and the firm increases its use of x_r at the expense of x_v . The substitution effect is indicated by $-S_v \sigma$ in III-10 and $S_r \sigma$ in III-11. Thus, when the price of the recycled input decreases, the quantity the firm demands will

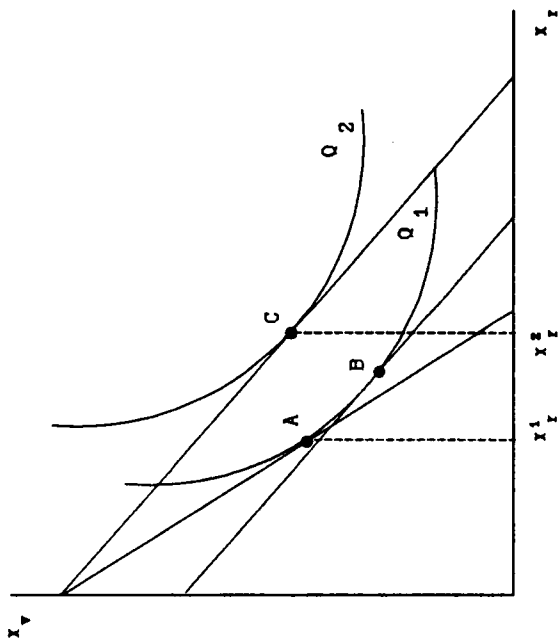
⁵We are ignoring the case of inferior inputs (output increases cause the quantity of the inferior input purchased to fall) since this is not relevant to the empirical analysis presented in chapter 4.

increase. The demand for the virgin input will increase or decrease, depending upon whether the substitution effect (which causes the firm to decrease its purchases of the virgin input) or output effect (which causes the firm to increase its purchases of the virgin input) is greater. The effects of a change in p_v are analogous.

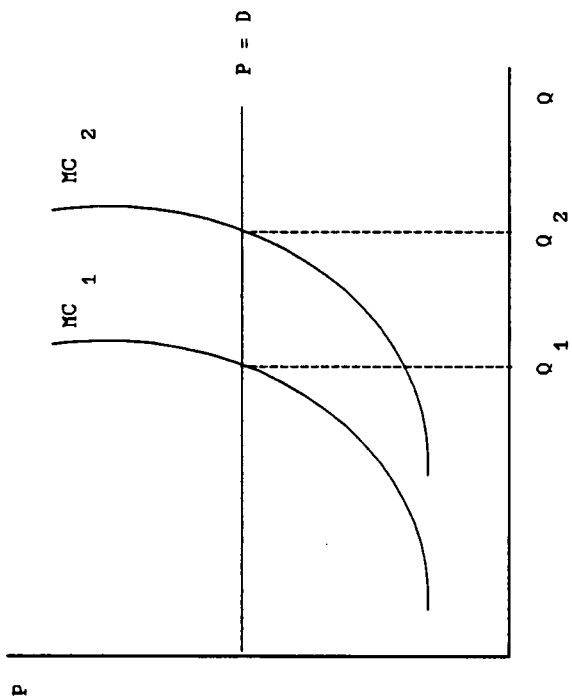
The substitution and output effects can also be depicted graphically. Figure III-1 illustrates the case of a decline in p_r . The total effect is shown by the movement from A to C. The substitution effect shows what would happen if output was held constant and is represented by the movement from A to B. However, a decline in p_r also shifts the firm's marginal cost (MC) curve downward. When MC shifts from MC_1 to MC_2 , a new profit-maximizing level of output is chosen. The final result is that purchases of x_r increase from x_r^1 to x_r^2 . It should be noted that, in Figure III-1, the price of Q was assumed to remain constant. In general, the product price will decline and somewhat dampen the output effect as illustrated.

In the preceding discussion, a decrease in the price of the recycled input unambiguously increased the quantity used. We are now in a position to discuss the factors that ultimately will determine the magnitude of the profit-maximizing firm's response to changes in recycled input prices. For this discussion, we will make use of III-10.

Note that the price elasticity of demand for the



Isoquant Map



Output Decision

Figure III-1

The Substitution and Output Effects Arising From
A Change in the Price of a Recycled Input
(Perfectly Competitive Case)

secondary input depends on the (market) elasticity of demand for a firm's final product. If reductions in final product price prompt large increases in the quantity that consumers purchase, then reductions in product price generated by lower production costs will stimulate the demand for the recycled input by a large amount. However, if final product demand is highly price-inelastic, lower product prices do not provoke a large output effect and the response to the change in p_r is less than it would be if final product demand is highly price-elastic.

Also, the magnitude of the response to changes in the price of the recycled input is affected by the fraction of total costs accounted for by the primary input. If purchases of the primary input account for a high percentage of total costs, a reduction in the price of a recycled input will cause a large decline in production costs if the substitution is made. For example, if the primary input accounts for 50 percent of the costs of producing a given output and the price of the competing recycled input drops by 20 percent, the firm will save 10 percent of the costs of producing its output by switching to the use of the recycled input, all other things held constant. If the share of the virgin input in total costs is much smaller, say 10 percent, and the price of the recycled input declines by 20 percent, the firm will save only two percent of the costs of producing its output. Thus, the incentive to switch to the

recycled input generated by the savings in total production costs is smaller when the share of the virgin input in total cost is smaller.

Another key factor is the degree to which the recycled and primary inputs can be substituted for one another in production. The greater the ease with which substitution can be initiated and accomplished, the greater will be the response to changes in the recycled input price. Difficulty in substitution, on the other hand, will dampen the firm's response to price changes.

There are a number of factors that can limit the substitutability of secondary for virgin materials. For one, the firm's fixed inputs may not be perfectly adaptable to the use of the secondary input. As will be seen in Chapter IV, the "unadaptability" of fixed inputs poses a major obstacle to the substitution of old newspapers for woodpulp in newsprint production.

Further, let us consider the case of paper recycling in general. Recycling is limited primarily by the physical properties of the fibers that make up paper and recycling paper technology. Paper fibers are damaged and shortened after repeated reprocessing, which diminishes strength of the product. Technology to prevent the fiber damage has not yet been developed. Technology, then, can limit the ease of substitution. Similarly, although glass theoretically is 100 percent recyclable, glass made from 100 percent cullet

tends to lack "fining" agents that reduce bubbles. Thus, lack of consistency with the final product made from 100 percent virgin materials places constraints on the economic substitutability of secondary glass for its virgin counterpart, silica sand.

Contamination is another complication. The polymer molecules that make up plastics are capable of absorbing contaminants into their molecular structure. This has evoked concern regarding their reuse as food containers, which is the original use for many plastics. Likewise, the main difficulty in aluminum recycling is separating the aluminum from other metals such as zinc, steel, and magnesium.

In summary, this simple analysis of the derived demand for a secondary input sheds some light on some of the important factors that influence the rate of recycling, or the use of secondary materials in place of virgin materials in a production process. While relative input prices determine the direction of the response, they do not determine the size of the response and are not necessarily the most important consideration. Recycling depends on the elasticity of demand for the product produced with recycled inputs as well the technical aspects of the firm's production process. These findings have important implications for future recycling policy and the overall efficacy of supply-side legislation.

Price Changes and the Demand for Recycled Inputs: The n
Input, Perfectly Competitive Case

Generalization of the results presented above to the n input case provides yet another interesting insight. The analysis proceeds as in the case of two inputs. For simplicity, the notation used to derive the rule for the profit maximizing firm's input decision will be used. It will be assumed, however, that the n inputs are ordered so that x_1 is the recycled input and x_2 is its virgin counterpart.

Applying III-4 yields

$$(III-12) \quad Pf_i - p_i = 0, \quad i = 1, \dots, n.$$

These equations are, as before, the firm's jointly derived input demand equations.

In the n input case, the condition for equilibrium in the output market becomes

$$(III-13) \quad Q = D(P) = f(x_1, x_2, \dots, x_n).$$

By partially differentiating III-12 and III-13 with respect to p_1 (the price of the recycled input) we obtain

$$\begin{aligned}
 & \mathcal{Q}ef_1 \left(\frac{\partial P}{\partial p_1} \frac{1}{P} \right) + \sum_i f_i \frac{\partial x_i}{\partial p_1} = 0 \\
 & f_1 \left(\frac{\partial P}{\partial p_1} \frac{1}{P} \right) + \sum_i f_{1i} \frac{\partial x_i}{\partial p_1} = \frac{1}{P} \\
 (III-14) \quad & f_2 \left(\frac{\partial P}{\partial p_1} \frac{1}{P} \right) + \sum_i f_{2i} \frac{\partial x_i}{\partial p_1} = 0 \\
 & \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
 & f_n \left(\frac{\partial P}{\partial p_1} \frac{1}{P} \right) + \sum_i f_{ni} \frac{\partial x_i}{\partial p_1} = 0
 \end{aligned}$$

i and j as defined by Allen (1938, pp. 504-509). The value for σ_{ij} depends on all the factors employed.⁷

Equations III-14 can be solved by applying Cramer's rule

$$(III-16) \quad \frac{\partial x_1}{\partial p_1} = \frac{\begin{vmatrix} Qe & 0 & f_2 & \dots & f_n \\ f_1 & \frac{1}{P} & f_{12} & \dots & f_{1n} \\ f_2 & 0 & f_{22} & \dots & f_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ f_n & 0 & f_{2n} & \dots & f_{nn} \end{vmatrix}}{\begin{vmatrix} Qe & f_1 & f_2 & \dots & f_n \\ f_1 & f_{11} & f_{12} & \dots & f_{1n} \\ f_2 & f_{12} & f_{22} & \dots & f_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ f_n & f_{1n} & f_{2n} & \dots & f_{nn} \end{vmatrix}} + \frac{\begin{vmatrix} Qe & f_1 & f_2 & \dots & f_n \\ f_1 & f_{11} & f_{12} & \dots & f_{1n} \\ f_2 & f_{12} & f_{22} & \dots & f_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ f_n & f_{1n} & f_{2n} & \dots & f_{nn} \end{vmatrix}}{\begin{vmatrix} Qe & f_1 & f_2 & \dots & f_n \\ f_1 & f_{11} & f_{12} & \dots & f_{1n} \\ f_2 & f_{12} & f_{22} & \dots & f_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ f_n & f_{1n} & f_{2n} & \dots & f_{nn} \end{vmatrix}}$$

Following Allen (1938, p. 508), and using the conditions of homogeneity as well as the conditions given by III-12, the first determinant can be rewritten as

$$(III-17) \quad \frac{1}{P} \left(\begin{vmatrix} 0 & f_2 & \dots & f_n \\ f_2 & f_{12} & \dots & f_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ f_n & f_{2n} & \dots & f_{nn} \end{vmatrix} + \begin{vmatrix} Qe & f_2 & \dots & f_n \\ 0 & f_{22} & \dots & f_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & f_{2n} & \dots & f_{nn} \end{vmatrix} \right)$$

$$= \frac{1}{P} (F_{11} - QeF_{011})$$

$$= \frac{x_1 F}{P} f_1 \left(S_1 \sigma_{11} - \frac{X_1 f_1}{Q} e \right) = \frac{x_1 F}{P_1} S_1 (\sigma_{11} - e)$$

where S_1 is as defined for the two input case.

⁷When the production technology is linearly homogenous, $Q = x_1 f_1 + x_2 f_2 + \dots + x_n f_n$ so that:

$$\sigma_{ij} = \frac{x_1 f_1 + x_2 f_2 + \dots + x_n f_n}{x_i x_j} \frac{F_{ij}}{F}$$

Hence, the partial elasticity of substitution between factors x_i and x_j depends upon all of the factors employed.

The second determinant is similarly rewritten

$$\begin{aligned}
 (III-18) \quad & \begin{vmatrix} 0 & f_1 & f_2 & \dots & f_n \\ f_1 & f_{11} & f_{12} & \dots & f_{1n} \\ f_2 & f_{12} & f_{22} & \dots & f_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ f_n & f_{1n} & f_{2n} & \dots & f_{nn} \end{vmatrix} + Qe \begin{vmatrix} f_1 & f_2 & \dots & f_n \\ 0 & f_{11} & f_{12} & \dots & f_{1n} \\ 0 & f_{12} & f_{22} & \dots & f_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ 0 & f_{1n} & f_{2n} & \dots & f_{nn} \end{vmatrix} \\
 & = F + QeF_0 = F
 \end{aligned}$$

and

$$(III-19) \quad \frac{\partial x_1}{\partial p_1} = \frac{x_1}{p_1} S_1(\sigma_{11} - e) \Rightarrow e_{x_1, p_1} = S_1(\sigma_{11} - e) .$$

Repeating this analysis we find that a general formula for the responsiveness of the usage rate of the recycled input to any price change can be derived

$$(III-20) \quad e_{x_1, p_j} = S_j(\sigma_{j1} - e) \quad (j = 1, \dots, n) .$$

Obviously, the results are similar to those obtained for the two input case. When the price of the recycled input decreases, production costs are lowered and more output is produced and sold. This output effect is indicated by the term $-S_j e$ in III-19. Also, the lower price for x_1 makes it relatively cheaper and causes the firm to substitute it for the other inputs since $\sigma_{11} < 0$ (Allen, 1938). The magnitude of the response is limited by the elasticity of demand for the final product and the ease of substitutability of the recycled input for the other inputs.

However, the n input case gives us one more interesting insight. Referring to III-20, the partial elasticity of substitution can be either positive or negative. If the inputs are competitive, then the partial elasticity of substitution will be positive and an increase in the price of the j th input will result in an increase in the purchases of the recycled input. If the inputs are cooperative, then the partial elasticity of substitution will be negative and an increase in the price of the j th input will result in a decrease in the purchases of the recycled input. Further, the absolute value for σ_{ji} determines the strength of the competitive/cooperative relationship and hence, determines the degree of response to price changes. Thus, the rate of recycling also depends upon the type and strength of the relationship between the secondary material and all other productive factors. In the two input case, the recycled and virgin input were substitutes and the concern was only with the relative ease of making this substitution, or how "positive" σ was. In the n input case, the concern is with both the sign and absolute value of the partial elasticity of substitution.

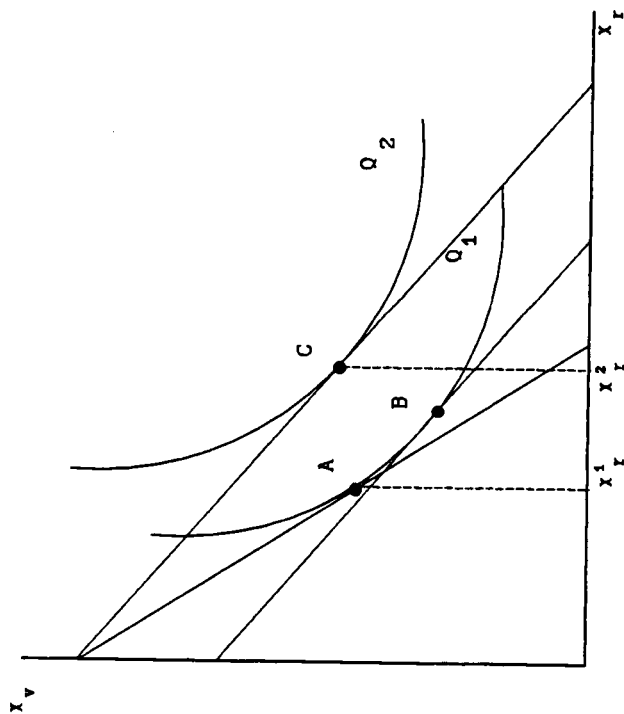
The case of aluminum recycling will serve to illustrate the significance this point. It is estimated that 55 percent of aluminum beverage containers are used to produce secondary aluminum. The success in aluminum can recycling is attributed to natural economic incentives. At least 50

percent of the costs of aluminum production come from energy consumption and using secondary aluminum requires 90-95 percent less energy than production of the same product with virgin raw materials. Studies indicate that the rate of aluminum recycling is more sensitive to the price of energy than it is to the price of secondary aluminum taken in isolation (Slade, 1980a and 1980b). In terms of III-20 then, when the price of energy increases, recycling increases substantially because 1) S_j , the share of energy in total costs is quite large and 2) σ_{ji} , the elasticity of substitution of secondary aluminum for energy is positive, and intuitively, large as well.

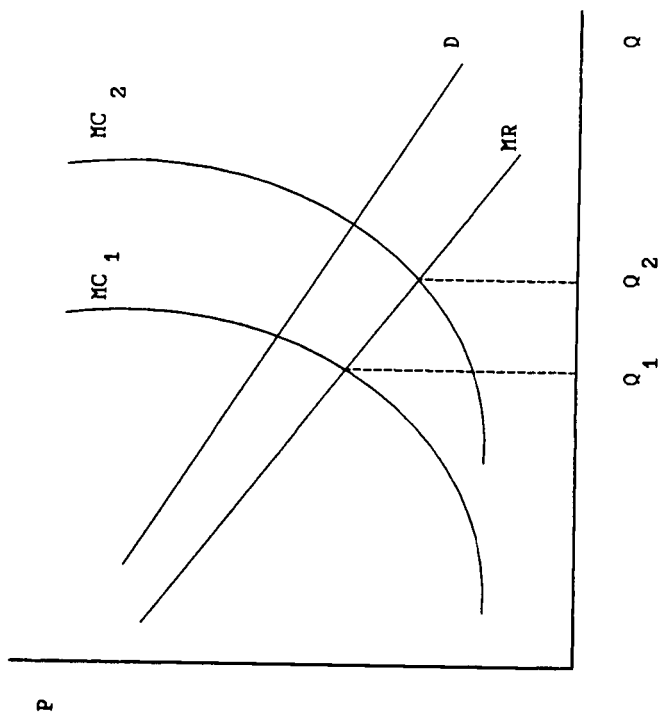
Imperfect Competition in the Output Market

Relaxing the assumption of perfect competition poses no special problem for the analysis of the derived demand for secondary inputs. Hence, this discussion will be brief and limited to a graphical analysis, or the two input case.

In Figure III-2, a decline in the price x_i causes the optimal input combination to shift from A to B on Q_1 , the isoquant representing the original output level. The substitution effect, then, is the same as in the perfectly competitive case. The output effect, however, is somewhat different. A decline in p_i shifts the firm's marginal cost curve outward, causing MR and MC to intersect at a larger output and lower MR value. Since MR is now lower (in the



Isoquant Map



Output Decision

Figure III-2

The Substitution and Output Effects Arising From
A Change in the Price of a Recycled Input

perfectly competitive case it remained constant), the output effect is smaller. In a sense, this "marginal revenue effect" causes the imperfectly competitive firm's demand for x_r to be less elastic than it would be if it were operating under conditions of perfect competition.

Exogenously Induced Output Changes

In the previous discussion, the two forces that come into play (the substitution and output effects) when the price of a recycled input changes were described. The key factor determining the size of substitution effect was the ease of substitutability between the recycled input and its virgin counterpart. In the n input case, the key factor was how easily the recycled input could be substituted for "all other factors" in production. Nothing has been said about the determinants of the magnitude of the output effect. Thus, the manner in which changes in the firm's scale of operations can affect the demand for a secondary input warrant further investigation.

In order to investigate how the rate of recycling responds to output changes, the analysis will be restricted to the firm producing with two variable inputs: a recycled input (x_r) and a virgin input (x_v). Since the concern is to assess the impacts of exogenous output changes, the firm's problem of minimizing cost subject to a give level of output will be considered.

The firm's problem, then, is to minimize

$$(III-21) \quad C = p_r x_r + p_v x_v$$

subject to

$$(III-22) \quad Q = \bar{Q} = f(x_r, x_v) \quad .$$

To find the minimum, use the Lagrangian multiplier method

$$(III-23) \quad \mathcal{L} = p_r x_r + p_v x_v + \lambda [f(x_r, x_v) - \bar{Q}]$$

The first-order conditions for a minimum are

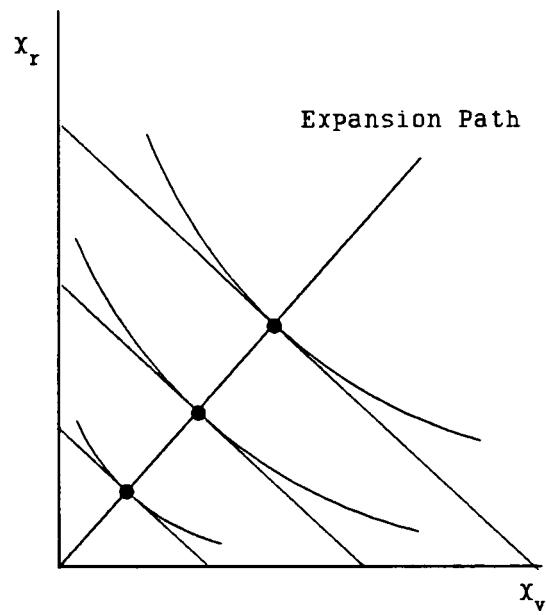
$$(III-24) \quad \begin{aligned} \frac{\partial \mathcal{L}}{\partial x_r} &= p_r - \lambda f_r = 0 \\ \frac{\partial \mathcal{L}}{\partial x_v} &= p_v - \lambda f_v = 0 \\ \frac{\partial \mathcal{L}}{\partial \lambda} &= f(x_r, x_v) - \bar{Q} = 0 \end{aligned}$$

which can be solved

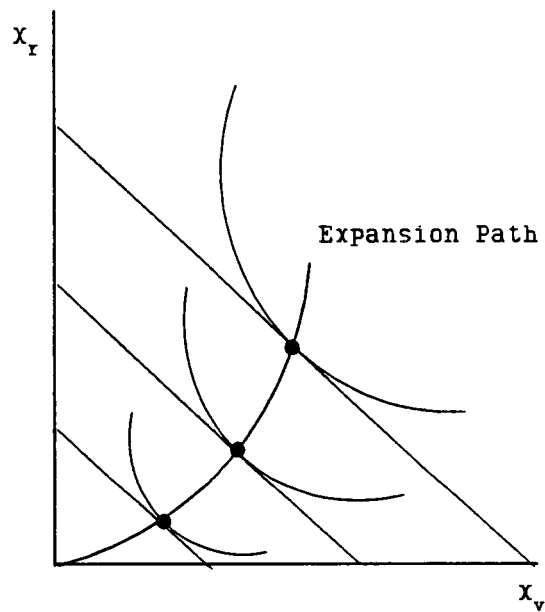
$$(III-25) \quad \frac{f_r}{p_r} = \frac{f_v}{p_v} = \frac{1}{\lambda}$$

Equations III-25 define the firm's expansion path for fixed input prices. At each output level, the additional output (marginal product) per dollar spent on the recycled input must equal the additional output per dollar spent on the virgin input. Two possible shapes for the expansion path are shown in Figure III-3.

The expansion path shown in III-3 (b) is of special interest. As output expands, production becomes more secondary material-intensive. The usage of x_r must be



(a)



(b)

Figure III-3

Impacts of Exogenously Induced Output Changes

increased relatively more than the usage of x_r because, given fixed input prices, the marginal product of x_r declines less rapidly as the firm's scale of operations are altered. For the production technology described in III-3 (b), it becomes more efficient to use the secondary input as the firm expands its long-run rate of output. In other words, when the firm expands its scale of operations, it can alter the inputs that were fixed at the previous level of output (e.g. capital) so that they are more capable of utilizing the secondary material. In contrast, for the production technology described by (a), the usage of x_r must be increased at the same rate as x_v when output expands because the marginal products decline at the same rate. In this case, the firm cannot (or does not) alter its fixed inputs so that it can more efficiently use the recycled input. One reason that the firm's expansion path may be depicted by (a) is that it is not technically possible to use proportionately more of the recycled input.

4. IMPLICATIONS FOR RECYCLING POLICY

In order to understand the demand side of secondary markets, recycling cannot be defined as simply the removal of materials from the solid waste stream. Recycling only occurs when a secondary material is substituted for a virgin raw material in a production process. Also, the nature of the demand for secondary materials is derived, or is an

input demand and the analysis of the demand side of secondary markets must be based on the theory of input demand.

In this review of input demand theory in the context of recycling, it has been found that recycling, or the substitution of secondary materials for virgin raw materials in the production process, will depend on a number of forces. Relative input prices may not be the most important consideration. Recycling depends on the elasticity of demand for the final product as well the technical aspects of the firm's production process. The ease of substitution as well as the manner in which the recycled input is tied to competitive and cooperating inputs affects the elasticity of its demand schedule. Further, it was shown that the demand for a recycled input will be less elastic if the firm operates under conditions of imperfect competition in the output market than if it operated under conditions of perfect competition. Any of these factors can constrain the firm's response to the lower recycled input prices generated by a supply-side policy and hinder these efforts to increase the rate of recycling for some secondary materials.

Of course, the relative importance of the factors that influence recycling is an empirical question. Once a functional form is specified for III-12, the parameters of the firm's jointly derived input demand equations can be

estimated using econometric techniques. The estimated parameters will permit us to gauge the importance of any of these factors in the firm's decision to substitute recycled inputs for virgin inputs in production. Such an estimation exercise will be taken up in Chapter V. Before turning this issue, it is necessary to set the problem within the context of a specific industry and a specific market. Chapter IV will provide the institutional framework for setting the problem in the context of the market for old newspapers as an input in newsprint production.

CHAPTER IV

THE MARKET FOR OLD NEWSPAPERS: INSTITUTIONAL FRAMEWORK

1. THE CHOICE OF MARKETS: A JUSTIFICATION

Several materials have been the target of policies to increase the rate of recycling. One of the most common materials is old newspapers (ONP). One reason is that ONP is relatively easy to source separate. Also, ONP alone comprises 6-20 percent of the trash in a community (NSWMA, 1990). Removing ONP contributes significantly to reaching legislatively-determined recycling targets. Further, prior to large scale implementation of separation and collection programs, ONP was considered a key commodity since it was expected by many to generate roughly 60 percent of the total revenue from sales of the separated and collected materials (Wall Street Journal, 1989). Sales of ONP would contribute substantially to covering the cost of recycling programs.

Other benefits have been cited as reasons for separating ONP from the rest of the MSW stream. Some proponents believe that reusing ONP will help conserve national forests. However, most newsprint producers are large, integrated companies that operate their forests on a sustained-yield basis. Motivated by long-run profit objectives, newsprint producers are likely to be committed to preserving their forests through forest management. In fact, the trees used to produce newsprint generally are

grown solely for that purpose. Decreased production of virgin newsprint, then, will result in less trees planted and grown. Thus, the net effect of ONP recycling will be that the size of these forests remains constant, at best, provided the forest lands are not put to an alternative productive use. If this is the case, an increase in ONP recycling could lead to a reduction in the size of forests (Wiseman, 1990).

Another potential benefit is the energy savings from producing newsprint from ONP rather than woodpulp. Recycled newsprint requires fewer Btu's per ton than virgin newsprint. However, as is the case with other paper products, the production of recycled newsprint may require more fossil fuels since wood by-products are burned as an energy source in the production of virgin paper (OTA, 1989). Also, fossil fuels are required to collect ONP.

Conservation of forests and potential energy savings do not appear to be the most important benefits to be realized by increased ONP recycling. While there may be other potential benefits (e.g., reduction of environmental damage), of the ones cited at this point, the most obvious one is the reduction in the MSW stream and the resulting avoidance of the costs associated with ONP disposal.

Three markets for ONP can be identified: fiber for newsprint production, fiber for other paper and board products, and exports. ONP recycling could be increased

through any one of these markets. Since these components of demand are derived from different production processes, each requires independent analysis. The focus of this study will be on the market for ONP as an input in newsprint production. As will be discussed below, this segment of the market for ONP has been the focus of policies to stimulate the demand for ONP.

One purpose of this study is to test the hypothesis that the demand for ONP as an input in newsprint production is highly price-inelastic. Empirical support for this hypothesis will be used to explain why policies to remove ONP from the solid waste stream (or shift the supply schedule for ONP) have not resulted in a large and immediate increase in the amount of ONP used in newsprint production. However, it is possible that the other markets for ONP may be characterized by a highly elastic demand schedule. If this is the case, then these other markets would be more relevant to the analysis of the potential effects of supply-side policy. The following discussion gives evidence that, although the demand for ONP in newsprint production may be highly price-inelastic, the demand for ONP in this market is more elastic than the demand in the other markets. Thus, it would be expected that if policies to remove materials from the solid waste stream are to result in any increase in ONP consumption, these increases will be most evident in the market for ONP as an input in newsprint production.

In Figure IV-1, for simplicity, the demand for ONP as an input in newsprint production (D_{NP}^{ONP}) is drawn as perfectly inelastic while the demand for ONP in the other markets (D_{Other}^{ONP}) is drawn as downward-sloping.¹ The horizontal summation of D_{NP}^{ONP} and D_{Other}^{ONP} determines the market demand curve (D_{Total}^{ONP}) for ONP.

Now suppose a policy (e.g., a separation and collection program) to shift the supply of ONP from S_1^{NP} to S_2^{NP} is implemented. The effect of such a policy is to cause the market price of ONP (P^{ONP}) to fall from P_1^{ONP} to P_2^{ONP} . When P^{ONP} falls, the quantity of ONP used in newsprint production remains constant at Q_{NP}^{ONP} while the quantity used in the other markets increases from Q_{Other}^{ONP} to $Q_{Other}^{ONP'}$. This situation can be stated equivalently by making use of the definition of the share of recycled ONP used to produce newsprint (S_{NP}^{ONP}):

$$(IV-1) \quad S_{NP}^{ONP} = \frac{Q_{NP}^{ONP}}{Q_{NP}^{ONP} + Q_{Other}^{ONP}}$$

If the demand for ONP in the other markets is more elastic than the demand for ONP in newsprint production, then the denominator of IV-1 would rise relative to the numerator when the price of ONP falls. In other words, it

¹It should be noted that the strength of the following argument does not depend upon D_{NP}^{ONP} being perfectly inelastic. Rather, in what follows, it is sufficient for D_{NP}^{ONP} to be less elastic than D_{Other}^{ONP} .

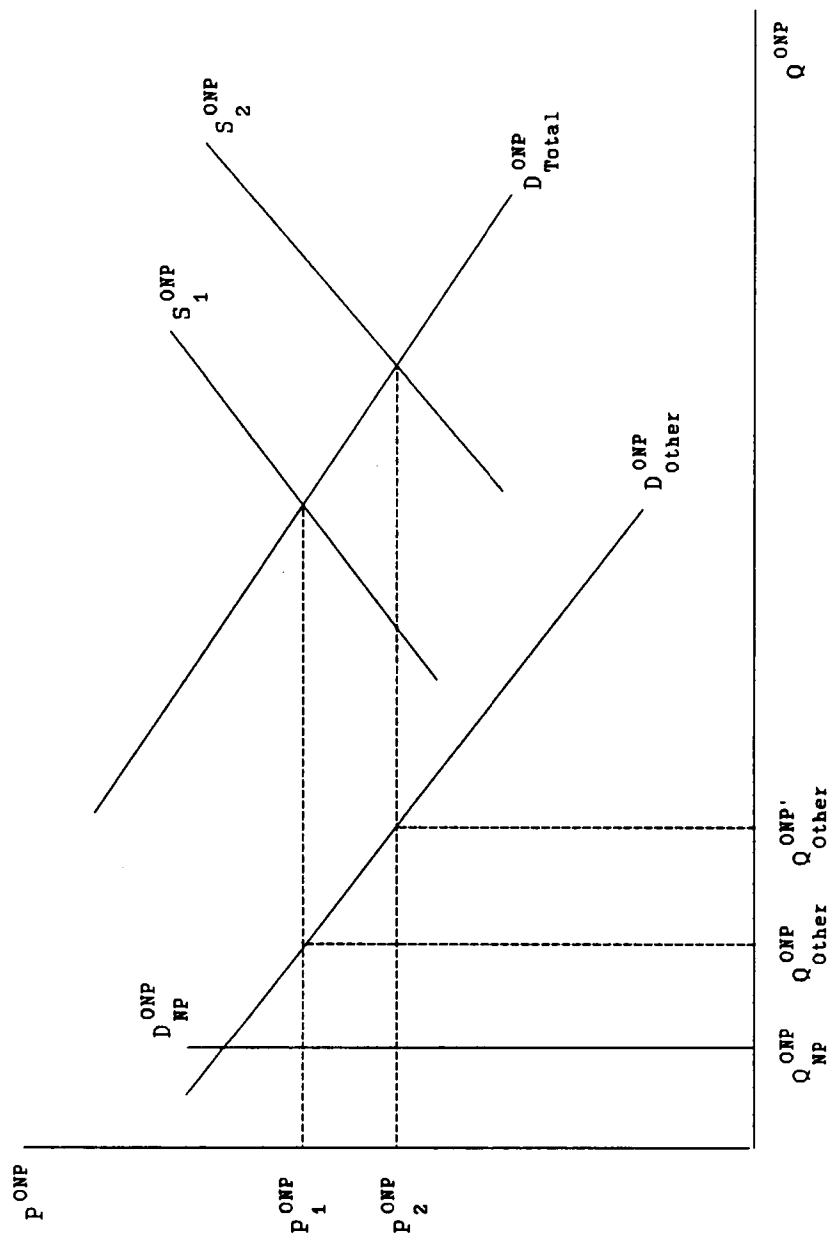


Figure IV-1
The Markets for ONP
(Not Drawn to Scale)

would be expected that S_{NP}^{ONP} and P^{ONP} are directly related. Thus, in order to give evidence for or refute the concern that the demand in the other markets for ONP is more elastic (and hence, more relevant to the analysis of the impacts of supply-side legislation), it will be sufficient to determine whether the relationship between S_{NP}^{ONP} and P^{ONP} is positive or negative. If the relationship is an inverse one, then this can be interpreted as the demand for ONP in newsprint production is more elastic than the demand for ONP in the other markets.

In Figure IV-2, the real price of ONP (measured by the producer price index for ONP divided by the producer price index for all goods) is graphed against the share of recycled ONP used in newsprint production. Note that the relationship appears to be negative. In fact, the Pearsonian coefficient of correlation between the two was computed and found to be $-.8169$. The relationship between S_{NP}^{ONP} and P^{ONP} is not only inverse, but quite strong as well. Thus, although the demand for ONP in newsprint production may be highly price-inelastic, the demand for ONP in this market is more elastic than the demand in the other markets. It is expected that if policies to remove materials from the solid waste stream are to result in any increase in ONP recycling, these increases will be most evident in the market for ONP as an input in newsprint production.

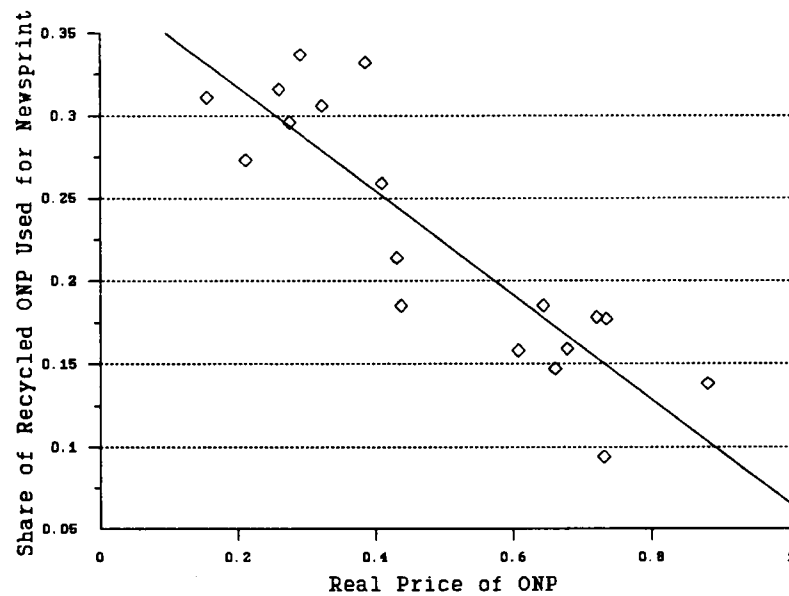


Figure IV-2

Share of Recycled ONP Used in Newsprint
Production versus the Real Price of ONP
(1970-1987)

Note: The data used to construct Figure IV-2 were taken from The American Paper Institute's Statistics of Pulp, Paper and Board.

2. POLICIES TO INCREASE ONP RECYCLING

At the federal level, no recently passed bills affect ONP recycling. Bills that aim to increase the demand for ONP have been proposed before both the House and the Senate. One bill (H.R. 3737) would impose a tax of \$7.50 per ton on the woodpulp used in paper production. Other bills (S. 1763, S. 1764, and H.R. 3483) would establish a system of tradable permits for reaching a minimum recycled fiber content for newsprint. These bills would require newsprint producers (importers) to either produce (import) newsprint with a minimum recycled content or purchase permits from firms that are producing (importing) newsprint with recycled content in excess of the minimum.

In contrast to the federal government, state and local governments have put several types of policies that affect ONP recycling into action. As was discussed in detail in Chapter II, a number of states and localities have passed mandatory separation and collection legislation. Also, some localities have banned the disposal of newspapers in landfills. These policies attempt to stimulate recycling by shifting the ONP supply schedule and lowering price. For a given demand curve, lower prices cause the quantity of ONP demanded to increase. The magnitude of the impact of these policies, of course, depends on the relative elasticity or inelasticity of the derived demand for ONP.

Another type of ONP recycling legislation attempts to

boost the rate by setting minimum recycled fiber content percentages for newsprint. In contrast to mandatory separation and collection legislation, these policies aim to shift the ONP demand schedule. As an example, Connecticut passed a law requiring newspapers to use 20 percent recycled newsprint by 1993. The percentage will gradually increase to 98 percent by 1998 (OTA, 1989). According to the New York Times, however, the Connecticut Newsprint Recycling Task Force recently has recommended that the law be replaced with a voluntary commitment on the part of newspaper publishers. If publishers fail to reach recycled content goals when recycled newsprint is available "at a price and quality comparable to virgin newsprint," mandatory controls and fines will be resorted to. A similar voluntary arrangement has effectively thwarted "mandatory content" legislation in New York.

3. IMPACTS OF ONP RECYCLING LEGISLATION

As was mentioned in Section 2, at the federal level, bills have only been proposed and none have been passed to encourage ONP recycling. Legislation to boost recycling has come predominantly from the state and local level. At the state/local level, two types of policies potentially affect ONP recycling. The first policy that will be discussed is mandatory content legislation, which aims to shift the ONP demand schedule. The second type of policy attempts to

increase ONP recycling by reducing the flow of ONP to landfills and incinerators.

Since mandatory content legislation has been qualified with "at a price and quantity comparable to virgin newsprint," it only acts to increase the notional demand for newsprint produced with secondary fiber. The efficacy of these policies will depend on how the increase in the notional demand is translated into an increase in the effective demand for recycled newsprint. The burden of increased ONP recycling (or equivalently, increased recycled newsprint production) rests upon the newsprint industry and these policies do not address this sector.

Another reason mandatory content legislation may not be very effective at increasing the use of ONP in newsprint production lies in the definition of recycled newsprint. In California's mandatory content statute, recycled newsprint is defined as newsprint containing 40 percent post-consumer fiber. According to the California law, newspaper publishers are required to increase purchases of recycled newsprint to 50 percent by 2000. However, the definition of recycled newsprint implies a minimum recycled fiber content of 20 percent (Wiseman, 1990). Given that Golden State Paper, one of the largest producers of newsprint containing 100 percent post-consumer fiber is located in the Los Angeles area, some publishers may already consume newsprint with a higher recycled content than is required under the

California law.

It is questionable whether mandatory content legislation will effectively increase the amount of ONP used to produce newsprint. Even if the legislation can effectively increase ONP recycling in the future, it is safe to assume that, at the time this study was undertaken, the effects of these policies had not yet been observed. First, these policies are new in comparison to separation and collection legislation. In fact, mandatory content legislation has been adopted at least partially in response to a perceived inefficacy of supply-side legislation. Also, mandatory content legislation has not been as widespread as policies that aim to shift the supply schedule for ONP. As of January 1990, only three states had adopted mandatory content legislation (Wiseman, 1990). Finally, the time frames for publishers to increase purchases of recycled newsprint (e.g. 2000) are generous and have not required a large and immediate increase in the consumption of recycled newsprint. For these reasons, the discussion of the impacts of recycling policy will be limited to policies that shift the ONP supply schedule policy.

The market for ONP is a prime example of a market where policies to augment supply have not been very effective at stimulating recycling. More specifically, expansion of separation and collection programs have only caused the price of ONP to drop rapidly. In some cases, the price

received for ONP has even become negative. For example, in July of 1988, wastepaper processors that once paid \$30 per ton of ONP charged the city of Barberton, Ohio \$10 per ton to haul the paper away (Wall Street Journal, 1989). Figure IV-3 illustrates the rapid drop in the producer price index of ONP that came directly after separation and collection programs came online in New York, New Jersey, and Connecticut, as well as other states.²

Because of the rapid drop in the price received from the sale of ONP, actual revenues from the sales of recyclables fell short of projected revenues and many communities were not able to cover the costs of collecting their recyclable materials. As a result, some cities completely closed their recycling operations. In other localities, rather than pay to unload separated and collected ONP, bans on the disposal of ONP were lifted or collection of ONP was simply discontinued (materials like aluminum and glass were still collected). In Youngstown, Ohio, residents were initially advised to store ONP but later were told to throw them out (Wall Street Journal, 1989). Despite these efforts to increase recycling, then, ONP wound up in the landfill in many cases and expectations for increases in recycling of ONP were not realized.

The case of ONP illustrates the effects of applying

²Data to construct Figure IV-2 were taken from The Bureau of Labor Statistics Producer Prices and Price Indexes.

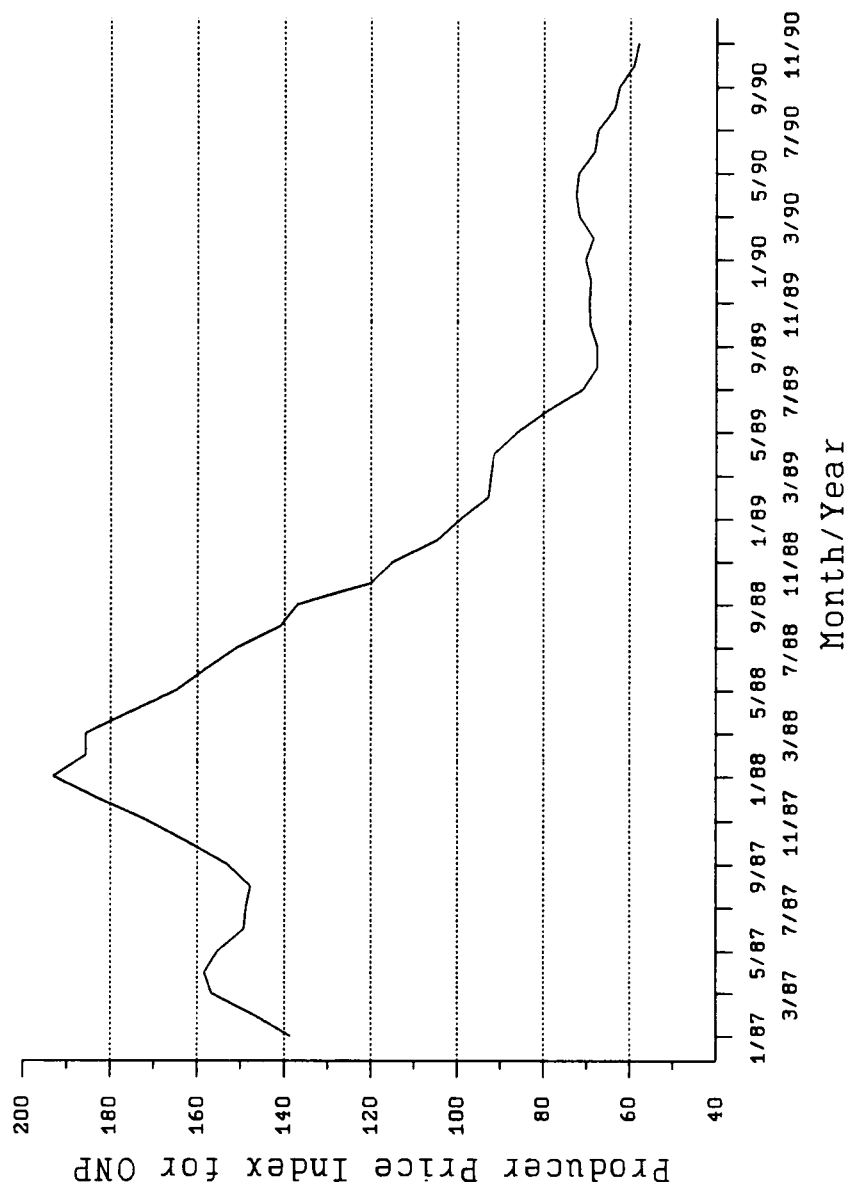


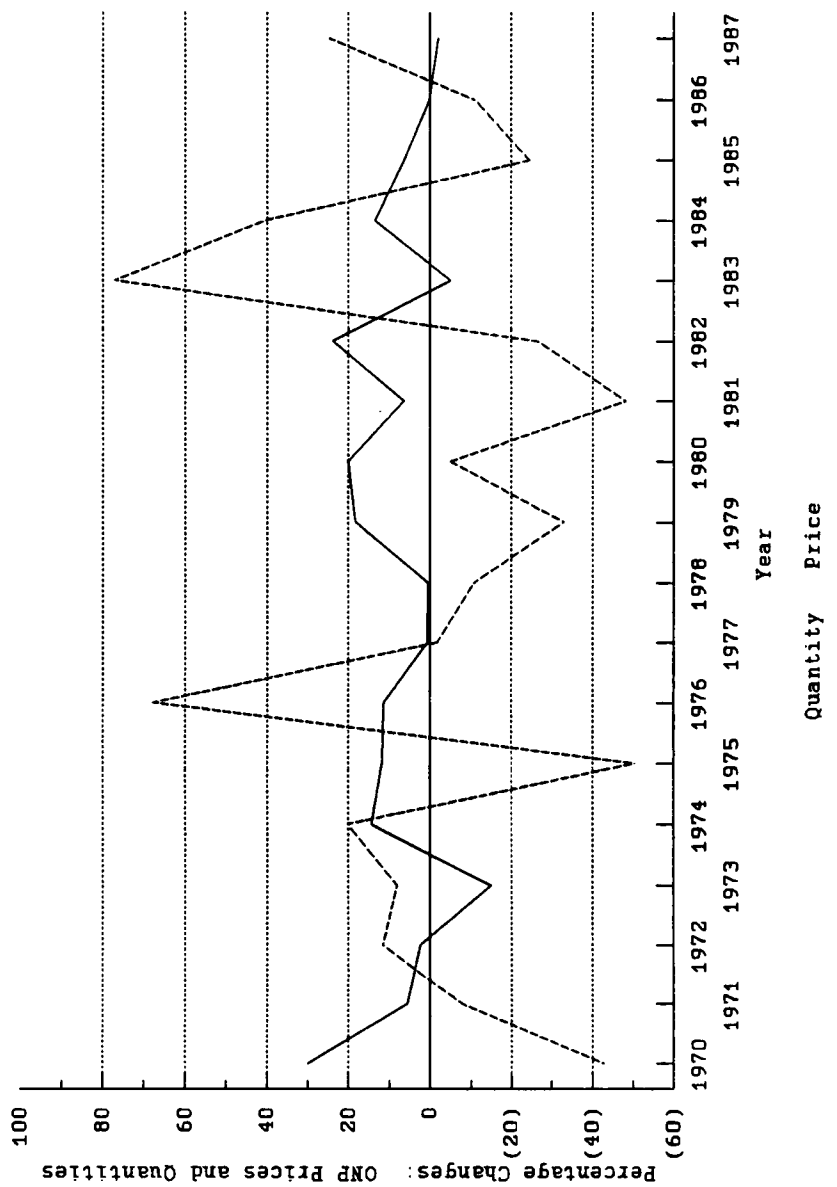
Figure IV-3
Producer Price Index for ONP
(January 1987-December 1990)

policies to shift the secondary material supply schedule without considering the nature of the demand schedule. At this point, it will be hypothesized that the reason that the price of ONP dropped so rapidly, is that the shifts in supply created by widespread implementation of separation and collection programs were coupled with a highly inelastic short-run ONP demand schedule. If this hypothesis is correct, then a more effective strategy will be to address the problem of increasing the rate of ONP recycling from the perspective of the potential consumer of ONP. In this study, the potential consumer of ONP is the newsprint producer.

Descriptively, the market for ONP as an input in newsprint production can be characterized by a relatively price-inelastic demand curve.³ In Figure IV-4, the percentage changes in the real price of ONP (as measured by the producer price index for ONP divided by the producer price index for all goods) are graphed against the percentage changes in the amount of ONP used to produce newsprint for 1970-1987.⁴ Note that, while the changes tend

³For the purposes of this discussion the standard definition of an elastic/inelastic demand curve will be used. The demand curve is defined as "elastic" if the price elasticity is greater than one and "inelastic" if the price elasticity is less than one.

⁴Data used to construct Figure IV-4 were taken from the Bureau of Labor Statistics Producer Prices and Price Indexes (ONP prices) and The American Paper Institute's Statistics of Pulp, Paper, and Board (ONP quantities).



to vary in the opposite direction as predicted by economic theory, the percentage change for prices tends to fluctuate more widely than the percentage change for quantities. Of course, all "other" factors were not held constant in the construction of Figure IV-4 and the changes observed do not represent movements along a single demand curve. For this reason, Figure IV-4 cannot be taken as conclusive evidence that the demand for ONP as an input in newsprint production is price-inelastic. Rather, Figure IV-4 merely suggests that the relative inelasticity of the ONP demand schedule may be a reasonable hypothesis.

Intuitively, there are reasons to believe that the market for ONP as an input in newsprint production can be characterized by a relatively inelastic demand schedule. The reasons lie in the market structure of the newsprint industry as well as in production processes for virgin and recycled newsprint. In Sections 4 and 5, the structure of the newsprint industry and the production processes for virgin versus recycled newsprint are examined in detail. The discussion provides the basis for the hypotheses that will be tested in Chapter V. These hypotheses will be formally stated in Section 6.

4. STRUCTURE OF THE NEWSPRINT INDUSTRY

Since 1940, the North American newsprint industry has been stable in comparison to the preceding years. Prices and capacity have increased steadily and there has been relatively little fluctuation in concentration ratios. Figure IV-5 illustrates the steady upward trend in prices while Figure IV-6 shows that, since 1940, concentration ratios have remained essentially unchanged. This stability has been attributed to an implicit price leadership system that emerged in the years just before World War II (Guthrie, 1941; Dagenais, 1976; Muller, 1978; Schaefer, 1979; McMurran, 1988).

Generally, while there is a consensus about price leadership in (and hence, the oligopolistic structure of) the newsprint industry, the type of price leadership practiced has been disputed. Muller (1978) modelled the price leadership system as a cost-plus-markup model, with the markup over cost being determined by a dominant firm. Dagenais (1976) applied the concept of entry-preventing price to the analysis of the newsprint industry's market structure. In Dagenais's study, the newsprint industry is modelled as implicitly adopting a mark-up price, the mark-up being set so as to maintain newsprint prices below the level that would attract new entrants. Schaefer (1979), noting that the price leader often changes and price changes are

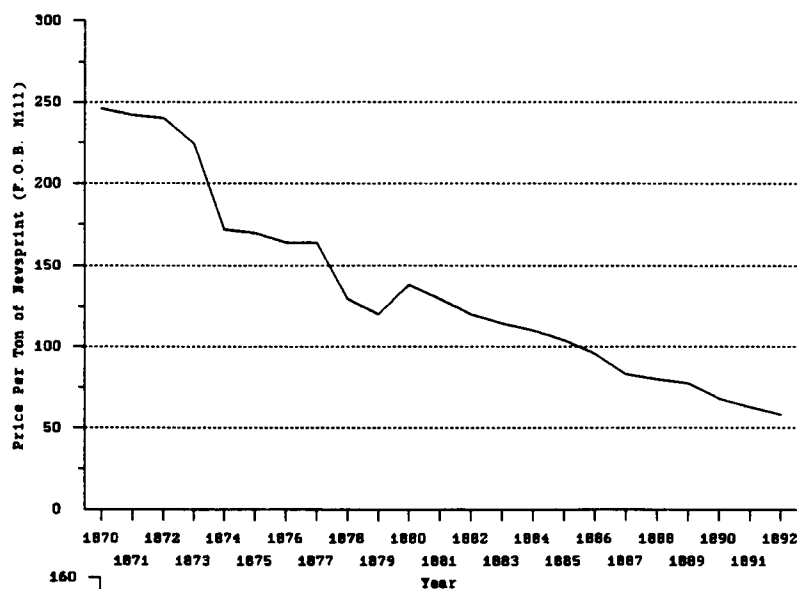
Figure IV-5

Price* of Newsprint

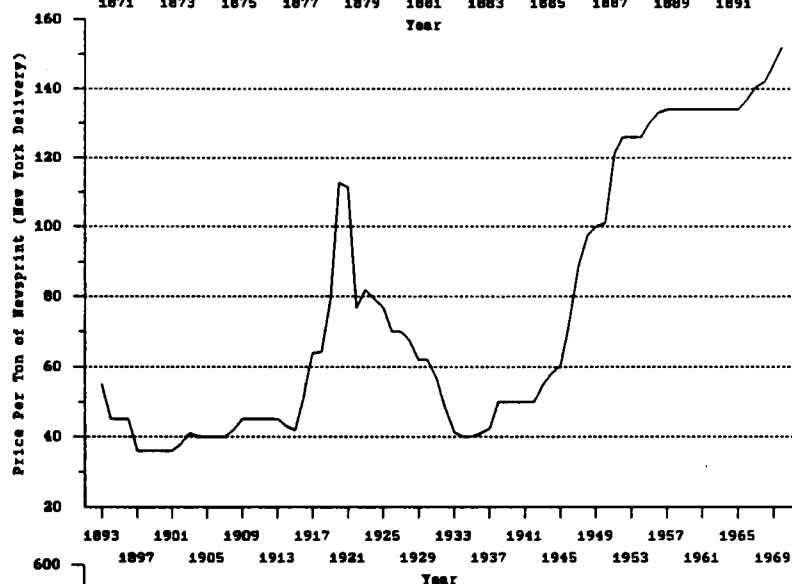
*Newsprint prices are measured differently in each of IV-5a through IV-5c. This is due to changes in the industry standard used to measure newsprint price in the industry. Prior to 1893, the standard was F.O.B mill. From 1893-1970, the standard measure was the New York Delivered price. After 1970, the measure of price was moved to a system of three regional base prices. The Eastern Delivered price was chosen for IV-5c because it is most comparable to the New York price.

Note: Data to construct Figure IV-5 were taken from Annual Newsprint Supplement; Miller-Freeman, 1989; Guthrie, 1941; and Muller, 1988.

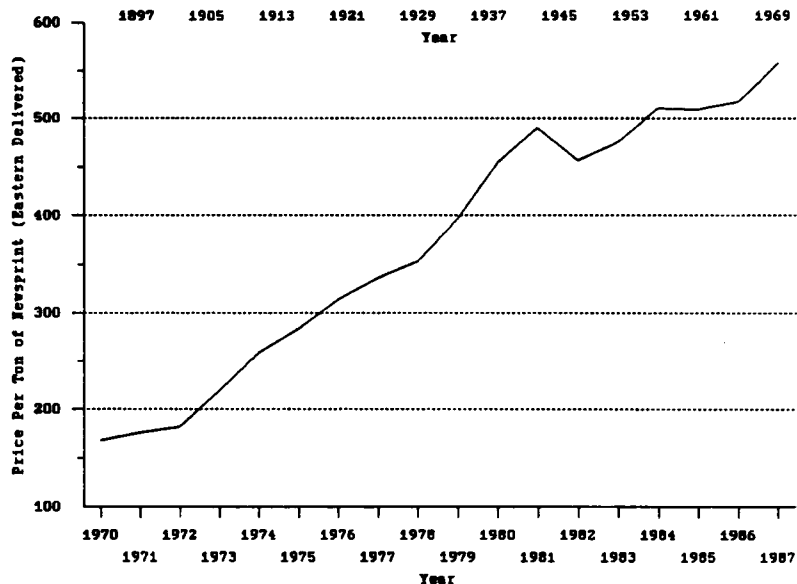
(a) 1870-1892



(b) 1893-1970



(c) 1970-1987



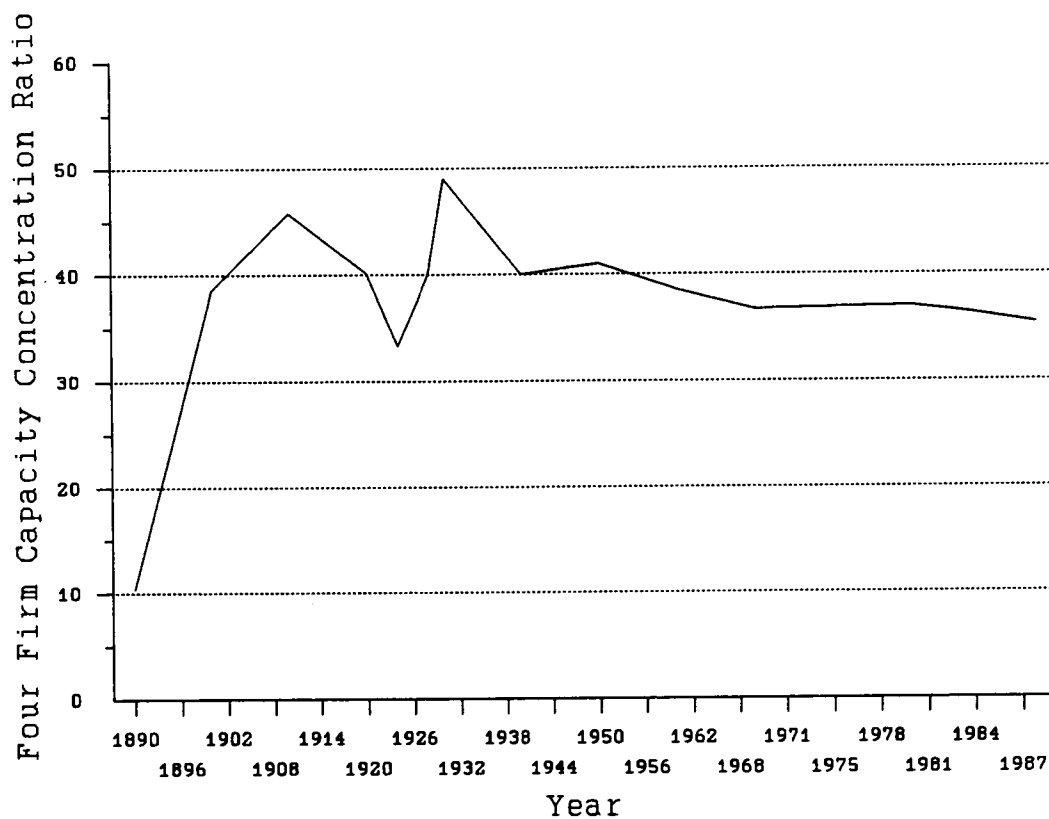


Figure IV-6
Four Firm Newsprint Capacity
Concentration Ratios
(1890-1987)

not always followed, argues that system is more closely approximated by a barometric price leadership model.

Regardless of the type of price leadership system practiced, there is evidence that it exists. Price leadership in the newsprint industry is documented by announcements of newsprint price changes in the paper industry trade journals. A few historical examples of price changes announced in the American Newspaper Publishers Association's Newsprint Bulletin appear in Table IV-1.

From 1972-1974, the announced price changes became extremely complex and will only be discussed briefly. In April of 1973, Bowater announced a price increase of \$5 per ton effective for July. Because of a price freeze announced by President Nixon, it was not implemented until September. Late in 1973, Bowater and Abitibi announced a price increase of \$15, which was to go into effect on January 1, 1974. This price increase was to be followed by another price increase of \$10 in July. Soon thereafter, International Paper announced a price increase of \$25. These price increases were followed, for the most part (Schaefer, 1979).

As for the 1980's, announcements of price changes continued to appear regularly in The Paper Trade Journal, and Pulp and Paper, and the Newsprint Bulletin as well in other business publications.⁵ This discussion indicates

⁵For some examples of these announced price changes as well as announcements to follow or not to follow the price changes in the 1980's see: "Bowater, Inc. Plans a 6.5%

Table IV-1
Price Leaders: Newsprint Industry

Year	Price Leader	Announced Price (\$US)	Final Price
1950	Powell	\$110	\$106
1951	Abitibi	116	116
1952	Abitibi	126	123- 125.50
1955	St. Lawrence	131	129-131
1957	Abitibi	134	134
1964	Macmillan-Bloedel	124	
1966	Crown-Zellerbach Bowater	134 144	139
1967	Consolidated	142	142
1969	International Bowater	147 152	146-147 151-152
1970	Anglo-Canadian	162	158-162
1971	International	165	165
1972	Kimberly-Clark Great Northern	163 170	163 170

Source: Schaefer, 1979.

Increase in its Newsprint Price to \$570 a Metric Ton for U.S. Customers, Effective April 1," The Wall Street Journal, November 14, 1984, p. 50; "Canadian Newsprint Producers Joining Move to Cut Prices," Editor and Publisher, the Fourth Estate November 15, 1982, p. 49; Gareau, G., "Producers Announce a 6% News Price Hike," Editor and Publisher, the Fourth Estate, November 15, 1986, p. 49; "News Price Hike for Jan. 1 Posted by Champion." Pulp and Paper, November, 1986 p. 29.

that the industry's rotating price leadership system is well-established and has been prominent since at least 1950.

There is an economic rationale for the emergence of this price leadership system. It has been argued that the price leadership system evolved in response to price wars, which prior to the 1940's had proved to be financially devastating to firms in the industry (Guthrie, 1941; McMurran, 1988). The newsprint industry, not unlike a public utility, is an industry where the benefits and feasibility of maintaining a competitive market structure are low since fixed (capital) costs are such a large proportion of total costs, about 40 percent (Miller-Freeman 1989; Guthrie, 1941).

In industries characterized by a large proportion of fixed costs, other devices (e.g., rate-regulation and price leadership) are necessary to prevent any one firm from gaining monopoly power. Without the establishment of a mechanism to control price competition, only one or two firms in the industry can survive. The firm that survives is the firm that cuts prices to expand output the most, thereby enjoying the greatest decrease in average costs and driving rivals out of business.⁶

⁶There is another reason that firms may be induced to cut price when there is a large number of firms in the industry and fixed (capital) costs are a high proportion of total costs. With large debt obligations associated with these fixed costs, firms may attempt to increase their cash flows by cutting prices and expanding output in order to meet their debt obligations (Lamoreaux, 1985).

Figure IV-7 illustrates the case where the presence of a large proportion of fixed costs causes average costs to decline over the relevant range of output, which is determined by the intersection of the market demand curve (D) and the horizontal axis. Competitive equilibrium requires that the output price equals marginal cost. Price is equated to marginal cost at the point where the market demand curve intersects the marginal cost curve. The perfectly competitive price, p_c , is lower than average cost, and the average firm in this industry will suffer a loss on every unit sold. Thus, a competitive solution in this industry cannot exist. The tendency in such an industry, as has been mentioned, is for the firms to engage in a "price war" in an effort to capture the entire market. The firm that survives is then able to charge the monopoly price, p_m . This tendency toward monopoly can be impeded with the adoption of some mechanism to control price competition. In the newsprint industry, the mechanism that has been adopted is an implicit price leadership system.

Besides the large proportion of fixed costs in total costs, there is another force that enhances the dynamic stability of this price leadership system. First, the demand for newsprint is highly price-inelastic since it is used primarily for newspaper publishing and there are no

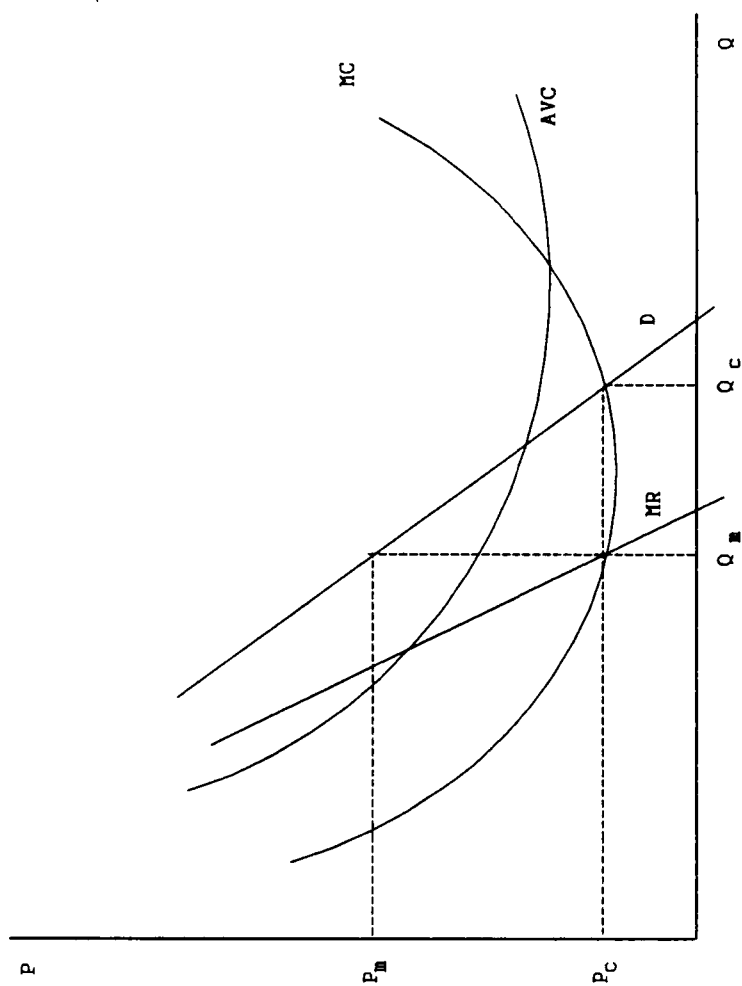


Figure IV-7

The Industry Characterized by Average Costs (AC)
Declining Over the Relevant Range of Output

close substitutes.⁷ The realization that the demand for their product is price-inelastic influences firms' "desire and willingness to act cooperatively" (Guthrie, 1941). When demand is price-inelastic, price decreases give rise to a less-than-proportionate increase in the quantities of newsprint purchased. For a given level of total costs, a price decrease will result in lower total revenues and lower profits. At the firm level, demand is, of course, more elastic and the gains from undercutting the prevailing price to gain a larger market share could be substantial. However, the knowledge that other newsprint firms will follow a price decrease and all firms involved will suffer from decreases in total profits is sufficient to prevent any one firm from taking such action.

The ability to maintain this market structure over time is also enhanced by the practice of newsprint mills signing long-term sales contracts, extending over several years, with newspaper publishers. Because of these contracts, newspaper publishers have a tendency to always purchase from the same sellers (Dagenais, 1976). Long-term contracts, then, increase the difficulty of new entrants gaining

⁷Muller (1976), for example, has estimated the price elasticity of demand for newsprint and found it not to be statistically different from zero. While the results of Muller's study are somewhat dated, there is no reason to believe that this demand elasticity has changed substantially over the past decade. No technological advancements have been made to find a substitute or a new use for newsprint.

admission into the market, or effectively erect a barrier to entry, even if potential entrants can sell below the prevailing price (Dagenais, 1976; Guthrie, 1941; Tirole, 1988).

The reason that the signing of these contracts has become an accepted practice is that both the newsprint producer and the publisher benefit. Contracts aid in newsprint producers' decisions to expand capacity or not. Building new capacity takes time, about three years, and can be costly. Thus, the signing of long-term contracts helps to reduce uncertainty for producers by assuring future sales outlets for their product before costly capacity expansions are made. Publishers benefit from these contracts as well. Even though newsprint is an almost homogeneous product, producers generally make it under slightly different specifications for each newspaper. Switching suppliers requires a period of adjustment for the publisher and new supplier to coordinate specification and this period of adjustment may be quite costly (Dagenais, 1976).

Guthrie (1941) and McMurran (1988) give historical evidence that the newsprint industry behaves according to the theory described above. In Figures IV-5 and IV-6, it can be seen that, prior to the emergence of price leadership, there were two periods of industry instability. These two periods of instability were characterized by intense (cut-throat) price competition. During the years

1890-1899, price competition and the resulting instability arose from technological advance in the newsprint production process. During 1925-1935, the source of instability was competition from Canadian producers (McMurran, 1988; Guthrie, 1941). These two periods of instability will now be discussed.

The modern newsprint industry began in the 1870's when wood replaced rags and straw as the major input in newsprint production. The transformation was made possible by the development of a new process in Germany during the 1840's. Wood was more plentiful than rags and straw and the costs of newsprint production declined.

One consequence was that the geography of the industry changed. The industry moved Northward and spread West, concentrating along the Wisconsin and Fox Rivers.

Another consequence was that the number of mills producing newsprint increased. The market now consisted of many sellers as indicated by low concentration ratios (see Figure IV-6). As would be predicted by the theory of an industry with a high proportion of fixed costs, the price of newsprint began to drop. In essence, the presence of a close-to-competitive market structure resulted in firms cutting prices in order to expand output, decrease average costs, and drive their rivals out of business.⁸ McMurran's

⁸The motives behind this price war can be disputed (see footnote 6). However, the motives are not of direct relevance to this study. Rather, the point that is being

research shows that, again as would be predicted by theory, the income returns of newsprint firms began to suffer as price decreases began to outweigh cost savings.

Instead of resulting in the survival of only one firm, however, price competition resulted in attempts at collusive behavior and mergers. In 1898, twenty-four newsprint firms were combined to form International Paper Co. This transformed the market from a competitive market into a dominant firm market (McMurran, 1988; Guthrie, 1941).

In 1911, newsprint was allowed in to the U.S. tariff-free for the first time, which prompted the second period of instability. During the period 1921-1935, Canada became a major producer of newsprint. Ontario and Quebec, with extensive timber and water resources, were ideal locations for newsprint firms. The number of firms in the newsprint industry again began to expand rapidly and concentration ratios declined.

In 1909, Canada supplied less than four percent of the newsprint consumed in the U.S. This percentage rose steadily in the following years. In 1913, Canadian mills supplied about 15 percent of U.S. consumption and by 1919 this percentage had reached over 33 percent. Table IV-2 illustrates this rapid expansion of Canadian exports to the

made here is that a close-to-competitive market has historically lead to cut-throat price competition and this is one reason for the adoption of price leadership in the newsprint industry.

Table IV-2
Growth in Canadian Imports to the U.S.
(1913-1940)

Year	Canadian Imports as a Percentage Of U.S. Consumption	Year	Canadian Imports as a Percentage Of U.S. Consumption
1913	14.7	1927	54.4
1914	17.8	1928	56.9
1915	21.8	1929	61.9
1916	25.9	1930	59.6
1917	27.6	1931	59.1
1918	34.3	1932	58.2
1919	33.1	1933	63.7
1920	30.9	1934	68.0
1921	32.1	1935	63.4
1922	36.7	1936	69.1
1923	39.8	1937	79.5
1924	42.1	1938	65.7
1925	43.6	1939	64.8
1926	51.3	1940	73.4

Source: Reader, 1981.

Note: After 1940 the ratio of Canadian imports to U.S. newsprint consumption continued to rise, but rose more slowly. After 1952, the ratio of Canadian imports to U.S. consumption began to fall.

U.S. As was true during the period 1890-1899, newsprint prices plummeted. Again, the end effect was an attempt to control price competition through the formation of trade associations, price and sales agreements, and mergers (McMurran, 1988).

McMurran also cites a historical example of the industry's ability to control price competition from potential new entrants, even if the entrants can produce at a lower total cost. In 1940, a potential source of disruption to this price leadership system was created. This was the expansion of capacity in the South. Before the 1940's, the southern pine was inappropriate for newsprint production since it had brown stains that were difficult to remove. A bleaching solution was discovered in the 1930's and improved upon in the 1940's and 1950's. Newsprint production costs declined in the South. As of 1988, the South still enjoyed a fiber cost advantage of about 16.9 percent over Canada and 27.9 percent over the Western U.S. (Miller-Freeman, 1989). The development of the southern pine technology did not prove to de-stabilize the price leadership system, though. While McMurran cites some incidents of price-cutting, overall, newsprint prices remained extremely stable. Instead of prompting a rapid capacity expansion, as in the periods 1890-1899 and 1925-1935, fiber cost advantages in the South produced gradual capacity expansion. By 1988, southern capacity still only

accounted for 19 percent of total North American capacity. McMurran attributes this, in part, to the industry's ability to control price competition through price leadership.

If the results of McMurran's research are correct, then a situation analogous to the development of southern pine technology is the development of technology to use deinked old newspapers (ONP) as the major material input in newsprint production. This advancement was prompted by the post-World War II "shortage" of newsprint. Newsprint was in short supply and consequently newsprint prices were so high that, in the early fifties, Richard B. Scudder (publisher and president of the Newark Evening News) set out to find a way to remove the ink from old newspapers and put the fibers back together as newsprint. Scudder needed more newsprint paper to publish a Sunday edition, but could not obtain enough at the price he was willing to pay.

The use of ONP as opposed to woodpulp had no raw material cost advantage. The real cost advantage was that an ONP-based mill did not require the huge investment at the back end of the process. Wood gathering, debarking, and pulping equipment were about 60 percent of the cost of building a new mill (Pulp and Paper, 1961). To Scudder, the development of recycled newsprint technology, then, was a relatively inexpensive means of expanding capacity to produce newsprint and to help alleviate the post-war "shortage" of newsprint (Pulp and Paper, 1973).

On October 26, 1961, Garden State Paper produced its first roll of commercial newsprint at a new mill in Garfield, New Jersey. Referred to as "Scudder's Folly" by some members of the paper industry, Garden State initially made newsprint at the rate of 100 tons per day. Garfield was an ideal location since New York City, where some of the world's largest newsprint consumers are located (and hence, where the largest supplies of ONP are located), is only 10 miles away. The first contracts were for \$10 under the New York price for newsprint (which was less than a 2 percent discount). The discount later was lowered to \$5 per ton.

While the opening of the Garden State mill was the most highly publicized early event in the development of recycling technology, Garden State was not the first to use deinked stock successfully. Manistique Paper in Michigan, a subsidiary of the Chicago Sun-Times reported several years earlier that it was successfully using deinked newspapers. In 1959, Manistique Paper was using 10,000 tons of ONP and magazine waste per year. According to Manistique officials, use of deinked wastepaper saved \$30 per ton (Editor and Publisher, 1959). In contrast to Garden State, Manistique sold its recycled newsprint to a captive market.

In February 1967, Garden State opened a second mill in Pomona, California, near the Los Angeles area. The \$10 million Pomona mill reportedly consumed 60,000 tons of ONP per day. A third mill opened in 1968 in the Chicago area.

It was not until 1979, however, that Garden State's deinking technology was licensed to another newsprint producer, Southeast Paper in Dublin, Georgia. At about the same time, Publishers Paper, a newsprint producer located in Newberg, Oregon came online with a 250 ton per day deinking system.

Thus, the diffusion of recycling technology has proceeded slowly, despite the reported lower costs for producing newsprint with deinked newspapers. This is analogous to the development of southern pine technology. In 1989, only eight out of 24 mills in the U.S. were ONP-based. These mills represent approximately 25 percent of total U.S. capacity and not all produce 100 percent recycled newsprint. In Canada, only three percent of capacity utilizes recycled fiber. Recycled newsprint capacity in both the U.S. and Canada amounted to less than 10 percent of total North American newsprint capacity in 1989.

While the diffusion of ONP technology has proceeded slowly, the rate of use of ONP as an input in newsprint production still has followed a steady upward trend. During the years 1958-1987 (which is the time period chosen for the empirical analysis in Chapter V), the amount of secondary fiber used to produce newsprint in the U.S. increased from essentially zero in 1958 to 1,386 thousand short tons in 1987 (American Paper Institute, 1988). Figure IV-8 illustrates this trend. The empirical analysis in Chapter V

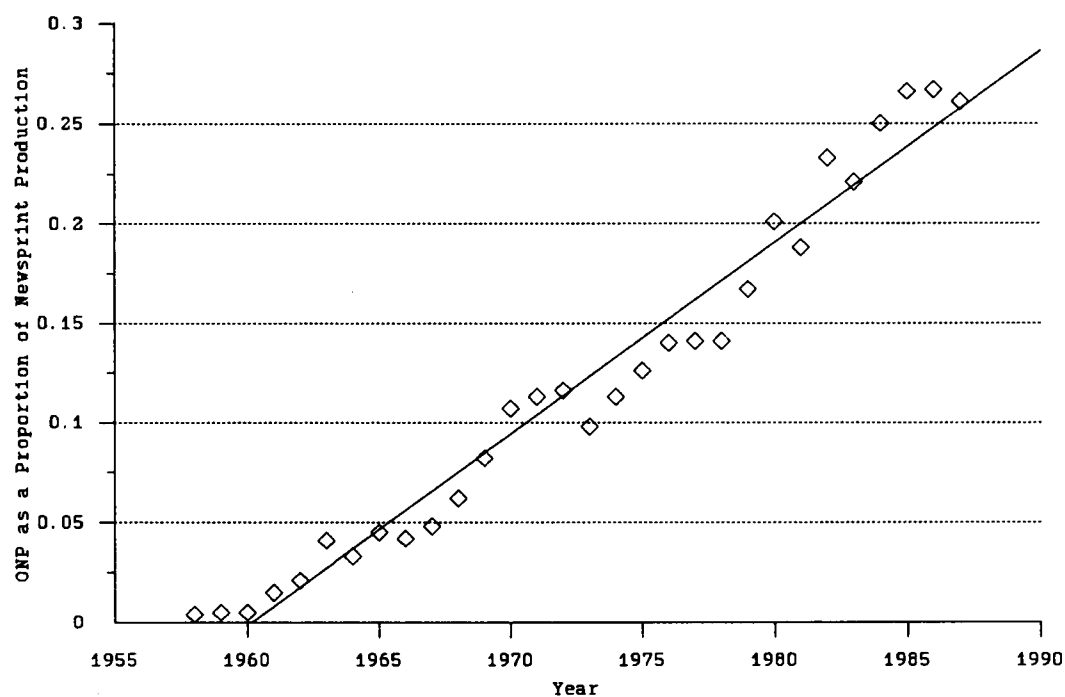


Figure IV-8

Recycling Trends: The U.S. Newsprint Industry
(1958-1987)

will attempt to explain the key factors that caused this expansion.

5. THE VIRGIN VS. RECYCLED NEWSPRINT PRODUCTION PROCESSES

Virgin newsprint production consists of three phases: pulpwood collection, woodpulp manufacturing, and papermaking. In contrast, recycled newsprint production consists of two phases: deinking of wastepaper and papermaking. The only real difference between the two processes is at the fiber production stage. However, the difference at this point of manufacture is considerable.

Pulpwood is generally collected in the late summer. Trees are cut into logs and piled. In the spring, the logs are shipped to the woodpulp manufacturer.

There are two basic types of woodpulp production. In groundwood production, pulpwood logs first are debarked, then cut into bolts. The bolts are forced against grinders driven by water or electric power to separate the wood fibers. This stage of production requires large amounts of water and power. The wood fibers are washed into a pit below and large particles are removed by screening. The fiber mash (mechanically produced woodpulp) that results from this stage of production is dried for shipment or directly fed into a paper machine in an integrated mill. In the sulphite process, logs are debarked, cleaned, and chipped before they are fed into a digester (a large steel

tank). In the digester, the pulpwood is mixed with an acidic solution (usually based on calcium, sodium, or magnesium bi-sulphite) and cooked under great pressure for several hours until half of the wood volume is dissolved, leaving cellulose behind. Again, the slurry can either be dried for shipment or fed directly into a paper machine. Generally, it is uneconomical to dry and ship the product of the woodpulping stage so all virgin fiber newsprint mills in the U.S. are located close to wood supplies, in conjunction with pulping facilities (Iannazzi, 1989).

In the virgin newsprint paper making process, groundwood and sulphite woodpulp (woodpulp produced in the sulphite process) are mixed in certain proportions, which varies from mill to mill. Groundwood, however, makes up the bulk of the fiber used in most virgin newsprint mills. If the woodpulp is dry, it is mixed with a water to form a solution of about 95.5% water. Otherwise, it is directly fed through a fourdrinier paper machine and pressed into a sheet of paper.⁹

In recycled newsprint production, collection of fiber is generally done outside of the industry (either through a separation and collection program or wastepaper dealer).

⁹The fourdrinier is the most common type of papermaking machine. The machine takes wet pulp in one end and passes it in a thin layer, first over wire mesh, then between pressure rollers, and finally through heated rollers. The objective of these processes is to remove all of the water from the pulp and convert it into a continuous sheet of paper.

Since the paper-making stage in recycled newsprint production is the same as in the virgin process, the only difference between the two processes is in the fiber pulping stage.

In recycled newsprint production, the fiber processing stage consists mainly of deinking wastepaper. Two types of deinking processes currently exist. In the washing process, ONP is mixed with a deinking chemical and water and pulped. After the wastepaper fibers are separated from foreign materials, they are washed to remove the deinking chemicals. In the flotation process, ink is separated from wastepaper by physical means. Once the wastepaper is repulped, it is transferred through a series of flotation tanks where the pulp is aerated. Bubbles of ink rise to the surface and accumulate at the top of the tank. Paddles remove the ink scum. In contrast to the washing process, the flotation process requires the presence of old magazines. The clay content of old magazines is necessary for efficient operation of the system. In 1989, only one recycled newsprint mill used the flotation process for ink removal.

Figure IV-9 illustrates the interrelationship between virgin and recycled newsprint manufacture. In 1987, about ten percent of the newsprint consumed in the U.S. was recycled into newsprint. This is depicted by pathway 1 in the diagram. Pathway 2 represents the 15 percent of post-consumer newsprint that was used as fiber for other paper

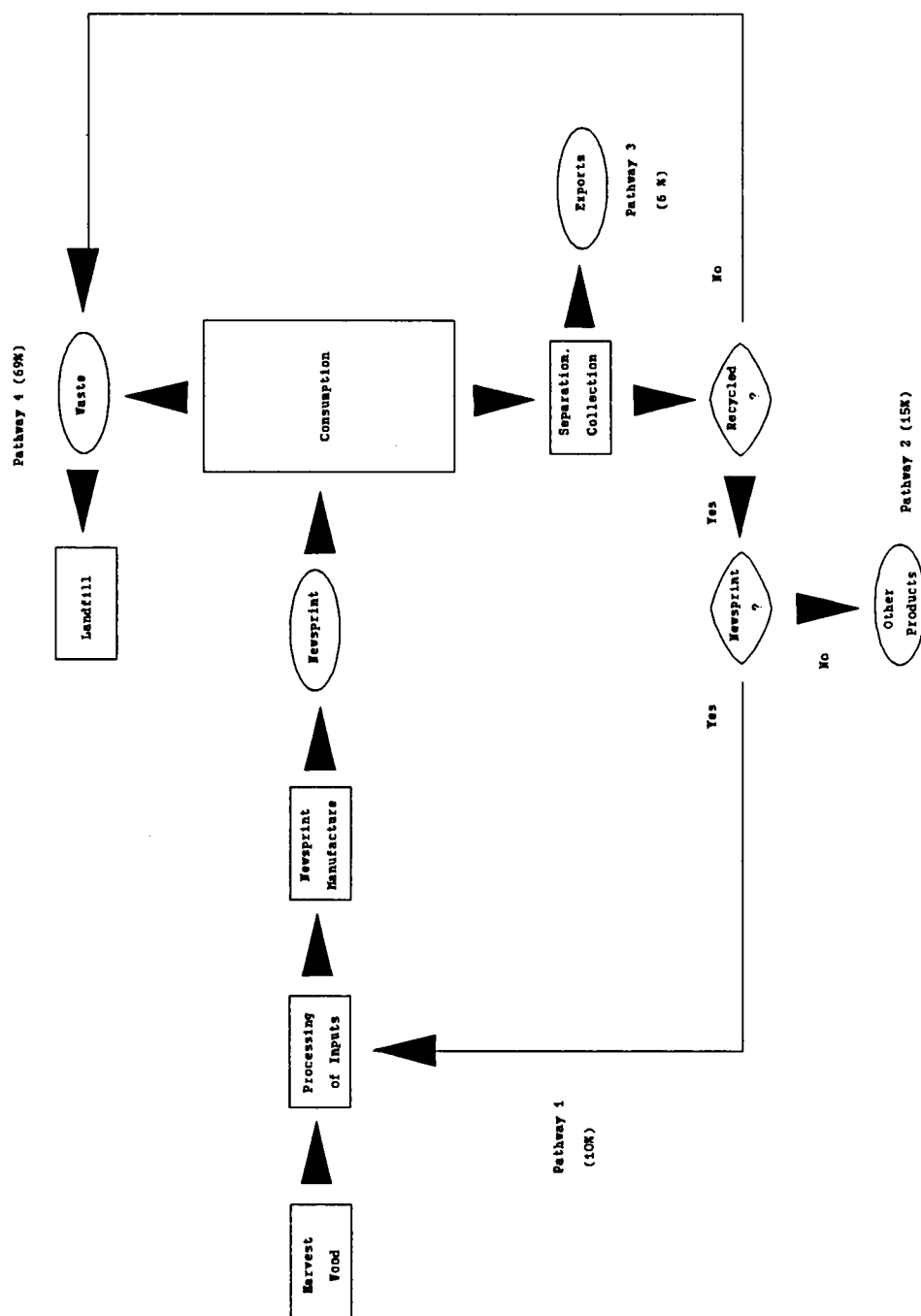


Figure IV-9
The ONP Generation and Disposal System

and board products. Pathway 3 indicates that six percent of ONP was exported. Thus, only 31 percent of the newsprint consumed in the U.S. in 1987 was recycled (Iannazzi, 1989). The remainder (69 percent) was disposed of in landfills or incinerators as illustrated by pathway 4.

6. ONP RECYCLING: THE PROBLEM DEFINED

Recycling legislation has dealt with the problem of increasing the rate of ONP recycling in two ways. First, is the supply-side legislation (e.g., mandatory source separation, banning disposal of newspapers, and variable landfill fees) as discussed in Chapter II. The second is mandatory content legislation, to which some states have resorted.

Descriptively, supply-side legislation has not been very effective at boosting the rate of recycling in the newsprint, in the short-run at least. At this point, it will be asserted that the reason is that the demand curve for ONP is relatively price inelastic. Also, due to the newness of mandatory content legislation and the generous time frames given for newspaper publishers to increase their purchases of recycled newsprint, the effects of these policies probably have not been observed.¹⁰ More will be

¹⁰It should be noted that, in the empirical analysis presented in Chapter V, it can be said with certainty that these policies have not had any influence on the rate of ONP recycling since the legislation was adopted after time series used.

said about the efficacy of "mandatory content" legislation in the future in Chapter V, in the context of the empirical model.

At this point, the reasons for the elasticity of the ONP demand schedule will be summarized in the context of the theory presented in Chapter III as well as in the context of the discussion of the structure of the newsprint industry and the production processes for virgin versus recycled newsprint. To do this, the following two equations will be used:

$$(IV-2) \quad \left(\frac{D}{D'} + P \right) f_{ONP} = P_{ONP}$$

$$(IV-3) \quad \epsilon_{ONP, Pj} = S_j(\sigma_{jONP} - \epsilon) , \quad j = ONP, \text{ Woodpulp, Capital} .$$

Equation IV-2 is recognized as the input demand equation for ONP, which was derived in Chapter III (see equation III-4). Recall, this is the condition for the profit-maximizing usage level of ONP. Equation IV-2 is interpreted as the firm will employ the ONP up until the point where the addition to total revenue (marginal revenue product) is just equal to the addition to total cost (marginal resource cost). Equation IV-3 is just the general formula for the responsiveness of the usage rate of ONP to any price change (see equation III-20). The only difference in the above equations is that the subscript "1," used to denote the recycled input in Chapter III, has been

replaced with the subscript "ONP," the recycled input in the newsprint industry. Further, the subscript "j" from Chapter III is limited to the inputs of ONP, woodpulp, and capital since the relationships among these inputs provide the basis for the hypotheses that will be tested in Chapter V.

In the short run, inelasticity of the derived demand for ONP is obvious. There are only eight plants in the U.S. that produce recycled newsprint. Further, U.S. capacity supplies only two-fifths of the total domestic demand for newsprint. The rest is imported primarily from Canada where only three percent of capacity produces recycled newsprint (Iannazzi, 1989). A limited capacity for recycled newsprint production creates a bottleneck in the ONP recycling system since, as was discussed in Section 5, the type of pulping capacity used for woodpulp is not the same as the type used for ONP.

Due to differences in pulping technology, an increase in the use of ONP will require that the industry alter its capital so that it is capable of utilizing larger quantities of ONP. In other words, one reason that supply-side legislation does not evoke the proper demand response from newsprint producers is that each type of existing newsprint capital is committed in its use of materials inputs. Therefore, while ONP and woodpulp are potential substitutes in newsprint production, each is tied to specific capital. In the context of equation IV-3, this "unadaptability" of

existing capital limits the size of the elasticity of substitution of ONP for woodpulp, $\sigma_{\text{ONP, Woodpulp}}$. Because installed production technology constrains the size of $\sigma_{\text{ONP, Woodpulp}}$, it is expected that the size of the response of the demand for ONP to a change in its own price ($\epsilon_{\text{ONP, pONP}}$) as well as a change in the price of woodpulp ($\epsilon_{\text{ONP, pWoodpulp}}$) would be limited.

In the long-run, the reasons for the inelasticity of the ONP demand curve are not quite so obvious since, over time, the industry will be able to alter its fixed input (capital) so that it is more capable of utilizing secondary fiber. Separation and collection programs will assure that the relative price of ONP is lowered over the long-run. Lower prices "should" create an incentive for the newsprint industry to alter its capital in favor of recycled newsprint production by generating a new, higher equilibrium level of ONP use. However, because newsprint production has evolved around the use of virgin fiber, the newsprint industry will approach the new equilibrium neither instantaneously nor costlessly. The major barrier to increased recycling at the industry level will be the adjustment costs inherent in switching production technology.

Because of these adjustment costs, future additions to capacity may not result in a rapid shift toward ONP-based mills. The location of existing mills coupled with the high capital costs associated with building a new mill may

partially offset an economic environment that would otherwise favor substituting ONP for virgin fiber.

The product of the pulping stage of the newsprint making process is a highly dilute slurry of pulp and a large amount of water. It is uneconomical to dry and ship the pulp so all virgin fiber newsprint mills in the U.S. are located close to wood supplies rather than urban areas, the source of large supplies of ONP (Iannazzi, 1989). Location places economic limitations on the extent to which ONP can be used to gradually expand the capacity of existing mills. Large amounts of ONP may not be able to be shipped the longer distances cost-effectively.

The location of existing mills suggests that the key to increasing newsprint recycling is to build new recycled newsprint mills close to the large supplies of ONP. The total capital cost for an ONP-based mill is significantly lower than for a virgin-fiber mill, since a huge investment in wood gathering and debarking equipment is not required. However, the cost of building a new mill is up to 50 percent more than the cost of expanding an existing one (OTA, 1989). Therefore, it still may be less expensive to expand an existing woodpulp-based mill than to build a new ONP-based mill.

The adjustment costs associated with this capital cost differential and with locational considerations could conceivably outweigh any reduction in production costs

attributable solely to a lower price for ONP and dampen the industry's response to ONP price changes. In the context of equation IV-2, the existence of adjustment costs affects the "true" marginal resource cost of ONP by raising its effective price. Including these adjustment costs, IV-2 can be rewritten as:

$$(IV-2a) \quad \left(\frac{D}{D'} + P \right) f_{ONP} = P_{ONP} + AJ$$

where AJ denotes adjustment costs.

For the discussion of the effects of adjustment costs, it will be assumed that the term in brackets remains constant. Further, it will be assumed that the effect of adjustment costs is to no more than exactly offset the effects of a decline in the price of ONP. If $AJ = 0$, then a decline in the price of ONP will result in the firm increasing its usage rate of ONP in order to lower its marginal product (f_{ONP}) and hence, maintain the above equality. However, if the adjustment costs partially offset the decline in p_{ONP} , the firm will not need to increase its usage rate of ONP by as large of an amount to maintain the above equality. If the adjustment costs associated with increased ONP use are exactly equal to the price decline, the firm will not alter its usage of ONP at all.

Further, in Chapter III, it was shown that the rate of recycling also depends upon the type and strength of the

relationship between the secondary material and all other productive factors. These "other factors," the price of capital in particular, may be more important determinants of the rate of ONP recycling than the price of ONP taken in isolation. That is, in terms of IV-2, $\epsilon_{\text{ONP}, p\text{Capital}}$ may be larger than both $\epsilon_{\text{ONP}, p\text{ONP}}$ and $\epsilon_{\text{ONP}, p\text{Woodpulp}}$.

From equation IV-3, it is seen that the response to changes in the price of the ONP will be affected by the fraction of total costs accounted for by the primary input. If purchases of the primary input, woodpulp, account for a high percentage of total costs, a reduction in the price of ONP will give rise to a larger response on the part of the consuming industry than if woodpulp accounted for small percentage of total costs. On average, in the U.S., woodpulp accounts for 20.4 percent of the total cost of newsprint production (Pulp and Paper, 1983). Thus, if the price of ONP declined by 50 percent, all other things held constant, the total savings in production costs would be 10.2 percent. If woodpulp accounted for 50 percent of the costs of producing newsprint, then the savings in production costs would be 25 percent and the incentive to switch to ONP-based mills created by lower ONP prices would be much larger. Further, given the fact that increases in ONP use will require investment in capacity capable of utilizing ONP (e.g., all other things cannot be held constant), the savings in production costs generated by lower ONP prices

alone will be less than 10.2 percent and this also acts to reduce the incentive to switch generated by lower ONP prices. The effects of the share of woodpulp in total costs on the elasticity of the derived demand for ONP will not be assessed empirically. The share of woodpulp in total newsprint production costs is offered as another justification for the hypothesis that the demand for ONP may be price-inelastic in both the short- and long-run.

A final consideration is oligopolistic inertia, which has been created by a well-established price leadership system. If the results of McMurran's research (described in Section 4 above) are correct and the system has effectively slowed expansion of capacity in the South, despite definite cost advantages, then it is possible for the system to impede the diffusion of recycling technology. Even if the results of McMurran's research are not correct, however, it was shown in Chapter IV, that when the firm operates under conditions of imperfect competition in the output market that there is a "marginal revenue effect" that dampens the firm's response to input price changes. Since the output market will not be analyzed in Chapter V, the effects of the oligopolistic structure of the newsprint industry on the demand for ONP will not be tested empirically. Rather, it is simply offered as another possible reason that the demand for ONP may be price-inelastic in the long-run.

One reason for the tendency toward this price-

leadership system that was discussed in Section 4 lies in newspaper publishers' relative unresponsiveness to newsprint price changes. The effects of inelasticity of the demand for newsprint on the derived demand for ONP can be described in terms of equation IV-3. Note that in IV-3, the responsiveness of the demand of ONP to any input price change is dependent upon the value ϵ , which, in this case, is the price elasticity of demand for newsprint. The larger is the value for ϵ , the larger is the expected response to changes in input prices. Again, since the newsprint output market will not be the object of this study, the effects of the size of the price-elasticity of demand for newsprint on the demand for ONP will not be tested empirically. As was the case with the share of woodpulp in total costs and the oligopolistic structure of the industry, the relative inelasticity of the demand for newsprint is just offered as an additional rationale for the hypothesis that the derived demand for ONP is price-inelastic.

In summary, the explanation for the inelasticity of the ONP demand schedule in the short-run that has been offered at this point is the unadaptability of existing capital. In the long run, the possible reasons for the inelasticity of the ONP demand schedule are 1) the existence of adjustment costs associated with switching production technology, 2) the manner in which ONP is tied to the cooperating input, capital, 3) the relatively small percentage of total

production costs accounted for by the virgin input, woodpulp, 4) oligopolistic inertia created by a well-developed price leadership system and 5) the low value for the elasticity of demand for newsprint.

The hypotheses that will be tested in Chapter V will now be summarized:

$$\begin{array}{llll}
 H_1: & \epsilon_{ONP, pONP} & < & 1 \\
 H_2: & \epsilon_{ONP, pWoodpulp} & < & 1 \\
 H_3: & \sigma_{ONP, Woodpulp} & < & 1 \\
 H_4: & \epsilon_{ONP, pCapital} & > & \epsilon_{ONP, pONP} \\
 H_5: & \epsilon_{ONP, pCapital} & > & \epsilon_{ONP, pWoodpulp}
 \end{array}$$

H_1 is just simply the hypothesis that the derived demand for ONP is price-inelastic in both the short- and long-run. H_2 is the hypothesis that the demand for ONP will not be relatively responsive to changes in the price of woodpulp in either the short- or long-run. H_3 is the hypothesis that difficulty in substitution between ONP and woodpulp in the long-and short-run, caused by the unadaptability of capital is a reason for the inelasticity of the ONP demand schedule. H_2 and H_3 together can be taken as assessment of the long- and short-run substitutability of ONP and woodpulp. H_3 and H_4 together are the hypotheses that the price of capital is a more important determinant of ONP recycling the newsprint industry than is either the price of ONP or the price of woodpulp taken in isolation.

Testing these hypotheses will require that a functional

form is specified for IV-12 so that the parameters can be estimated using econometric techniques. The estimated parameters will be used to calculate the elasticities in order to test the hypotheses stated above. The first part of Chapter V will be devoted to developing the empirical specification of IV-12.

CHAPTER V

A MODEL OF THE DEMAND FOR ONP AS A PRODUCTIVE INPUT

1. THEORETICAL SPECIFICATION

Models of production are often based on the assumption that each observation for input use levels represents a full static equilibrium quantity. This is not a tenable assumption for every production process. A departure from the full static equilibrium assumption is justified when the firm cannot adjust quickly to a desired production technique without incurring a substantial cost beyond the direct rental charges of factors. These costs can be attributed to internal or external costs of adjustment to different input use levels. In the presence of these adjustment costs, a more plausible assumption is that the firm is in equilibrium with respect to a subset of inputs conditional on the remaining inputs. This condition is called partial static equilibrium.¹

The newsprint industry is a case where departure from the assumption of full static equilibrium is justified. The material inputs of woodpulp and ONP are capital- specific.

¹An alternative to this partial static equilibrium specification is to model the factor demands as truly dynamic. An attempt to model the newsprint input demand equations dynamically was made. Briefly, in this alternate specification, the input demand equations were derived as a solution to an optimal control problem. Estimation of these input demand equations, however, yielded parameter estimates that did not converge.

Further, the industry is unable to alter its usage level of either without incurring substantial adjustment costs.

Let us begin by specifying a general production function of the form:

$$(V-1) \quad Q = f(K, L, E, M_1, M_2, T) \quad .$$

K , L , E , M_1 , M_2 , and T represent capital, labor, energy, woodpulp, secondary fiber (ONP), and technology, respectively.

If the production function has convex isoquants and costs are minimized for every level of output, then there exists a dual total cost function of the form:

$$(V-2) \quad TC = TC(Q, P_K, P_L, P_E, P_{M1}, P_{M2}, T) \quad .$$

P_K , P_L , P_E , P_{M1} , and P_{M2} are the respective input prices. However, if costs are minimized with respect to the variable inputs for every level of output and the level of a fixed factor K associated with that output level, then the dual restricted variable cost function takes the form:

$$(V-3) \quad VC = VC(Q, P_L, P_E, P_{M1}, P_{M2}, K, T) \quad .$$

The short-run demand equations can be obtained for the variable inputs by applying the Shepard-Uzawa-McFadden lemma, which states that the cost-minimizing demand levels for the variable inputs are given by the first partial derivative of the dual variable cost function with respect to the prices of the variable inputs:

$$(V-4) \quad Q_i = \frac{\partial VC}{\partial P_i} = VC_i(Q, P_L, P_E, P_{M1}, P_{M2}, K, T) ,$$

$$i = L, E, M_1, M_2 .$$

Samuelson (1953, pp. 19-20) has shown that the partial derivative of the restricted variable cost function with respect to the fixed input, K , must equal the negative of its rental price, P_K ,

$$(V-5) \quad -P_K = \frac{\partial}{\partial K} VC(Q, P_L, P_E, P_{M1}, P_{M2}, K)$$

$$= VC_K(Q, P_L, P_E, P_{M1}, P_{M2}, K) .$$

The long-run cost-minimizing level for K , K^* , can be obtained by solving the above expression for K :

$$(V-6) \quad K^* = VC^*(Q, P_K, P_L, P_E, P_{M1}, P_{M2}) .$$

Once we specify a functional form for VC , we can derive estimating equations for the demand for variable inputs (short-run) as well as the optimal level of the fixed input K by applying V-4 and V-5.² Then, it will be relatively easy to obtain estimates for the short-run price elasticities of demand and substitution elasticities among the variable inputs. Since K is assumed to be fixed in the short-run, these elasticities will not be defined between K and the variable inputs. We can also obtain long-run price and substitution elasticity estimates between the variable

²At this point it will be noted that the ability to derive a closed-form expression for K^* depends upon the choice of functional form.

inputs and between K and the variable inputs. Thus, estimating the short-run equations and the equation for K^* will completely characterize both the short-run and the long-run. These concepts will be developed more completely in terms of the empirical specification of the model.

2. EMPIRICAL SPECIFICATION

For the empirical analysis, a normalized quadratic approximation to the unit variable cost function has been chosen. The quadratic form has advantages in that it places no a priori restrictions on the substitution elasticities. Further, the Hessian of second-order partial derivatives is a matrix of constants, which facilitates derivation of elasticity estimates. The most important advantage is that it allows analytical derivation of a closed-form expression for K^* . The only disadvantage is that parameter estimates will not be invariant to the choice of numeraire input.³ The approach that will be taken here is to adopt the convention of normalizing by the price of labor.

The normalized restricted average variable cost function takes the form:

³The Generalized Leontief is another functional form that allows for the derivation of a closed form expression for the optimal level of capital stock. This functional form has the additional benefit that parameter estimates are invariant with respect to the choice of numeraire input. Estimation using the Generalized Leontief, as was the case with the dynamic specification for the newsprint input demands, yielded parameter estimates that did not converge.

$$\begin{aligned}
 AVC &= \frac{1}{Q} (L + P_E E + P_{M1} M_1 + P_{M2} M_2) \\
 &= \alpha_0 + \alpha_{0T} T + \sum_j \alpha_j P_j + \sum_j \alpha_{jT} P_j T \\
 (V-7) \quad &+ \frac{1}{2} \sum_i \sum_j \delta_{ij} P_i P_j + \alpha_K \frac{K}{Q} + \frac{1}{2} \alpha_{KK} \left(\frac{K}{Q} \right)^2 \\
 &+ \sum_j \gamma_{jK} P_j \frac{K}{Q} + \alpha_{KT} \frac{K}{Q} T, \\
 &\quad i, j = E, M_1, M_2.
 \end{aligned}$$

P_E , P_{M1} , and P_{M2} are normalized by the price of labor.

By applying V-4, we can derive input-output equations for E , M_1 , and M_2 . The input-output equation for L is derived by substituting the input-output equations for E , M_1 , and M_2 into AVC and solving for L . The derivation of these equations is presented in detail in the appendix.

$$\begin{aligned}
 \frac{E}{Q} &= \alpha_E + \sum_j \delta_{Ej} P_j + \alpha_{ET} T + \gamma_{EK} \frac{K}{Q} \\
 \frac{M_1}{Q} &= \alpha_{M1} + \sum_j \delta_{M1j} P_j + \alpha_{M1T} T + \gamma_{M1K} \frac{K}{Q} \\
 (V-8) \quad \frac{M_2}{Q} &= \alpha_{M2} + \sum_j \delta_{M2j} P_j + \alpha_{M2T} T + \gamma_{M2K} \frac{K}{Q} \\
 \frac{L}{Q} &= \alpha_0 + \alpha_{0T} T - \frac{1}{2} \sum_i \sum_j \delta_{ij} P_i P_j + \alpha_K \frac{K}{Q} \\
 &\quad + \alpha_{KT} \frac{K}{Q} T + \frac{1}{2} \alpha_{KK} \left(\frac{K}{Q} \right)^2
 \end{aligned}$$

The estimating equation for the optimal capital stock is just as easily obtained by applying the relationship V-5:

$$\begin{aligned}
\frac{\partial AVC}{\partial \frac{K}{Q}} &= -P_K \\
(V-9) \quad &\rightarrow \alpha_K + \alpha_{KK} \frac{K}{Q} + \sum_i \gamma_{Ki} P_i + \alpha_{KT} T = -P_K \\
&\rightarrow \left(\frac{K}{Q} \right)^* = -\frac{1}{\alpha_{KK}} \left[\alpha_K + \sum_i \gamma_{Ki} P_i + \alpha_{KT} T + P_K \right] .
\end{aligned}$$

Since K^* is not observed, we must re-write equation V-9 in terms of observed variables, or in terms of K . To do this, let us specify a partial adjustment scheme. That is, we will assume that the difference between the observed current-period and next-period capital stock represents a partial adjustment to the optimal level of K , or K^* :

$$\begin{aligned}
\left(\frac{K}{Q} \right)_{+1} - \left(\frac{K}{Q} \right) &= (1 - \lambda) \left[\left(\frac{K}{Q} \right)^* - \left(\frac{K}{Q} \right) \right] \\
&= (1 - \lambda) \left[\left(-\frac{1}{\alpha_{KK}} \right) \left(\alpha_K + \sum_i \gamma_{Ki} P_i + \alpha_{KT} T + P_K \right) \right] \\
(V-10) \quad &- (1 - \lambda) \left(\frac{K}{Q} \right) \\
&\rightarrow \left(\frac{K}{Q} \right)_{+1} = (1 - \lambda) \left[-\left(\frac{1}{\alpha_{KK}} \right) \left(\alpha_K + \sum_i \gamma_{Ki} P_i + \alpha_{KT} T + P_K \right) \right] \\
&\quad + \lambda \left(\frac{K}{Q} \right) .
\end{aligned}$$

To summarize, five equations are to be estimated: the four variable input-output demand equations (V-8) and the capital-output equation (V-10). For purposes of estimation, an additive disturbance is appended to each of the equations. Note that since simultaneity is not a problem, the system of equations can be estimated by using iterative

Zellner techniques.⁴

Finally, expressions for the short-run, intermediate-run, and long-run price and substitution elasticities will be derived. These elasticities will completely summarize the dynamic behavior of factor demands for the newsprint industry. In the tradition of Marshall, the short-run elasticities will be defined as those elasticities observed when K is fixed. The intermediate-run elasticities are the elasticities observed when K has partially adjusted. The long-run elasticities will be defined as the elasticities observed when K has fully adjusted to K^* . The short- and long-run price elasticities are

$$\begin{aligned}
 \epsilon_{Q_i, P_j}^{SR} &= \left[\frac{P_j}{Q_i} \right] \left[\frac{\partial Q_i}{\partial P_j} \right]_{K=\bar{K}} = \delta_{ij} \left(\frac{P_j}{Q_i} \right) \\
 (V-11) \quad \epsilon_{Q_i, P_j}^{LR} &= \left[\frac{P_j}{Q_i} \right] \left[\frac{\partial Q_i}{\partial P_j} \right]_{K=\bar{K}} + \left[\frac{P_j}{Q_i} \right] \left[\frac{\partial Q_i}{\partial K^*} \frac{\partial K^*}{\partial P_j} \right] \\
 &= \left[\frac{P_j}{Q_i} \right] \left[\delta_{ij} - \frac{\gamma_{Ki} \gamma_{Kj}}{\alpha_{KK}} \right] .
 \end{aligned}$$

where SR and LR denote the short-run and long-run, respectively and Q_i denotes the ratio of the i th input to total output.

The intermediate-run (IR) elasticities are

⁴Since each of the input-output equations contains only one endogenous variable, the system of equations is not simultaneous, but seemingly unrelated. The technique to be used to estimate this system of equations, the iterative Zellner technique, has been shown to be equivalent to maximum likelihood estimation (Kmenta, pp. 635-648).

$$\begin{aligned}
 (V-12) \quad \epsilon_{Q_i, P_j}^{IR} &= \left[\frac{P_j}{Q_i} \right] \left[\frac{\partial Q_i}{\partial P_j} \right]_{K=\bar{K}} + (1 - \lambda^t) \left[\frac{P_j}{Q_i} \right] \left[\frac{\partial Q_i}{\partial K^*} \frac{\partial K^*}{\partial P_j} \right] \\
 &= \left[\frac{P_j}{Q_i} \right] \left[\delta_{ij} - (1 - \lambda^t) \frac{\gamma_{Ki} \gamma_{Kj}}{\alpha_{KK}} \right].
 \end{aligned}$$

t is the number of periods allowed for the adjustment.⁵

⁵As an example, the detailed derivation of short-, long- and intermediate- run own-price elasticities for the ONP input-output equation will be presented. First, recall that the equations for the ONP input demand schedule and the optimal level of capital are:

$$\begin{aligned}
 \frac{M_2}{Q} &= \alpha_{M2} + \sum_j \delta_{M2j} P_j + \alpha_{M2T} T + \gamma_{M2K} \frac{K}{Q} \\
 \left(\frac{K}{Q} \right)^* &= - \frac{1}{\alpha_{KK}} \left[\alpha_K + \sum_i \gamma_{Ki} P_i + \alpha_{KT} T + P_K \right]
 \end{aligned}$$

To obtain the expression for the short run elasticity, simply differentiate the ONP input-output equation with respect to the price of ONP as follows:

$$\frac{\partial \frac{M_2}{Q}}{\partial P_{M2}} = \delta_{M2M2} \rightarrow \epsilon_{M1, PM1}^{SR} = \frac{P_{M1}}{\left(\frac{M_1}{Q} \right)} \frac{\partial \left(\frac{M_1}{Q} \right)}{\partial P_{M1}} = \delta_{M2M2} \frac{P_{M2}}{\left(\frac{M_2}{Q} \right)}$$

To obtain the expression for the long-run elasticity, first note that when capital fully adjusts to its optimal level,

$$\frac{K}{Q} = \left(\frac{K}{Q} \right)^*$$

and substitute this into the ONP input-output equation.

Differentiating the M_2 input-output equation respect to P_{M2} , when the optimal level of capital is substituted for the observed level yields:

$$\begin{aligned}
 \frac{\partial \frac{M_2}{Q}}{\partial P_{M2}} &= \delta_{M2M2} + \frac{\partial \frac{M_2}{Q}}{\partial \left(\frac{K}{Q} \right)^*} \frac{\partial \left(\frac{K}{Q} \right)^*}{\partial P_{M2}} = \delta_{M2M2} - \frac{\gamma_{KM2}^2}{\alpha_{KK}} \\
 \rightarrow \epsilon_{M1, PM1}^{LR} &= \frac{P_{M1}}{\left(\frac{M_1}{Q} \right)} \frac{\partial \left(\frac{M_1}{Q} \right)}{\partial P_{M1}} = \frac{P_{M1}}{\left(\frac{M_1}{Q} \right)} \left[\delta_{M2M2} - \frac{\gamma_{M2M2}^2}{\alpha_{KK}} \right]
 \end{aligned}$$

The substitution elasticities are obtained by making use of the relationship

$$(V-13) \quad \sigma_{ij} = \frac{e_{ij}}{S_j} .$$

S_j denotes the share of the j th input in total cost. These substitution elasticities are similar to, but not the same as the elasticities in equation III-20 since they are derived from the cost function (Christensen and Greene, 1976). In Chapter III, the substitution elasticities were derived from the production function.

Estimation of the parameters of the K , L , E , M_1 , and M_2 equations, then, will allow us to calculate the implied values for the price and substitution elasticities in both

The intermediate-run elasticities are obtained by noting that in one year the proportion of the gap between the optimal level of capital and the observed level that is closed is $(1 - \lambda)$, the proportion of the gap closed after 2 years is $(1 - \lambda^2)$, etc. The proportion of the gap closed after t years is $(1 - \lambda^t)$ (Kmenta, p. 530). Thus, after t years

$$\frac{K}{Q} = (1 - \lambda^t) \left(\frac{K}{Q} \right)^*$$

Substituting this expression into the M_2 input-output equation and differentiating yields:

$$\begin{aligned} \frac{\partial \frac{M_2}{Q}}{\partial P_{M2}} &= \delta_{M2M2} + \frac{\partial \frac{M_2}{Q}}{\partial \left(\frac{K}{Q} \right)^*} \frac{\partial \left(\frac{K}{Q} \right)^*}{\partial P_{M2}} = \delta_{M2M2} - (1 - \lambda^t) \frac{\gamma_{KM2}^2}{\alpha_{KK}} \\ \Rightarrow e_{M1, PM1}^{IR} &= \frac{P_{M1}}{\left(\frac{M_1}{Q} \right)} \frac{\partial \left(\frac{M_1}{Q} \right)}{\partial P_{M1}} = \frac{P_{M1}}{\left(\frac{M_1}{Q} \right)} \left[\delta_{M2M2} - (1 - \lambda^t) \frac{\gamma_{M2M2}^2}{\alpha_{KK}} \right] \end{aligned}$$

The detailed derivation of the other price elasticities is directly analogous.

the short- and the long-run. The elasticity estimates will allow us to reject or give evidence in support of the hypotheses as presented in Chapter IV. Also, the calculation of intermediate-run elasticities will give some insights on how the values of the elasticities adjust over time.

3. DATA

To estimate the parameters of the K , L , E , M_1 , M_2 input-output equations, data on input prices and quantities as well as total newsprint production were required. Although quarterly or monthly data would have been preferable, only annual data for the years 1958-1987 were available for all series.

The prices of E , M_1 , and M_2 were measured by the Bureau of Labor Statistics (BLS) producer price indices for energy, woodpulp, and old newspapers. A user cost of capital was constructed by multiplying the BLS price index for capital by the sum of Moody's Industrial Bond Rate and the rate of depreciation for the paper and allied products industry. Moody's Industrial Bond rate was obtained from The Economic Report to the President (1989) while the rate of depreciation for the paper and allied products industry was obtained from the American Paper Institute's Statistics of Pulp, Paper, and Board (1988).

Newsprint is a five-digit industry (26211). Data on

labor costs and quantities were only available at the four-digit level, and hence, these series had to be constructed. Both were constructed using Census of Manufactures data. For the price of labor, the total wages paid to productive workers (SIC 2621) was divided by total manhours to get an average hourly wage for papermills for each of the years 1958-1987. This annual wage rate was used to approximate the average annual wage rate in the newsprint industry.

The value for the quantity of labor was constructed by allocating total manhours for productive workers on the basis of the ratio of newsprint production to total production for papermills (SIC 2621). The resulting series was used to approximate annual manhours used in newsprint production.

For the quantity of energy (E), prior to 1972, Census data were the only information available. From 1972 to 1987, energy quantities were published by the American Paper Institute (Statistics of Pulp, Paper, and Board, 1989). Unfortunately, both sources only published data for the paper industry as a whole. These data were used to compute an average Btu requirement per ton of paper product, which when multiplied by total newsprint production, gave an estimate for the total Btu's used annually in the production of newsprint. To transform the census data into annual data, the Chow-Lin algorithm for best linear unbiased

interpolation was applied.⁶ Applying the algorithm, the resulting interpolation equation was $E = 833.7 - 18.3 T - 1.4 P_E$, where T is an index of technology and P_E is the producer price index for energy. The estimates for the energy quantities seemed reasonable as they followed the same steady downward trend that was observed for the years 1972-1987.

Values for the amounts of woodpulp and secondary fiber used in newsprint production were also required. The American Paper Institute began publishing data for the amount of secondary fiber used in newsprint production in 1970. From this, it is easy to derive the amount of woodpulp used. Since very little chemicals or additives are used in newsprint production, the total amount of fiber (in short tons) used must be approximately equal to the total weight of the final product. For the four years (1958, 1963, 1983, and 1987) that both woodpulp and secondary fiber data were available, it was found that the ratio of fiber to output was about 1.01 (suggesting that there is a small amount of fiber "waste" in the production process). Thus, for the years 1970-1987, the total short tons for woodpulp

⁶The Chow-Lin algorithm applies Generalized Least Squares to obtain the best linear unbiased estimates of missing values by regressing the series with missing values on a related series (Chow and Lin, 1971). It is most commonly used to obtain monthly series from quarterly series, but the application to transform Census into annual data is analogous.

was computed as a residual, so that the ratio of total fiber to total newsprint production was equal to 1.01.

Prior to 1970, the only data available were census data. In 1958, totals were given for woodpulp and an "other materials" category, which included rags and straw. The "other" category was not disaggregated for disclosure reasons. Since wood replaced rags and straw as the primary material input in newsprint production during the late 1800's, it was assumed that "other" materials were all secondary fiber. Further, during this time, there was only one newsprint producer using wastepaper, a probable reason for the failure to disaggregate. For 1963, the materials used for producing newsprint were nicely disaggregated into woodpulp and secondary fiber. The figures for secondary fiber in 1967, based on an industry sample, seemed "too small" according to the industry literature and thus were not used.

In order to convert the census data into annual data, the Chow-Lin algorithm was applied. The interpolating equation for woodpulp (W) was $-1810.7 + 2638.5 Q - 25.7 T$, where Q is annual newsprint production and T represents an index of technology. Quantities for secondary fiber were computed so that the ratio of total fiber to newsprint production was equal to 1.01.

Annual year-end newsprint capacity (in short tons) was used to measure capital stock, K. K as well as total

newsprint production (in short tons) was taken from The American Paper Institute's Newsprint Statistics (various issues).

Finally, T, the index of technology was measured as a time trend variable.

4. RESULTS

Using the data described above, the parameters of the K, L, E, M_1 , and M_2 input-output equations were estimated by applying iterative Zellner techniques. It should be noted that variables representing real U.S. GNP and the level of Canadian capacity were added to the capital equation since these variables surely influence investment decisions. It is hypothesized that investment in newsprint capacity in the U.S. will be positively related to GNP and inversely related to Canadian capacity. Parameter estimates are presented in Table V-1 while R-squares and the results of tests for autocorrelation are presented in Table V-2.

The high values for R^2 in the L, E, M_1 , and M_2 equations imply that a great deal of variation is explained. The R^2 is lower for the K equation, but is still reasonably high. The Durbin-Watson statistics for the L, M_1 , and M_2 equations fall in the "inconclusive" region at the 0.01 level of significance. For the E equation, the Durbin-Watson test indicates that no autocorrelation is present at the 0.01

Table V-1

Iterative Seemingly Unrelated Estimates (Ratio of
Parameter Estimate to Asymptotic Standard
Error in Parentheses)

Parameter	Estimate	Description
α_0	3.1754 (4.56)	Intercept, L equation
α_K	-5.6001 (-4.49)	Intercept, K equation
α_E	0.2692 (22.80)	Intercept, E equation
α_{M1}	1.2430 (18.43)	Intercept, M_1 equation
α_{M2}	-0.2276 (-3.42)	Intercept, M_2 equation
α_{KT}	0.0083 (1.73)	Technology Coefficient, K equation; Coefficient on (K/Q)T, L equation
α_{OT}	-0.2276 (-2.10)	Technology Coefficient, L equation
α_{ET}	-0.0023 (-27.57)	Technology Coefficient, E equation
α_{MIT}	-0.0101 (-23.17)	Technology Coefficient, M_1 equation
α_{M2T}	0.0099 (23.44)	Technology Coefficient, M_2 equation
δ_{EE}	0.0000 (0.94)	Price of Energy Coefficient, E equation; Coefficient on P_E^2 , L equation
δ_{M1M1}	-0.0030 (-1.66)	Price of Woodpulp Coefficient, M_1 equation; Coefficient on P_{M1}^2 , L equation
δ_{M2M2}	-0.0083 (-4.93)	Price of ONP Coefficient, M_2 , equation; Coefficient on P_{M2}^2 , L equation

Table V-1 (continued)

Parameter	Estimate	Description
δ_{EM1}	0.0002 (0.20)	Price of energy Coefficient, M_1 equation; Price of Woodpulp Coefficient, E equation; Coefficient on $P_{M1}P_E$, L equation
δ_{EM2}	-0.0001 (-0.09)	Price of Energy Coefficient, M_2 equation; Price of ONP Coefficient, E equation; Coefficient on $P_{M2}P_E$, L equation
δ_{M1M2}	0.0048 (2.38)	Price of Woodpulp Coefficient, M_2 equation; Price of ONP Coefficient, M_1 equation; Coefficient on $P_{M1}P_{M2}$, L equation
α_{KK}	2.5475 (4.62)	Coefficient on $(K/Q)^2$, L equation.
γ_{EK}	-0.0278 (-2.68)	Capital Coefficient, E equation
γ_{M1K}	-0.1922 (-3.21)	Capital Coefficient, M_1 equation
γ_{M2K}	0.1816 (3.09)	Capital Coefficient, M_2 equation
λ	0.6531 (9.10)	Adjustment Parameter
β_{RGNP}	0.0001 (2.87)	Coefficient for Real GNP, K equation
β_{CCAP}	-0.0001 (-4.55)	Coefficient for Canadian Capacity, K equation

Table V-2

Regression Results: Miscellaneous Information

	R ²	Durbin-Watson
L equation	.9272	1.8647
E equation	.9768	1.9824
M ₁ equation	.9709	1.0941
M ₂ equation	.9702	1.3845
K equation	.5150	**

**Since the Durbin-Watson Statistic is not a valid test for autocorrelation in the presence of a lagged dependent variable, the m test was used to test for autocorrelation in the K equation. The test equation was:

$$e_t = .099 + .002P_E + .029P_{M1} + .017P_{M2} - .030K_{t-1} - .119e_{t-1},$$

(4.71) (.12) (.83) (.28) (-.85) (-1.00)

where e is the GLS residual. Clearly, the hypothesis of no autocorrelation could not be rejected since the coefficient on e_{t-1} is not significant.

level of significance. No correction for autocorrelation, then, was required in the estimation of any of the L, E, M_1 , or M_2 equations. Finally, the m test was applied to test for autocorrelation in the K equation, due to the invalidity of the DW test in the presence of a lagged dependent variable as an explanatory variable.⁷ The hypothesis of no autocorrelation in the K equation was not rejected and the estimation of the K equation did not require an instrumental variables technique.

For the most part, the estimated parameters had the expected sign. The price of ONP coefficient for the ONP (M_2) equation was negative and statistically different from zero implying, as would be predicted by economic theory, that the proportion of ONP used to produce newsprint varies inversely with the price of ONP. This must not be interpreted as contrary to the hypotheses that the demand for ONP is relatively price-inelastic, however. In order to give support to or reject the hypothesis that the ONP demand

⁷The m test consists of calculating the least squares residuals (e_t) from the regression equation and applying ordinary least squares to:

$$e_t = \beta_1 + \beta_2 P_E + \beta_3 P_{M1} + \beta_4 P_{M2} + \beta_5 K_{t-1} + \beta_5 e_{t-1} .$$

The hypothesis

$$H_0: \beta_5 = 0 \quad (\text{no autocorrelation})$$

is tested using the standard t test (Kmenta, p.333).

schedule is relatively price-inelastic the short- and long-run, the ONP-own price elasticity must be calculated and this will be done below. Similarly, the negative sign for and the significance of the price of woodpulp in the woodpulp (M_1) equation indicates that as the price of woodpulp increases, less woodpulp is used to produce newsprint. The statistical insignificance of the price of energy coefficient in the energy (E) equation suggests that the price of energy has no effect on the quantity consumed, or equivalently, that the amount of energy used to produced a given level of output must be applied in a fixed proportion in the short-run.

The price of energy coefficient in both the M_1 and M_2 equations is not statistically different from zero. Thus, the price of energy does not influence either the proportion of woodpulp or the proportion of ONP used to produce a given level of output. This result was not that surprising, given the fact that wood by-products are often used as an energy source in the production of paper products. It would be expected that the price of energy would not be an important determinant of the proportion of woodpulp used to produce newsprint. Since the price of energy does not affect the proportion of woodpulp, it cannot affect the proportion of ONP since the ratio of total fiber (woodpulp plus ONP) to newsprint production is fixed.

Further, the coefficient on the price of woodpulp in

the M_2 and the price of ONP in the M_1 equation was positive and statistically different from zero. This is interpreted as ONP and woodpulp are substitutes. Again, this must not be interpreted as contrary to the hypothesis that capital constrains the substitutability of ONP for woodpulp. In order to give support to or reject the hypothesis that the substitutability of ONP is constrained in the short- and long-run, the relevant price and substitution elasticities must be calculated.

The technology coefficient for the M_1 equation is negative and significant, suggesting that over time the newsprint production process has become less woodpulp-intensive. Likewise, the proportion of ONP use to produced newsprint has increased over time, as indicated by the positive and significant technology coefficient for the M_2 equation. Naturally, if the industry increases the proportion of ONP used over time, it must decrease the proportion of woodpulp used since the ratio of total fiber to output is fixed. These results were anticipated, given that Figure IV-8 showed that the proportion of ONP used to produce newsprint has followed a steady upward trend.

The signs on the capital coefficients are of particular interest. As the level of capital in the industry increases, the proportion of ONP used to produce newsprint increases as well. This is indicated by the positive and significant capital coefficient for the M_2 equation. If the

proportion of ONP used increases, then the proportion of woodpulp must decline, which it does as shown by the negative and significant capital coefficient for the M_1 equation. The hypothesis that capital is the primary determinant of recycling in the newsprint industry is beginning to gather some support.

Finally, λ , the adjustment parameter, is interpreted as approximately 15 percent of the gap between the observed and long run optimal level of capital is closed in one year. Also, the sign on the coefficient for real GNP is positive and significant while the sign on the coefficient for Canadian capacity is negative and significant, as was hypothesized.

Estimates of elasticities over several time periods can be obtained by substituting the estimated parameters of the model into formulas V-11, V-12, and V-13. The estimates for these elasticities will be used to give empirical support for the hypotheses stated in Chapter IV.

Table V-3 presents estimates for the short-run own- and cross-price elasticities, as well as the demand for ONP-output elasticity and the elasticity of substitution of ONP for woodpulp. Note that the demand for ONP is completely unresponsive to the prices of capital, labor, and energy in the short-run. The demand for ONP is unresponsive to the price of energy in the short-run since the price-of-energy coefficient is not statistically different from zero in the

Table V-3
Short-run* Elasticity Estimates
(Evaluated at the Mean)

	Estimate	Description
$\epsilon_{M2,PK}$	0.0000	Elasticity of the ONP demand schedule with respect to the price of capital
$\epsilon_{M2,PL}$	0.0000	Elasticity of the ONP demand schedule with respect to the price of labor.
$\epsilon_{M2,PE}$	0.0000	Elasticity of the ONP demand schedule with respect to the price of energy.
$\epsilon_{M2,PM1}$	0.0291	Elasticity of the ONP demand schedule with respect to the price of woodpulp.
$\epsilon_{M2,PM2}$	-0.0475	Elasticity of the ONP demand schedule with respect to its own price.
$\epsilon_{M2,Q}$	-0.4579	Elasticity of the ONP demand schedule with respect to newsprint production.
σ_{M2M1}	0.2079	Elasticity of substitution of ONP for woodpulp.

* The short run is defined as the period of time for which capital is fixed (see footnote 5 for how these elasticities are derived when capital is fixed).

demand for ONP equation. The reason the ONP-price of capital elasticity is zero is, of course, that capital is assumed to be fixed in the short-run.

The ONP-own price elasticity is small but of the correct (negative) sign. This result can be interpreted as that, in the short-run, a lower price for ONP causes ONP-based capital to be utilized more intensely than woodpulp-based capital. The demand for ONP is also inversely related to output. Further, the demand for ONP is positively related to the price of woodpulp, implying correctly that ONP and woodpulp are substitutes. However, the substitution of ONP for woodpulp is limited in the short-run as indicated by the small value for this elasticity as well as the small value for the substitution elasticity. The primary reason that all of these elasticities are so small is that the fixity of capital in the current period places economic constraints on the relative proportions of ONP and woodpulp that can be used to produce newsprint, even if their relative prices change dramatically.

Table V-4 presents intermediate-run elasticities and demonstrates how the elasticities change after the quasi-fixed input, capital, partially adjusts to its long-run optimal level. The demand for ONP remains fairly unresponsive to its own price and the prices of labor, energy, and woodpulp. One interesting observation is that the demand for ONP becomes increasingly responsive to and

Table V-4

Intermediate Run* Elasticity Estimates
(Evaluated at the Mean).

	1 year	3 year	5 year
$\epsilon_{M2,PK}$	-0.9154	-1.9037	-2.3252
$\epsilon_{M2,PL}$	-0.0025	-0.0053	-0.0065
$\epsilon_{M2,PE}$	-0.0067	0.0140	0.0171
$\epsilon_{M2,PM1}$	0.0578	0.0889	0.1022
$\epsilon_{M2,PM2}$	-0.0732	-0.1009	-0.1128
$\epsilon_{M2,Q}$	2.8265	6.3724	7.8848
σ_{M2M1}	0.4123	0.6350	0.7300

* In the intermediate run, capital adjusts partially to its optimal level (see footnote 5 for how these elasticities are derived when capital partially adjusts).

Note: The elasticities are defined in Table V-3.

inversely related to the price of capital. Even more interesting, after one year, the output elasticity changes sign, becoming positive, and very large. This change in the sign of the output elasticity can be interpreted as that, in the short-run, an exogenous increase in output causes the proportion of ONP used to produce newsprint to fall. This is due the fact that output expansion is achieved in the short-run by more intense capital utilization (as opposed to capital expansion). Since the bulk of U.S. capacity in the U.S. is woodpulp-based, an increase in the rate of total newsprint capacity utilization will cause the usage rate of

woodpulp to increase relative to the usage rate of ONP. After capital is able to adjust, however, ONP-based capital can be increased relative to woodpulp-based capital and hence, the proportion of ONP used to produce newsprint can increase as well. As would be expected, the substitution elasticity grows larger over time, implying that it becomes easier to substitute ONP for woodpulp.

The corresponding long run elasticities are reported in Table V-5. As is the case with the intermediate-run elasticities, all price elasticities except for the ONP-price of capital elasticity are small even in the long-run. The largest elasticity is the ONP-output elasticity. The substitution elasticity implies greater substitution of ONP for woodpulp. However, as indicated by the value for the substitution elasticity, making this substitution for a given output level still is not extremely easy. In other words, the value for the substitution elasticity suggests that the percentage change in the ratio of ONP to woodpulp relative to the percentage change in the ratio of ONP price to woodpulp price is small even in the long run. As pointed out in Chapter IV, the capital cost differential between expanding an existing mill versus building a new mill and the adjustment costs inherent in switching production technology places limitations on the economic substitutability between ONP and woodpulp.

Table V-5
Long Run* Elasticity Estimates
(Evaluated the Mean)

Elasticity	Estimate
$\epsilon_{M2,PK}$	-2.6388
$\epsilon_{M2,PL}$	-0.0073
$\epsilon_{M2,PE}$	0.0194
$\epsilon_{M2,PM1}$	0.1120
$\epsilon_{M2,PM2}$	-0.1216
$\epsilon_{M2,Q}$	9.0010
σ_{M2M1}	0.8000

*In the long run, capital fully adjusts to its optimal level (see footnote 5 for how these elasticities are derived when capital fully adjusts).

Note: The elasticities are defined in Table V-3.

Clearly, referring to the hypotheses stated in Chapter IV, these results give evidence that supports the hypothesis that the derived demand for ONP is inelastic in both the short- and long-run. Further, these results give evidence that indicates the demand for ONP is not very responsive to changes in the price of woodpulp in either the short- or long-run. The low values for the short- and long-run elasticity of substitution of ONP for woodpulp, caused by the unadaptability of capital, is a reason for the inelasticity of the ONP demand schedule. The value for the elasticity of ONP demand with respect to the price of capital suggests that the price of capital is a more

important determinant of ONP recycling in the newsprint industry than is either the price of ONP or the price of woodpulp taken in isolation.

These elasticity estimates have a number of implications for recycling policy. First, policies designed to simply remove materials from the MSW stream, which work by lowering the price of ONP, will not be very effective at stimulating the rate of recycling in the U.S. newsprint industry even in the long run. Furthermore, although the price of woodpulp has been held artificially low through tax policy originally designed to encourage growth in the timber industry, such fiscal biases in favor of virgin raw materials probably have not hindered recycling in the newsprint industry that much. This is due, for one, to the location of newsprint mills. Removal of these subsidies will do little to stimulate the use of ONP in the U.S. newsprint industry. Since the derived demand for ONP is highly sensitive to and inversely related to the price of capital, tax preferences aimed at encouraging investment in newsprint capacity may be more effective than either of these policies.

The most significant finding, however, that growth in ONP consumption has arisen as a consequence of output growth in the U.S. industry, was not part of the formal statement of hypotheses to be tested. The following discussion will explain how this finding gives additional support to the

hypothesis that capital is the key determinant of recycling in the U.S. newsprint industry.

The high values for the intermediate- and long-run output elasticities indicate that growth in output, which occurs over time, is the force that will assure that the rate of ONP use will also increase. In the context of the theory presented in Chapter III, exogenously-induced output growth is the primary force that drives the rate of ONP recycling for the U.S. newsprint industry. Referring to Figure III-3, the expansion path for the U.S. newsprint industry is described by panel (b). That is, as the industry expands its scale of operations, it is able to alter its capital so that it is more capable of utilizing ONP.

Note that this finding is similar to the Gill-Lahiri result, discussed in the literature review in Chapter III, in that ONP recycling is more responsive to the final output market parameter than it is to relative input prices. However, in this case, the explanation for this finding differs. Historically, a key motive for the development of recycled newsprint technology was that it was a relatively inexpensive means of expanding U.S. newsprint capacity to alleviate the post-World War II "shortage" of newsprint. Expansion in output has required investment in new newsprint capacity and this investment appears to have been biased

toward ONP-based mills.⁸ Further, this result implies that policies to encourage output expansion or the development of the U.S. newsprint industry would be the most effective recycling policies of all.

To give additional support to these findings, the empirical model of the derived demand for ONP was used to simulate the impacts of various policies that have been suggested for increasing the rate of recycling in newsprint production. The predictive capacity of the model was assessed by graphing the observed historical rates of ONP use against those predicted by the model, as shown in Figure V-1. Note that the model neither consistently over-predicts nor under-predicts. Rather, the values predicted by the model tend to follow a smoother trend than the actual values. Thus, the model seems to predict the historical trend in ONP recycling with reasonable accuracy.

To perform the simulations, a number of policy scenarios were constructed. These policy scenarios were constructed by making highly optimistic assumptions regarding the impacts of various recycling policies. Thus,

⁸It is interesting to note that, over the past three or four decades, the Canadian industry has been losing its share of the U.S. newsprint market to U.S. firms. This loss in market share is most often attributed to the expansion of capacity in the southern states. The expansion of capacity in the South has been an important source of competition but so has the expansion in ONP-based capacity. As has been mentioned, from 1958-1987, the total capacity utilizing secondary fiber increased from essentially zero to approximately 25 percent of total U.S. newsprint capacity.

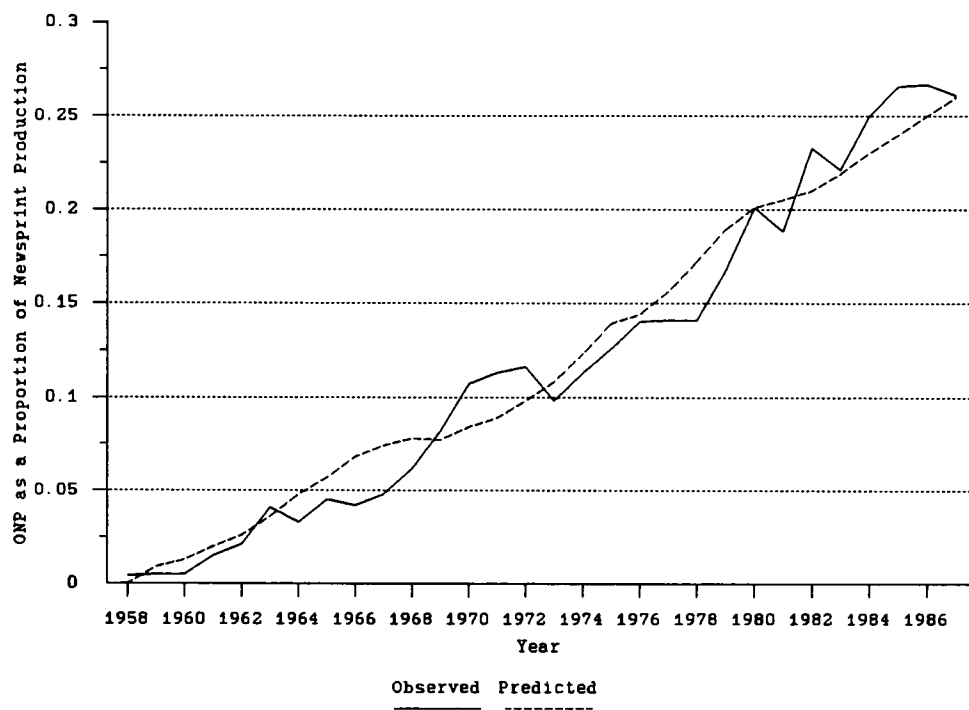


Figure V-1
Observed vs. Predicted Rates of ONP Recycling

the purpose of the simulations is so much to examine the actual effects to be expected under different policies as it is to examine the sensitivity of the model to changes in the values of the exogenous variables.

The base case scenario was constructed by holding all prices constant at 1987 levels and allowing output to continue to grow at historical rates. The base case scenario can be interpreted as the future time path of ONP recycling in the newsprint industry in the absence of any exogenous shocks. Scenario 2 represents the case of a 15 percent increase in the price of woodpulp, which is more than the maximum possible increase that could be obtained with removal of federal subsidies (Andersen and Spiegelman, 1977). In scenario 3, the price of ONP was reduced by 50 percent to represent the effects of supply-side policies. The choice of 50 percent was arbitrary but seemed plausible, given the status of passed and pending legislation. In scenario 4, the price of capital was reduced by 25 percent to reflect tax preferences that could be given to the industry as an incentive to expand capacity.⁹ Again, the choice of 25 percent was arbitrary. Scenario 5 is the case where newsprint production is held constant at 1987 levels

⁹In this model, the price of capital refers to the user cost of one unit of newsprint capacity (both recycled and virgin). The price of capital can be reduced by reducing any one of its three components: the market price for machinery, the rate of depreciation, or the interest rate (see the discussion of how the user cost of capital was constructed).

until the year 2000. Finally, in scenario 6, newsprint production is allowed to grow by an equal percentage each year until 2000. By 2000, imports from Canada, which accounted for approximately 60 percent of the newsprint consumed in the U.S. in 1987 (with U.S. producers supplying the remaining 40 percent) are reduced to zero.

The simulated time paths for the ratio of ONP to newsprint production are presented in Table V-6. Note that in the base case, the rate of recycling increases from 28.93 percent in 1990 to 39.37 percent in 2000. The reason for the increase is that the simulation is simultaneous in the sense that the values for all dependent variables are predicted. Prices in 1987 determine a current period level of capital stock (and ONP demand). This current period level of capital stock determines the next period capital stock as well as the next period ONP demand and so forth. In other words, the rate of growth in ONP consumption stems from the partial adjustment specification of the capital stock equation. Also, output is increases at historical rates and this allows the rate of ONP recycling to increase in the base case. Figure V-2 illustrates this growth in ONP consumption.

Changes in the price of woodpulp, ONP, and capital, as depicted by scenarios 2, 3, and 4, respectively, do little to impact the time path of ONP recycling. Changes in the price of capital, however, affect the future rate of ONP

Table V-6

Simulated Time Paths for the Rate of Recycling
in the Newsprint Industry Under Various
Scenarios (ONP as a Proportion of
Total Newsprint Production)

Year	(Scenario)					
	1	2	3	4	5	6
1990	.2893	.2911	.2923	.3006	.2526	.2860
1991	.3027	.3047	.3060	.3169	.2970	.3686
1992	.3147	.3169	.3182	.3307	.2878	.3680
1993	.3257	.3280	.3294	.3430	.2966	.4076
1994	.3361	.3385	.3399	.3542	.2994	.4274
1995	.3461	.3486	.3500	.3647	.3042	.4593
1996	.3559	.3584	.3598	.3749	.3084	.4844
1997	.3655	.3680	.3694	.3847	.3128	.5149
1998	.3750	.3775	.3789	.3943	.3171	.5419
1999	.3844	.3869	.3883	.4038	.3214	.6214
2000	.3937	.3963	.3977	.4132	.3257	.5970

Scenario 1: The base case; all prices are held constant at 1987 levels.

Scenario 2: 15% increase in the price of woodpulp

Scenario 3: 50% reduction in the price of ONP

Scenario 4: 25% reduction in the price of capital

Scenario 5: Newsprint production is held constant at 1987 levels.

Scenario 6: Output grows by an equal percentage each year. In 2000, the U.S. newsprint industry is able to meet projected U.S. consumption (e.g. there are no imports)

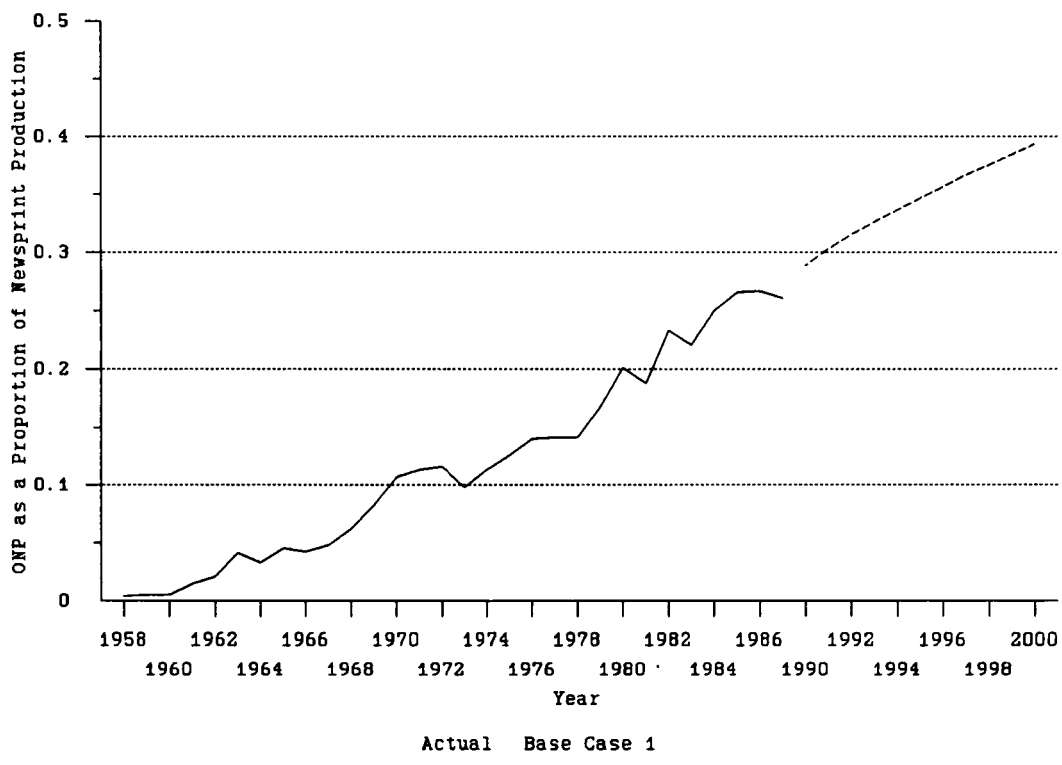


Figure V-2

Simulated Future Rates of ONP Recycling When
All Prices Are Held Constant

recycling more than changes in ONP price or woodpulp price.¹⁰ Referring to Figures V-3 through V-5, such incentive policies will (slightly) affect future levels of ONP recycling. Further, despite the fact that output is held constant in scenario 5, the rate of ONP use still increases from 25.26 in 1990 to 32.57 in 2000. It appears that, in Figure V-6, 1987 prices are sufficient to elicit a substitution effect.

The greatest increase in ONP use occurs under scenario 6. Scenarios 5 and 6 taken together underscore the impacts that output growth in the U.S. newsprint industry have on the rate of ONP use. As shown in Figure V-7, output expansion influences both the level and rate of increase in ONP recycling. These results are suggestive of the locational advantage that the U.S. newsprint industry has over the Canadian industry regarding ONP use.

As a sensitivity test, the model was also used to simulate these policies under the assumption that the variables either 1) exogenous to the model or 2) cannot be directly measured are held constant. These variables are embodied in the generic "technology" variable (measured as a time trend variable) and include such economic factors

¹⁰The small impact of a change in the price of capital on the time path of ONP recycling may appear surprising given the size of the ONP-price of capital elasticity. However, the reader is reminded that the dependent variable in the simulations is the ratio of ONP to newsprint output (not the total tonnage of ONP).

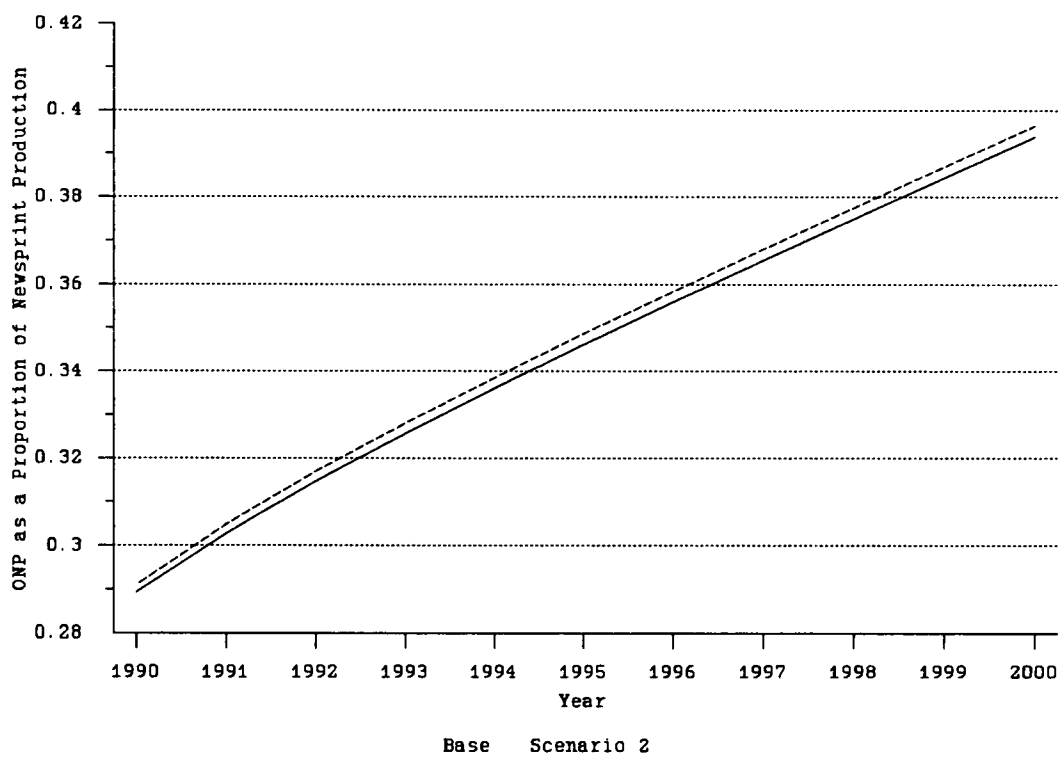


Figure V-3

Impacts of a 15% Increase in the Price of Woodpulp

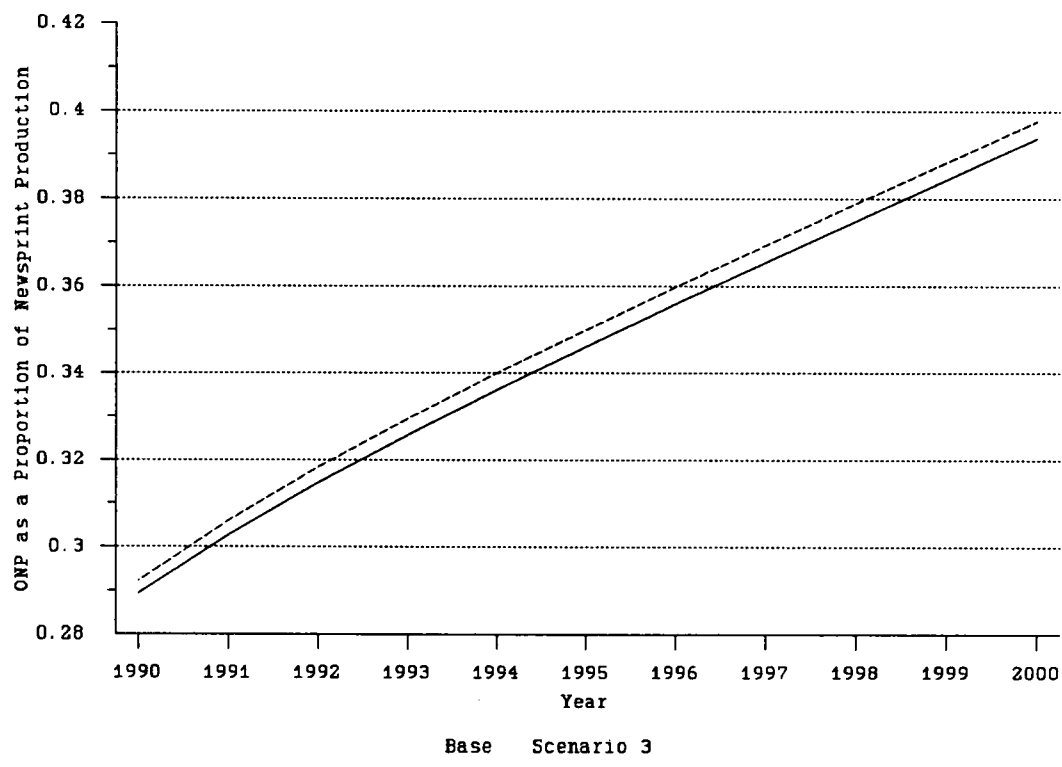


Figure V-4

Impacts of a 50% Decline in the Price of ONP

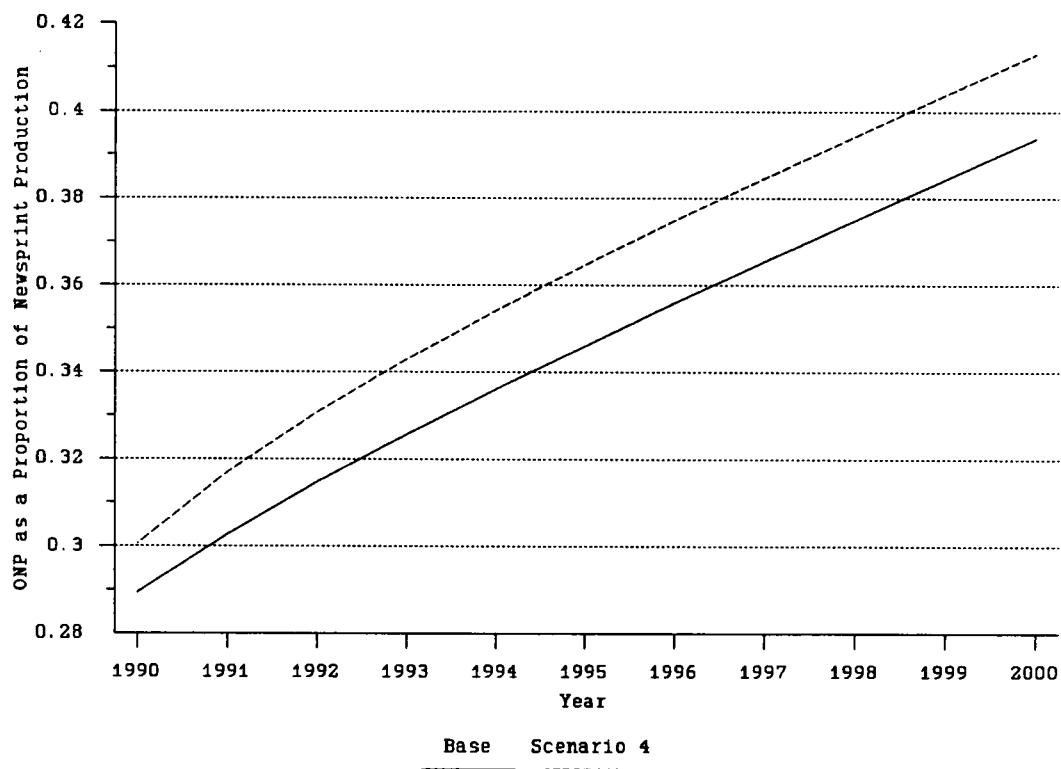


Figure V-5

Impacts of a 25% Decline in the Price of Capital

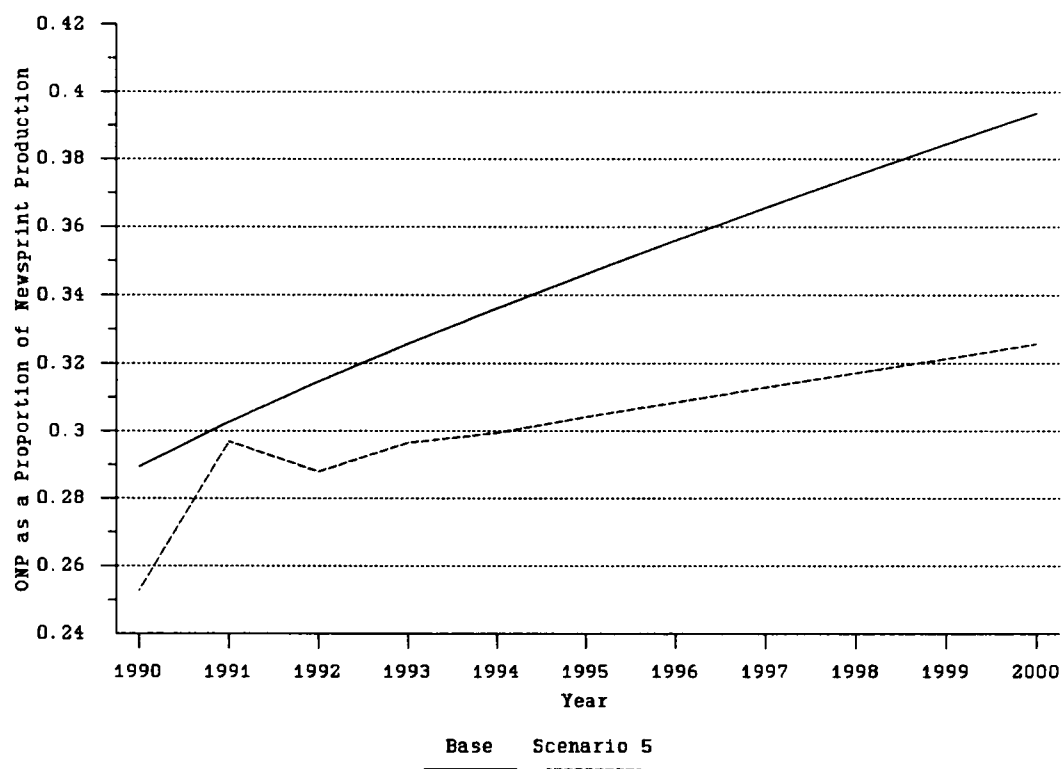


Figure V-6

Simulated Future Rates of ONP Recycling When
Output is Held Constant

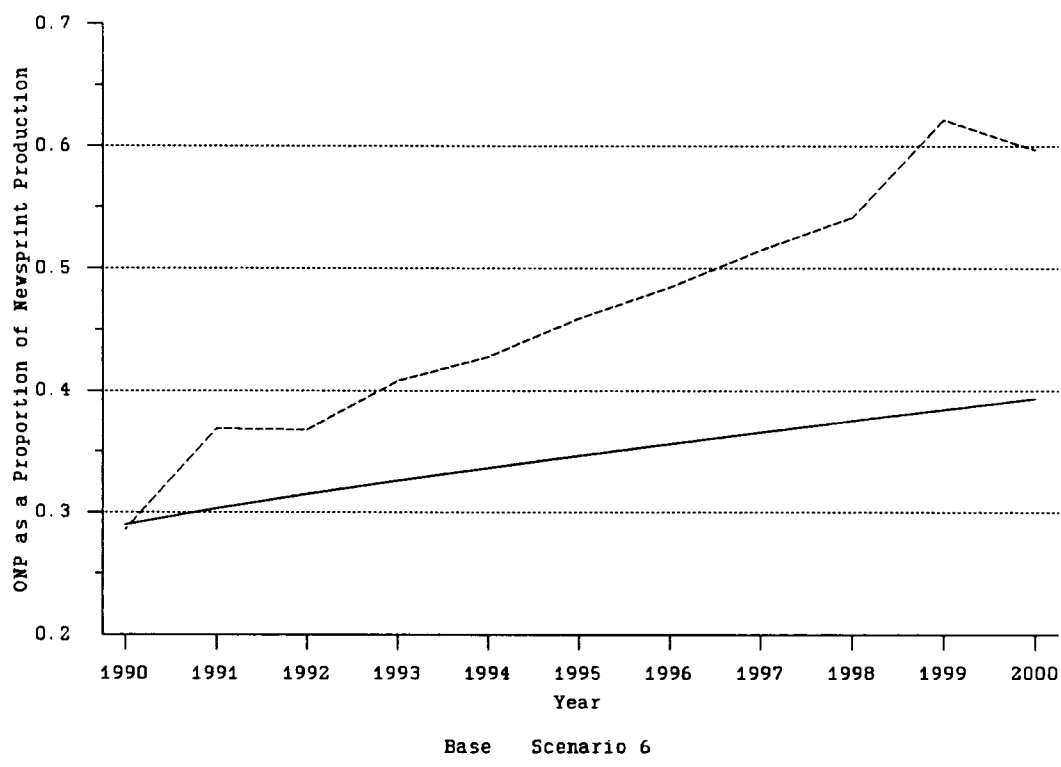


Figure V-7

Simulated Future Rates of ONP Recycling When Output Grows
to Meet Future Levels of Newsprint Consumption

as advancements in the industry that improve the efficiency of the use of secondary fiber and the locational advantage that the U.S. has over Canada regarding the use of ONP, as well as such noneconomic factors as the desire of the industry to increase recycling since it is generally perceived to be a socially desirable goal. The results of this sensitivity test are presented in Table V-7.

Figure V-8 shows how holding these factors (as well as input prices) constant affects future rates of recycling and Figure V-9 compares the two base case scenarios. Base case 2 suggests that, without technological advancements to improve the efficiency of the use of secondary fiber, the locational advantage that the U.S. has over Canada regarding the use of ONP, and the industry's general desire to increase recycling, expected future increases in recycling will be small and immediate.

Holding the variables embodied in the generic "technology" variable constant does not influence the impact of incentive policies on the time paths of recycling. As with the first set of simulations, changes in the price of woodpulp, ONP, and capital, as depicted by scenarios 2, 3, and 4, respectively, only impact the time path of ONP recycling marginally. Further, these policies only result in a small increase in the level of recycling and do not stimulate the rate of growth in ONP use. Figures V-10 through V-12 help to illustrate the impacts to be expected

Table V-7

Simulated Time Paths for the Rate of Recycling
in the Newsprint Industry Under Various
Scenarios (Sensitivity Test)

Year	(Scenario)					
	1	2	3	4	5	6
1990	.2698	.2715	.2727	.2810	.2440	.2773
1991	.2737	.2757	.2770	.2878	.2839	.3556
1992	.2762	.2784	.2797	.2922	.2705	.3508
1993	.2778	.3801	.2815	.2951	.2750	.3859
1994	.2789	.2813	.2827	.2970	.2735	.4014
1995	.2796	.2820	.2834	.2982	.2740	.4290
1996	.2801	.2825	.2839	.2990	.2738	.4499
1997	.2804	.2828	.2843	.2995	.2739	.4760
1998	.2806	.2830	.2845	.2999	.2739	.4970
1999	.2807	.2832	.2846	.3001	.2730	.5738
2000	.2808	.2833	.2847	.3003	.2739	.5451

Scenario 1: Base case 2; Technology and prices are held constant.

Scenario 2: 15% increase in the price of woodpulp

Scenario 3: 50% reduction in the price of ONP

Scenario 4: 25% reduction in the price of capital

Scenario 5: Newsprint production is held constant at 1987 levels.

Scenario 6: Output grows by an equal percentage each year. In 2000, the U.S. newsprint industry is able to meet projected U.S. consumption (e.g. there are no imports).

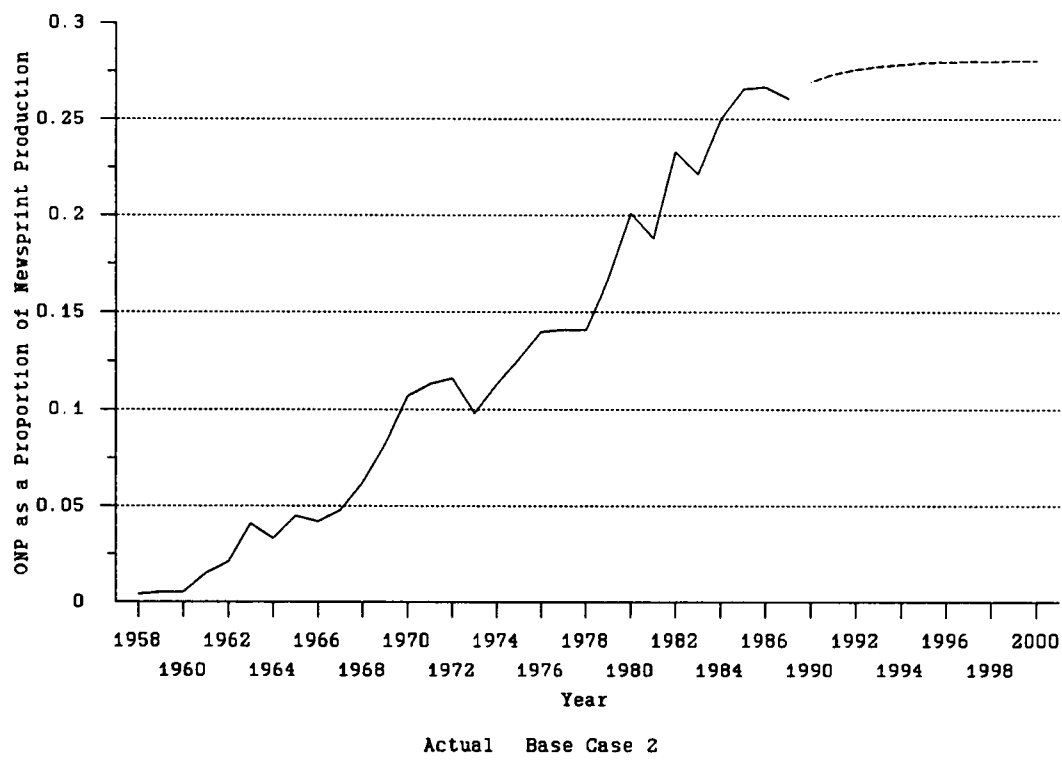


Figure V-8

Simulated Future Rates of ONP Recycling When
Output and Technology are Held Constant

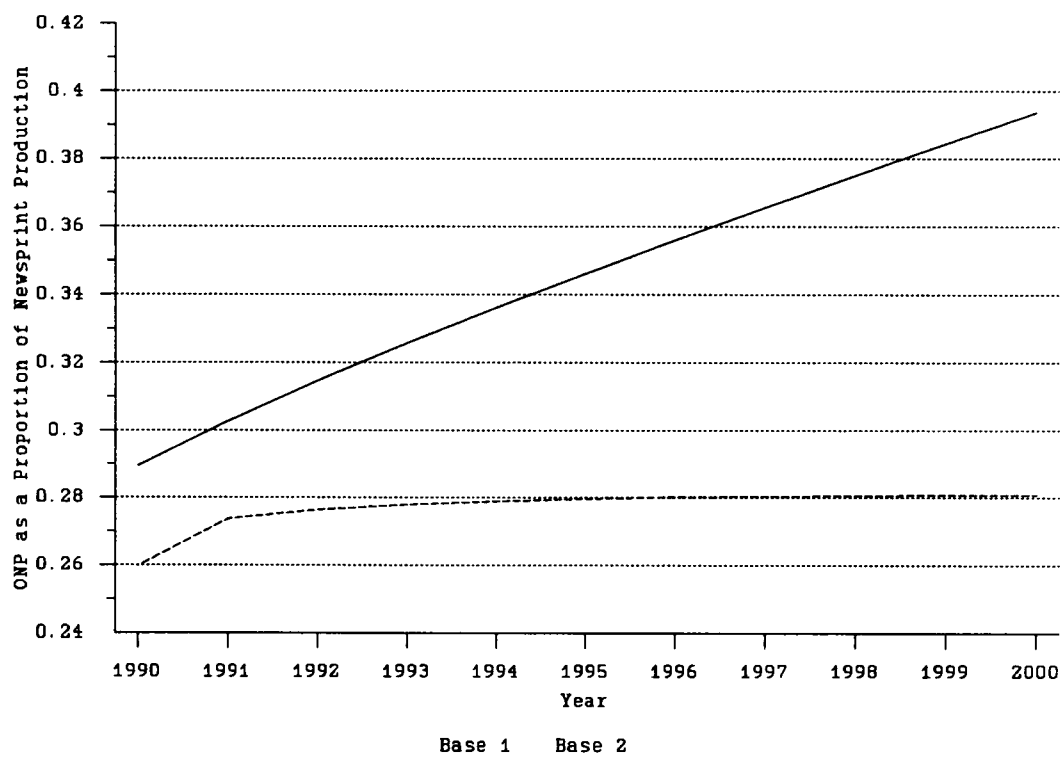


Figure V-9
Comparison of Base Case 1 and Base Case 2

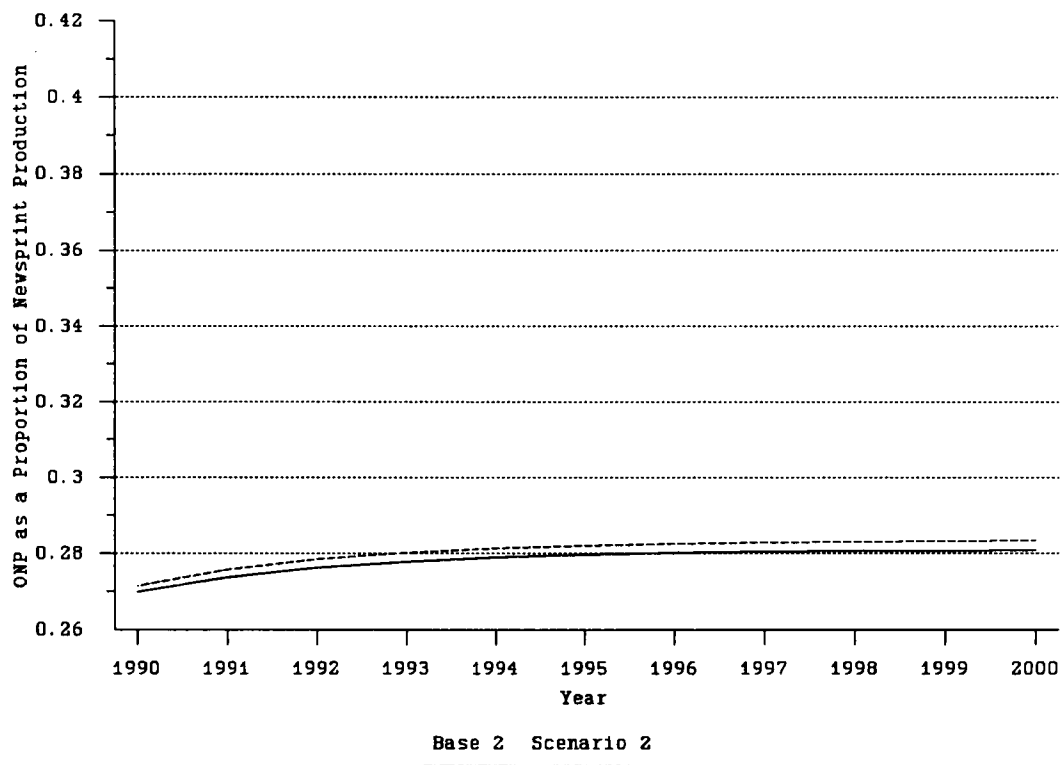


Figure V-10

Impacts of a 15% Increase in the Price of Woodpulp
(Base Case 2)

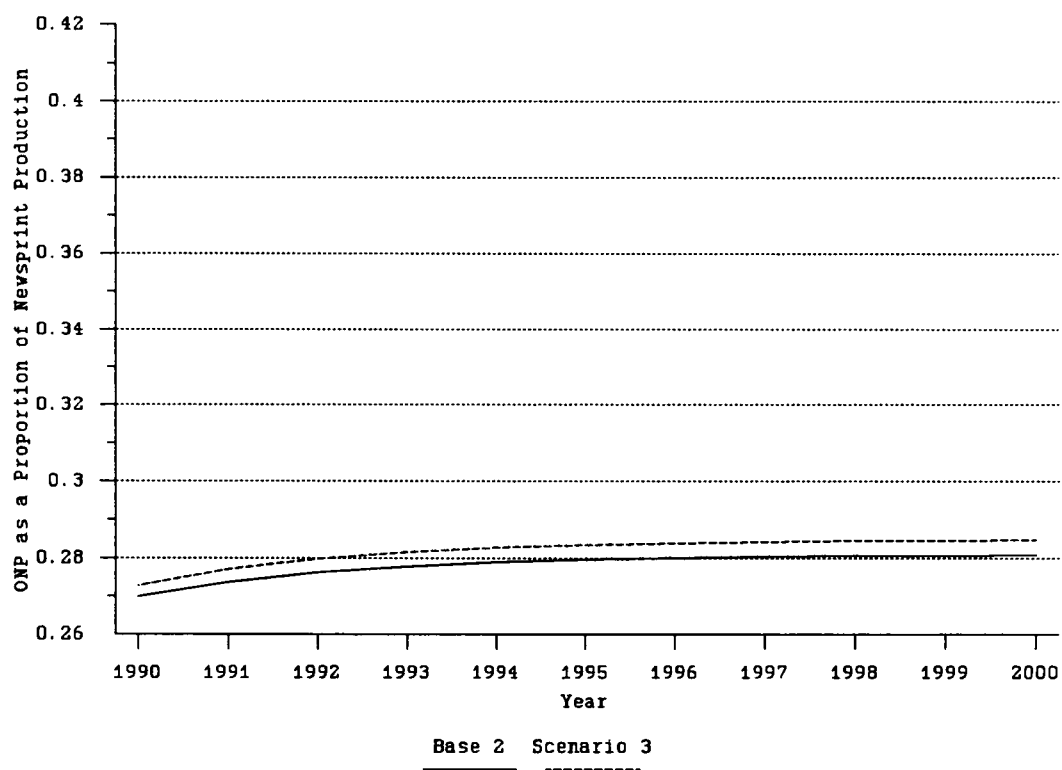


Figure V-11

Impacts of a 50% Decline in the Price of ONP
(Base Case 2)

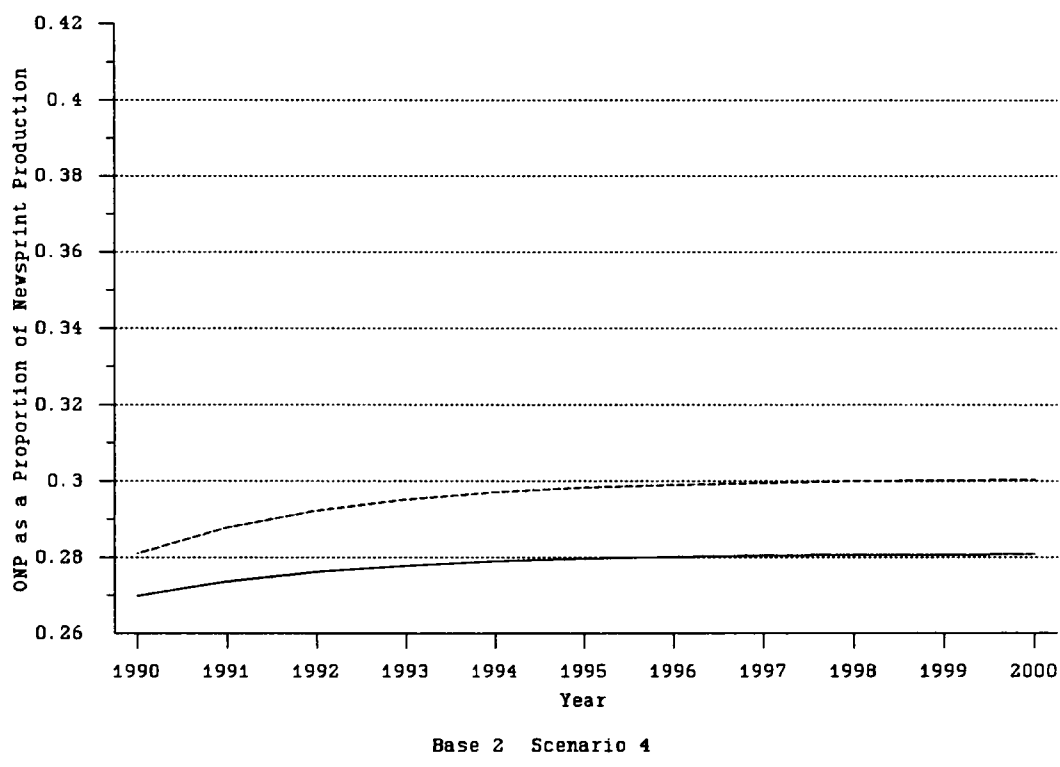


Figure V-12

Impacts of a 25% Decline in the Price of Capital
(Base Case 2)

when technology is held constant.

By comparing Figures V-6 and V-13, it is seen that the effects of holding output constant under both base cases are very similar. Specifically, 1987 prices are sufficient to elicit a small substitution effect. The primary difference is that this substitution effect loses its impact after 1991, as indicated by Figure V-14. Thus, technology influences the magnitude of the rate of increase in ONP use arising from pure substitution.

Finally, the greatest increase in ONP use again occurs under scenario 6, which is depicted by Figure V-15. The time path of recycling with an output expansion policy appears to be quite similar to base case 1. Figure V-16 shows that output is highly, but not perfectly, correlated with technology. That is, the output appears to capture one or more of the variables embodied in the generic "technology" variable, most likely the locational advantage that the U.S. has over Canada regarding the use of ONP. The "other" factors like technological advancements to improve the efficiency of the use of secondary fiber and the industry's general desire to increase recycling seem to have a greater influence over the longer run. This final result can be interpreted as indicating expansion in output is the primary force that has driven recycling in the U.S. newsprint industry. The reason is that expansion in output requires investment in capacity and this investment has been

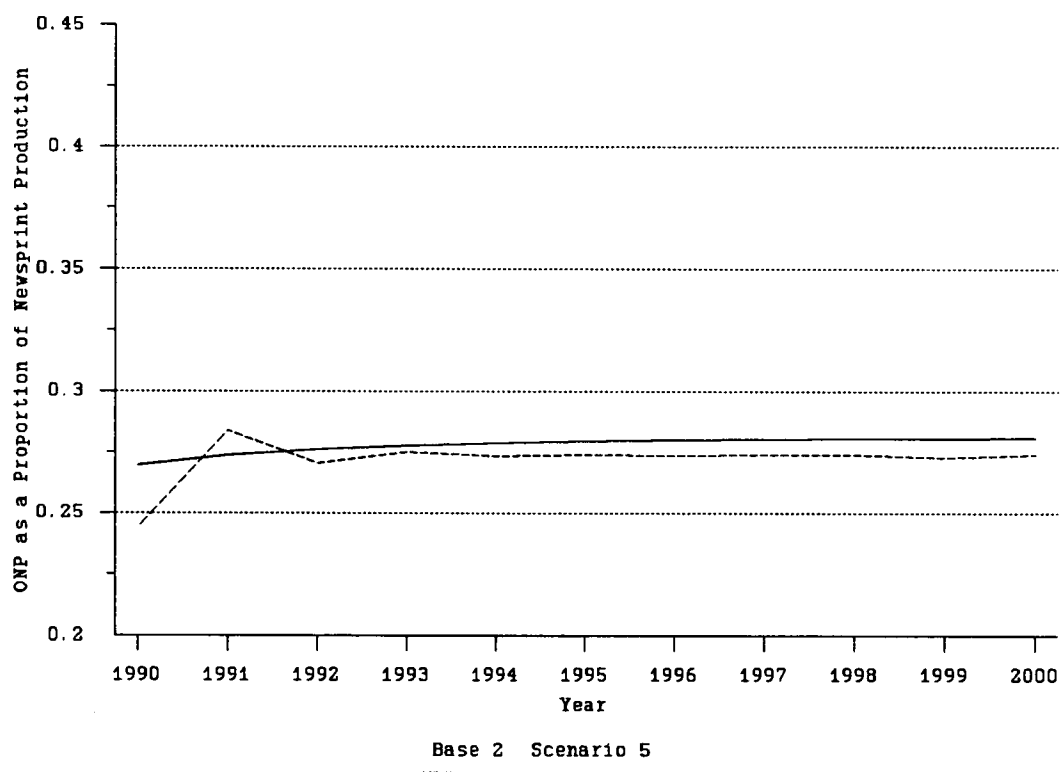


Figure V-13

Simulated Future Rates of ONP Recycling When Output and Technology are Held Constant

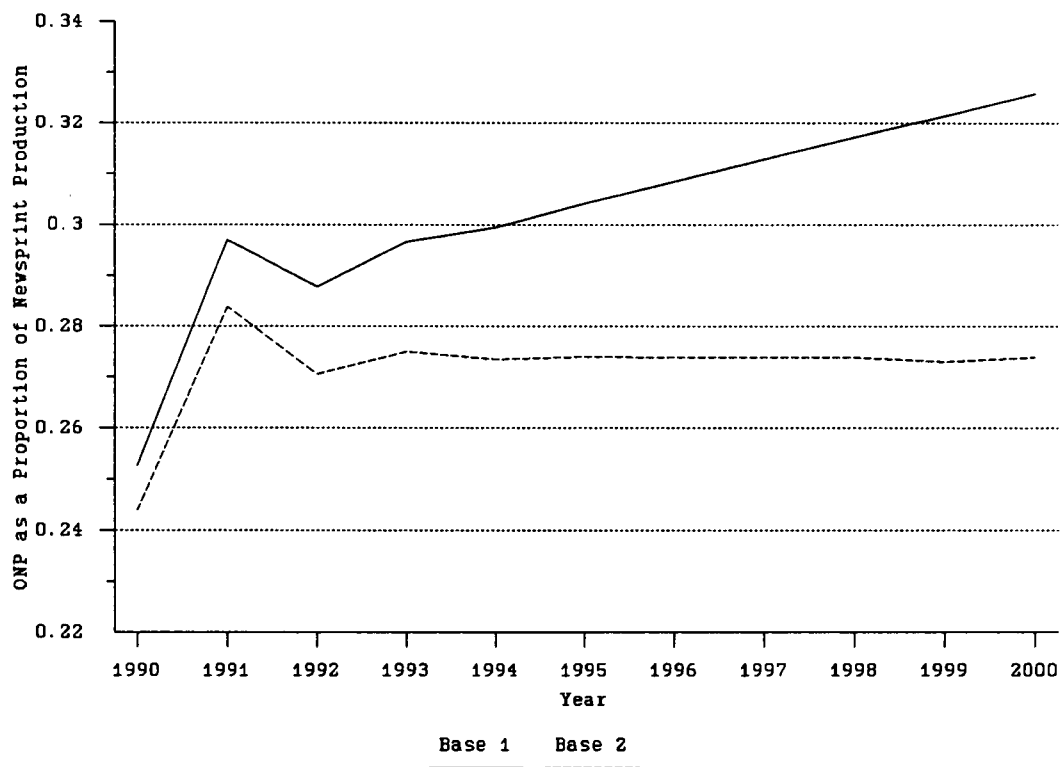


Figure V-14

Comparison of the Simulated Future Rates of ONP
Recycling When Output is Held Constant
(Base Case 1 vs. Base Case 2)

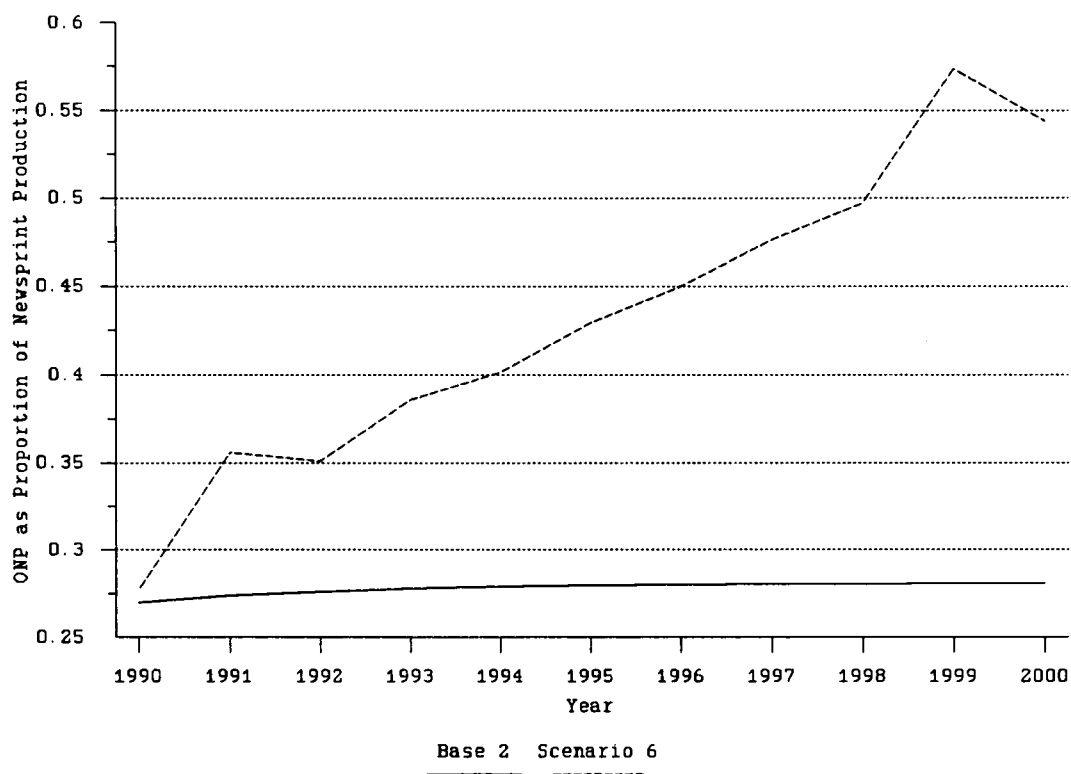


Figure V-15

Simulated Future Rates of ONP Recycling When Output Grows
To Meet Future Levels of Newsprint Consumption
(Base Case 2)

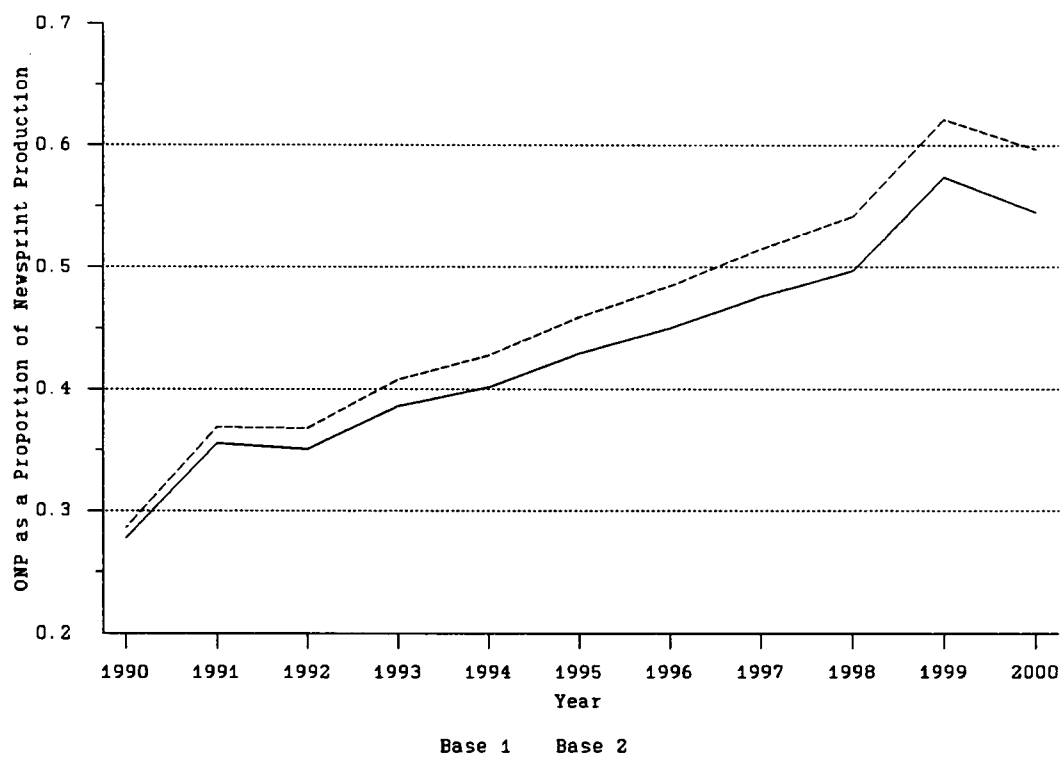


Figure V-16

Comparison of the Simulated Future Rates of ONP
Recycling When Output Grows To Meet Future
Levels of Newsprint Consumption
(Base Case 1 vs. Base Case 2)

biased toward ONP. Due to the locational advantage that the U.S. has over Canada regarding ONP use, expansion in recycled capacity has been a relatively inexpensive means of expanding U.S. newsprint capacity, in general.

5. CONCLUSIONS AND IMPLICATIONS FOR PUBLIC POLICY

Recycling legislation has dealt with the problem of increasing the rate of ONP recycling in two ways. First are policies that shift the supply of ONP. These policies range from mandatory source separation to banning disposal of newspapers and variable landfill fees as discussed in Chapters II and IV. Second, some states have resorted to "mandatory content" legislation as a means for increasing the demand for ONP. Other policies to shift the demand for ONP, like the removal of virgin materials subsidies, have been suggested, but not tried.

Before discussing the implications of the analysis of the derived demand for ONP for public policy, a word of caution is in order. First, as noted in Chapter I, the benefits and costs of the various ONP recycling policies have not been measured. Thus, policy conclusions cannot be drawn on the basis of efficiency considerations (e.g., on the basis of which policy yields the highest benefit-cost ratio). Secondly, the analysis has ignored any equity or distributional issues. A complete policy analysis would incorporate both efficiency and equity considerations. In

the following discussion, the various recycling policies will be judged according to the criteria of which policy achieves the highest rate of ONP recycling. Finally, it must be mentioned that the analysis is based on historical information and the validity of any conclusions depends upon whether the results of the analysis can be assumed to hold in the future.

Supply-side policies, which lower the relative price of ONP, will not be very effective at stimulating the rate of recycling in the U.S. newsprint industry even in the long run. This is due to the inelasticity of the derived demand for ONP. Separation and collection programs, which have proven to be quite costly for localities, will achieve little benefit in terms increased recycling of ONP. Since the demand for ONP is highly price-inelastic, a more effective strategy may be to apply policies that shift the demand for ONP.

Environmentalists have criticized tax policy targeted at encouraging growth in the timber industry for impeding recycling on a large scale. In the case of ONP, it was found that these concerns are unfounded. Fiscal biases in favor of virgin materials probably have not proven a major hindrance to recycling in the newsprint industry. This tax policy was designed to encourage aggregate economic growth (OTA, 1989). It is not likely that elimination will result in a large shift in the ONP demand schedule and hence, yield

benefits (in terms of increased ONP recycling) that more than offset the loss in the aggregate economic benefits, assuming, of course, that there are any.

The derived demand for ONP is significantly more sensitive to and inversely related to the price of capital. The simulations suggest that tax preferences aimed at encouraging investment in recycling capital will be the most effective "incentive" policy for shifting ONP demand. However, the benefits to be realized through such tax policy will only be minimal.

Growth in ONP consumption has historically arisen as a consequence of output expansion in the U.S. newsprint industry. The results of this study indicate that continued growth in output will be sufficient to shift the ONP demand schedule and calls into question the need to apply any demand-side policy.

If, however, the goal of increased ONP recycling is to be aggressively pursued, this result suggests policies to promote output growth beyond historical levels will be the most effective recycling policy of all. Since the output market was not modelled in this study, the precise variables that determine output expansion, which could be the target of incentive policies that aim to encourage growth in recycling through their effects on output expansion, were not analyzed.

Turning to the effects of mandatory content

legislation, the legislation has been designed under the assumption that the major barrier to increased ONP consumption in the newsprint industry has been a lack of demand for recycled newsprint. Historically, there is no evidence to support this assumption. ONP consumption has steadily increased over the past 30 years and producers have been able to sell their recycled output with practically no price differentiation between the recycled and virgin product.

If mandatory content legislation does translate into an increase in the effective demand for recycled newsprint, it will result in a significant increase in ONP consumption. The reason, however, is not that legislation removes a demand-side constraint. Rather, the legislation will change the geography of the North American newsprint industry much like the technological advancement in the 1870's that caused wood to replace rags and straw as the major input in newsprint production. This technological advancement allowed Canada, with its extensive timber resources, to become a major producer of newsprint. Analogously, an increase in demand for newsprint produced with recycled fiber will tip the scales in the favor of the U.S. (with its vast resource of ONP). Thus, mandatory content legislation achieves an implicit trade restriction, which will surely act to stimulate output growth in the U.S. newsprint industry.

Figures V-17 through V-19 will illustrate the potential effects of mandatory content legislation if it translates into an increase in the effective demand for recycled newsprint. Figure V-17 describes the process (temporarily ignoring the structure of marginal cost in the industry) of price-output determination in the newsprint industry. Recall in Chapter IV, it was noted that the price of newsprint (P) is determined by price leadership. This price probably lies somewhere between the monopoly price P^M (where marginal revenue, MR , equals marginal cost, MC) and the perfectly competitive price P^C (where price equals marginal cost). At the price determined by the price leadership system (P^*), the firm depicted in V-17 will produce Q^* units of output. The following discussion will assume that the price of newsprint remains constant at P^* and that there is no differentiation between recycled and virgin newsprint since this has historically been the case.

If the demand for recycled newsprint is increased, then firms that produce recycled newsprint in excess of the minimum content (as stated in the legislation) would experience an outward shift in the demand for their product. This situation is shown in Figure V-18 (a). The shift in demand causes the firm to expand newsprint production (recycled newsprint, in this case) from Q_1 to Q_2 , assuming that the price of newsprint remains constant at P^* . For the

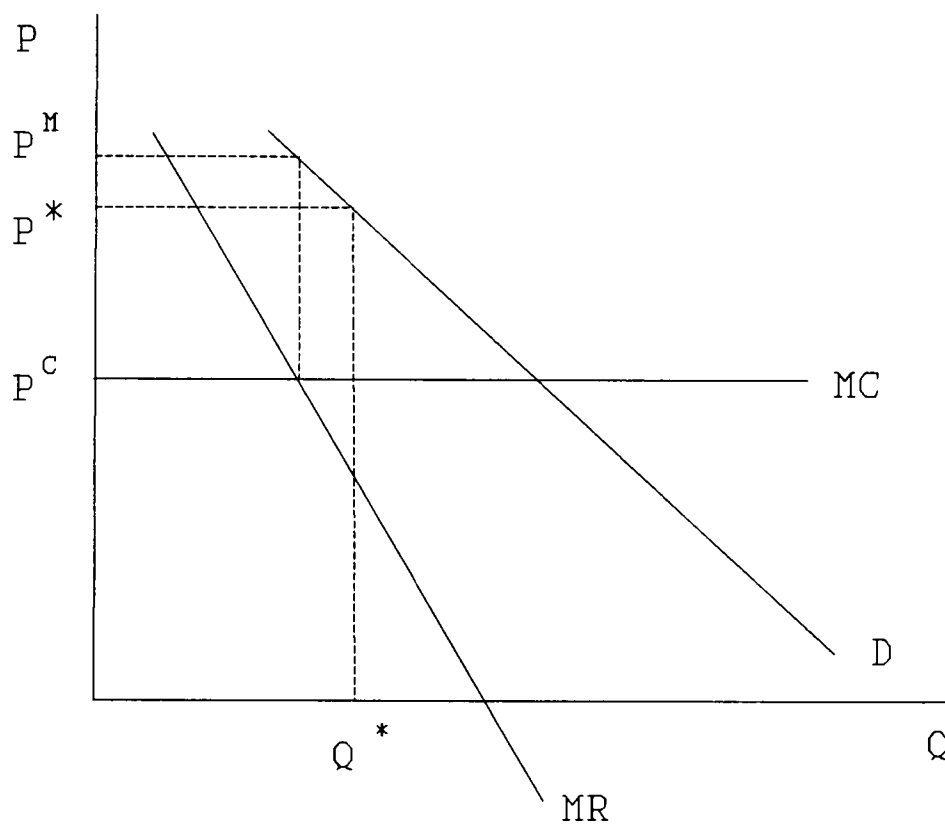
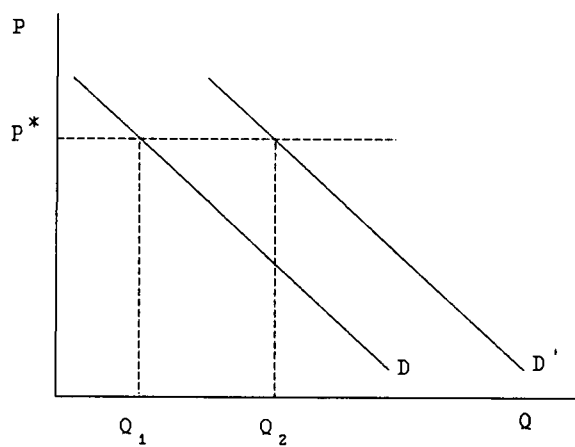
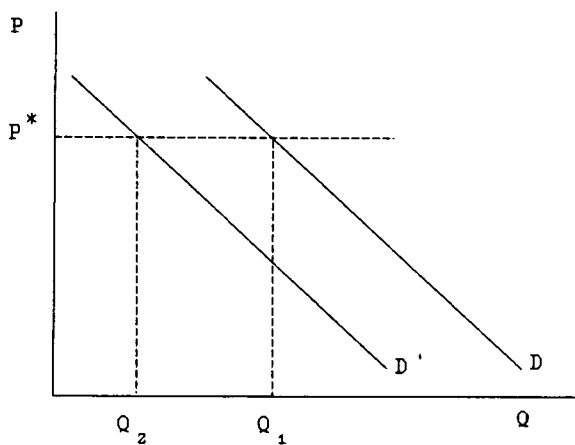


Figure V-17

Price and Output Determination
in the Newsprint Industry



(a)



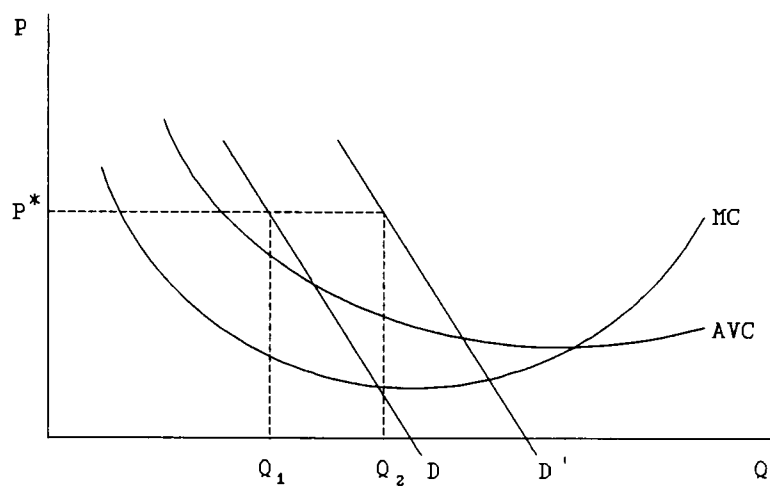
(b)

Figure V-18

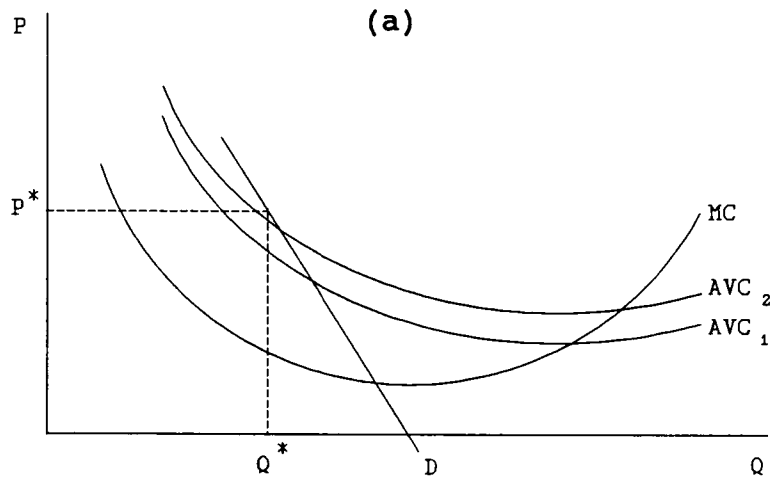
The Effects of a Shift in Demand on the
Newsprint Firm's Output Decision

Figure V-19

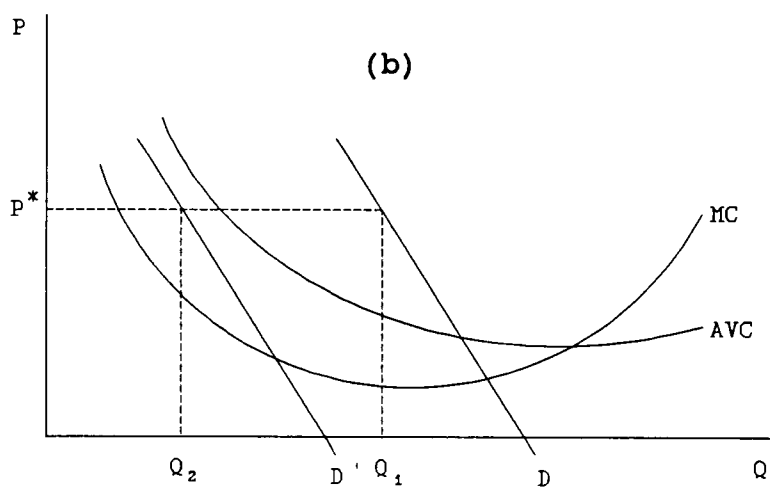
The Possible Effects of Mandatory Content Legislation



(a)



(b)



(c)

virgin fiber mill, the change in demand will depend upon whether the firm is able to switch to the recycled production technology. The ability of the firm to switch depends upon the shape of its costs curves and these will be added to the analysis below. If the firm is unable to switch, then the firm will experience a decline in the demand for its product, as shown in Figure V-18 (b). In Figure V-18 (b), output falls from Q_1 to Q_2 when price remains constant at P^* . If the firm is able to switch to exactly meet the minimum content standard, then demand will neither shift inward nor outward.

Now let us add the cost structure of the typical newsprint firm (presented in Chapter IV) to Figures V-17 and V-18. For firms already producing newsprint with recycled content in excess of the minimum, demand will shift outward and output will expand. Expansion in output will allow these firms to realize lower average costs, as shown in Figure V-19 (a). Note that, in this case, the excess of price over average costs becomes greater and this will act to exert downward pressure on price. Whether price declines or not depends upon the ability of the price leadership system to maintain price discipline among these firms in the industry.

In Figure V-19 (b), the firm producing with virgin fiber is able to switch to the recycled technology and exactly meet the minimum content standard. Thus, demand

does not shift and the firm does not alter its level of output. Switching production technology causes average costs to shift from AC_1 to AC_2 . Note that, although average costs shift upward, price is still greater than average cost at Q and the firm earns a profit on every unit of newsprint sold.

Figure V-19 (c) illustrates the case of the newsprint firm that is unable to switch to recycled technology. In essence, any increase in demand to be realized by making the switch will be outweighed by an upward shift in average costs. As Figure V-19 (c) is drawn, the downward shift in demand causes the firm to suffer a loss on every unit sold and the firm eventually will shut down.

Due to their locational disadvantage regarding recycled newsprint production, it is more likely that firms located in the Canada than firms located in the U.S. will be depicted by V-19 (c). Further, almost all of the firms that can be described by V-19 (a) are located in the U.S.

The actual speed of the adjustment will depend upon a number of forces. If the price of newsprint falls, then this will speed the process since virgin newsprint mills will be forced to follow. A decline in the price of newsprint will cause more virgin newsprint firms to operate at a loss (or if the price decrease is not followed, virgin output will decrease and these firms will experience an increase in average costs which could also cause them to

operate at a loss). If the price of newsprint does not fall, then the increase in profits realized by recycled newsprint firms could attract new firms into the industry, depending upon how effective a barrier to entry contracts (discussed in Chapter IV) and the high level of fixed costs associated with building a new mill pose.

CHAPTER VI

SUMMARY

The so-called solid waste "crisis" is characterized by a municipal solid waste stream that has rapidly increased in recent years and continues to increase. At the same time, disposal capacity is not increasing sufficiently to meet projected levels of solid waste generation. At the simplest level, alleviating the solid waste "crisis" involves maintaining adequate disposal capacity to meet projected levels of MSW generation.

However, efforts to increase MSW disposal capacity by building new facilities have been largely unsuccessful. Environmental concerns regarding MSW management have caused siting of new MSW facilities to become a major impediment to the expansion of solid waste capacity. Further, new, more stringent, regulations regarding performance and technical standards for landfills also act to reduce available MSW capacity by resulting in closure rather than compliance for existing facilities and by increasing the cost of building new facilities.

Difficulty in siting new MSW facilities coupled with a decline in available MSW capacity and rising costs of solid waste disposal, the key characteristics of the solid waste crisis, have caused many localities to turn to recycling as an alternative to disposing of waste in landfills and

incinerators. While there are other motives behind the drive to recycle, it was argued in Chapter II that the solid waste crisis has been a primary force in shaping the policy responses to the problem of increasing the rate of waste recycling. More specifically, recycling has come to be viewed predominantly as an alternative to disposing of waste in landfills and incinerators. When recycling is viewed as a waste management alternative, the logical focus of recycling policy is to attempt to encourage recycling by reducing the flow of waste to landfills and incinerators or equivalently, by shifting the supply of secondary materials. While some efforts to increase the demand for secondary materials have been made, these efforts have not been as widespread and often end up being measures to boost the collection of secondary materials and still result in an outward shift in supply.

Because of its focus on removing materials from the solid waste stream, recycling policy has been charged with taking an unbalanced approach. A concern has been expressed that the neglect to implement policies to stimulate demand will result in a surplus of secondary materials or a glut in secondary markets. From the perspective of economic theory, of course, concerns of a glut are unfounded since demand-side measures are not necessary for markets to clear, in the absence of a constraint to prevent price from adjusting.

However, the concerns regarding the unbalanced approach

to recycling are valid in the sense that market-clearing may not imply a large increase in the rate of waste recycling. To the extent that market-clearing implies a large increase in recycling depends on the price-elasticity of demand for secondary materials. If demand is highly inelastic, then the shifts in supply caused by policies to remove materials from the solid waste stream will not result in a substantially higher market-clearing level of recycling. For markets characterized by a highly inelastic demand schedule, the implementation of policies to shift the demand for waste materials will result in a larger increase in recycling.

In the development of policies to shift the demand for secondary materials, secondary markets must be viewed from the perspective of the potential consumer of the waste material, which is the firm that uses secondary materials as substitutes for virgin materials in a production process. In the case of secondary markets where demand is highly inelastic, then, pursuing the goal of increased recycling will require a departure from the perspective that recycling is an issue of solid waste management. Rather, recycling becomes an issue of resource use or substitution.

From the standpoint of economic theory, the analysis of the demand side of secondary markets is a straightforward application of input demand theory. Recycling, or the substitution of secondary materials for virgin raw materials

in production, depends on a number of forces and relative input prices may not be the most important consideration. Recycling depends on the structure of the final output market as well the technical aspects of the firm's production process. The ease of substitution as well as the manner in which the recycled input is tied to competitive and cooperating inputs affects the elasticity of its demand schedule. Any of these factors can constrain the firm's response to the lower recycled input prices generated by supply-side programs and hinder these efforts to increase the rate of recycling for some secondary materials.

The demand for old newspapers (ONP) as an input in newsprint production is a prime example of a price-inelastic secondary material market. Recycling legislation has attempted to increase the rate of ONP recycling with two different approaches. First is supply-side legislation (e.g., mandatory source separation, banning disposal of newspapers, and variable landfill fees). Second is mandatory content legislation to which some states have resorted.

Descriptively, supply-side programs have resulted only in lower ONP prices, not substantially greater use of ONP in the newsprint industry. The primary reason lies in the inelasticity of the long-run ONP input demand schedule. As for mandatory content legislation, the efficacy will depend on how the increase in the notional demand for recycled

newsprint is transmitted to the newsprint producer. The burden of increased ONP recycling (or equivalently, increased recycled newsprint production) still rests upon the newsprint industry and these policies only address this sector indirectly.

The rationale for the inelasticity of the ONP demand schedule in both the short- and long-run has been given in the context of economic theory as well as in the context of the history of the U.S. newsprint industry and the technical aspects of the processes for virgin versus recycled newsprint production. In the short-run, the primary reason for the inelasticity of the ONP demand schedule is the unadaptability of existing capital. In the long run, the possible reasons for the inelasticity of the ONP demand schedule are 1) the existence of adjustment costs associated with switching production technology, 2) the manner in which ONP is tied to the cooperating input, capital, 3) the relatively small percentage of total production costs accounted for by the virgin input, woodpulp, 4) oligopolistic inertia created by a well-developed price leadership system, and 5) the low value for the elasticity of demand for the final product, newsprint.

Econometric analysis of the derived demand for ONP revealed that the demand for ONP by newsprint producers is price-inelastic in both the short- and long-run. Thus, supply-side policies, which lower the relative price of ONP,

will not result in a large increase in the rate of recycling in the U.S. newsprint industry even in the long run.

Further, because the ONP demand schedule was estimated as a system of five input demand equations, the relative efficacy of other policies suggested as means for increasing the demand for ONP recycling was evaluated. Tax policy has been criticized for discouraging recycling for a number of secondary materials. In the case of ONP, it was found that fiscal biases in favor of virgin materials have not proven a major hindrance to recycling in the newsprint industry. Removal of these tax preferences will not result in a large outward shift of the ONP demand schedule. A policy that may shift the ONP demand schedule slightly more is tax preferences that alter the price of capital and create an incentive to expand newsprint capacity.

The major finding of this study was that ONP recycling in the newsprint industry is more dependent upon the parameters of the final output market than it is on relative input prices. Growth in ONP consumption has historically arisen as a consequence of output expansion in the U.S. newsprint industry. In the context of input demand theory, exogenously-induced output growth is the primary force that drives the rate of ONP recycling in this industry. This result should not be surprising since one of the early motives for the development of recycled newsprint technology was as a relatively inexpensive means of expanding U.S.

newsprint capacity to alleviate the post-World War II shortage of newsprint. In sum, expansion in output requires investment in new newsprint capacity and this investment has been biased toward ONP-based mills.

As for mandatory content legislation, it was noted that if the legislation translates into an increase in the effective demand for recycled newsprint, it will result in a significant increase in ONP consumption. The reason, though, is not that legislation removes a demand-side constraint. Due to the locational advantage that the U.S. has over Canada regarding recycled newsprint production, mandatory content legislation achieves an implicit trade restriction by tipping the scales in the favor of the U.S. newsprint producers. As a result, U.S. newsprint production will increase and the demand for ONP will increase substantially as well.

These results, however, must be interpreted with caution. There are limitations to the analysis of the derived demand for ONP and these warrant explicit discussion.

First, this study was based on historical information and any policy conclusions drawn from the analysis are accurate only if the forces described above continue into the future. It is possible that separation and collection programs could act to stabilize the price of ONP at lower levels in the long-run, provided that there is government

intervention to prevent the abandonment of these programs when the price of ONP drops below the level at which sales of ONP are no longer profitable. Stabilizing the price of ONP at lower levels (Figure IV-3 gave evidence that this has occurred to some extent) could encourage investment in ONP capacity. Investment in ONP capacity will speed the rate of ONP-woodpulp substitution by shifting the demand for ONP outward.

Next, most input demand studies, this study included, are based on the assumption that input prices are exogenous to the model. This is not a realistic assumption if the firm (or industry) can affect prices through the quantities of inputs it purchases. It is unlikely that the newsprint industry can affect the price of energy. Further, the industry probably cannot affect the price of woodpulp through the quantities it uses. Guder and Buongiorno (1984) justify the assumption of an exogenously determined woodpulp price on the basis that the newsprint industry accounts for such a small percentage of total pulp consumed. In 1986, for example, the newsprint industry accounted for less than ten percent of the total woodpulp consumed at U.S. paper and board mills (American Paper Institute, 1988). As for the price of ONP, assuming exogeneity may not pose a problem in the historical context since, in 1987, reuse in the newsprint industry still only accounted for ten percent of the total ONP generated.

Even if the exogeneity of input prices is an unrealistic assumption, little advantage would have been gained by endogenizing input prices and estimating the input demand and factor price equations simultaneously. The bias resulting from not estimating the prices and quantities as a simultaneous system would merely be replaced with the bias of applying an estimation technique with only large sample properties to a small sample. Theoretically, there is no guidance to which of the two biases would be smaller.

Endogenizing output may be a more important next step. Output was shown in this study to be the driving force regarding ONP recycling. Modelling the output market may give additional insights to the precise variables that cause output growth and hence, ONP recycling. These variables could be the target of incentive policies that aim to encourage growth in recycling through their effects on output expansion.

Another shortcoming, common to most input demand studies, lies in the measurement of capital. Due to data limitations, capital is often not decomposed into the components that allow for efficient substitution of one factor for another. For example, studies of interfuel substitution do not generally discuss how firms alter their capital stock over time so that they are able to substitute one fuel for another, say natural gas for oil. Thus, another direction for future work is to decompose the

aggregate measure of capital into recycled and virgin capital to explore the forces that govern the decision to invest in recycling versus woodpulp-based capital, assuming that the data can be obtained.

Other limitations stem from the narrow focus of the study. The study was concerned with explaining why policies aimed at reducing the flow of MSW to landfills and incinerators may not achieve the policy goal of increased recycling. The costs and benefits of various recycling policies were compared only very descriptively. Benefits were defined narrowly as an increase in the rate of ONP recycling and hence, the study focused only on a subset of the potential benefits of increased ONP recycling. Costs were not measured at all.

Also, the study of the market for ONP as an input in newsprint production was only a partial analysis. The other ONP markets may be equally important to increasing the rate of ONP recycling. Since removing ONP from the solid waste stream contributes significantly to reaching legislatively-determined recycling targets, an assessment of the potential for increased ONP recycling in these markets would be an important extension of this study. Such an extension will require that a full model of the ONP generation and recycling system be developed.

Despite these limitations, the analysis of the market for ONP as an input in newsprint production achieved its

primary objective. That is, this study has shed light on the key forces that have historically driven the rate of recycling in the U.S. newsprint industry by applying basic economic theory to the estimation of a model of the derived demand for ONP. These forces were shown to have some important implications for the formation of policy to most effectively achieve the goal of increased recycling.

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APPENDIX

DERIVATION OF THE VARIABLE INPUT-OUTPUT DEMAND EQUATIONS

The detailed derivation of input-output equations for L, E, M₁, and M₂ is rather straightforward.

The functional form that was chosen to approximate the AVC function was the normalized restricted average variable cost function:

$$\begin{aligned}
 (A-1) \quad AVC = & \alpha_0 + \alpha_{0T}T + \sum_j \alpha_j P_j + \sum_j \alpha_{jT} P_j T \\
 & + \frac{1}{2} \sum_i \sum_j \delta_{ij} P_i P_j + \alpha_K \frac{K}{Q} + \frac{1}{2} \alpha_{KK} \left(\frac{K}{Q} \right)^2 \\
 & + \sum_j \gamma_{jK} P_j \frac{K}{Q} + \alpha_{KT} \frac{K}{Q} T, \\
 & i, j = E, M_1, M_2.
 \end{aligned}$$

The input-output equations for E, M₁, and M₂ are derived by applying the Shephard-Uzawa-McFadden lemma and differentiating the normalized quadratic with respect to their prices:

$$\begin{aligned}
 (A-2) \quad \frac{\partial AVC}{\partial P_E} &= \frac{E}{Q} = \alpha_E + \sum_j \delta_{Ej} P_j + \alpha_{ET} T + \gamma_{EK} \frac{K}{Q} \\
 \frac{\partial AVC}{\partial P_{M1}} &= \frac{M_1}{Q} = \alpha_{M1} + \sum_j \delta_{M1j} P_j + \alpha_{M1T} T + \gamma_{M1K} \frac{K}{Q} \\
 \frac{\partial AVC}{\partial P_{M2}} &= \frac{M_2}{Q} = \alpha_{M2} + \sum_j \delta_{M2j} P_j + \alpha_{M2T} T + \gamma_{M2K} \frac{K}{Q}
 \end{aligned}$$

These are the same as the equations shown in V-8.

The input output equation for L is obtained by first noting that,

$$(A-3) \quad AVC = \frac{1}{Q}(L + P_E E + P_{M1} M_1 + P_{M2} M_2)$$

A-3 is the definition of average costs and must be true regardless of the functional form assumed for AVC. Further, recall that in the empirical analysis, P_E , P_{M1} , and P_{M2} were divided by (or normalized by) by the price of labor. Thus, at any point on AVC, the price of labor is unity.

The input output equation for L is obtained by first rearranging A-3

$$(A-4) \quad \frac{L}{Q} = AVC - (P_E E + P_{M1} M_1 + P_{M2} M_2)$$

The term in parenthesis can be rewritten by substituting in the functional relationships for E, M_1 , M_2 as derived in A-2

$$\begin{aligned} (P_E E + P_{M1} M_1 + P_{M2} M_2) &= P_E \left(\alpha_E + \sum_j \delta_{Ej} P_j + \alpha_{ET} T + \gamma_{EK} \frac{K}{Q} \right) \\ &+ P_{M1} \left(\alpha_{M1} + \sum_j \delta_{M1j} P_j + \alpha_{M1T} T + \gamma_{M1K} \frac{K}{Q} \right) \\ (A-5) \quad &+ P_{M2} \left(\alpha_{M2} + \sum_j \delta_{M2j} P_j + \alpha_{M2T} T + \gamma_{M2K} \frac{K}{Q} \right) \\ &= \sum_j \alpha_j P_j + \sum_j \alpha_{jT} P_j T + \sum_i \sum_j \delta_{ij} P_i P_j \\ &+ \sum_j \gamma_{jK} P_j \frac{K}{Q} \end{aligned}$$

Substituting A-5 into A-4 and combining like terms yields:

$$\begin{aligned}
\frac{L}{Q} &= AVC - (P_E E + P_{M1} M_1 + P_{M2} M_2) \\
&= \alpha_0 + \alpha_{0T} T + \sum_j \alpha_j P_j + \sum_j \alpha_{jT} P_j T \\
&\quad + \frac{1}{2} \sum_i \sum_j \delta_{ij} P_i P_j + \alpha_K \frac{K}{Q} + \frac{1}{2} \alpha_{KK} \left(\frac{K}{Q} \right)^2 \\
&\quad + \sum_j \gamma_{jK} P_j \frac{K}{Q} + \alpha_{KT} \frac{K}{Q} T - \sum_j \alpha_j P_j - \sum_j \alpha_{jT} P_j T \\
&\quad - \sum_i \sum_j \delta_{ij} P_i P_j - \sum_j \gamma_{jK} P_j \frac{K}{Q} \\
&= \alpha_0 + \alpha_{0T} T - \frac{1}{2} \sum_i \sum_j \delta_{ij} P_i P_j + \alpha_K \frac{K}{Q} \\
&\quad + \alpha_{KT} \frac{K}{Q} T + \frac{1}{2} \alpha_{KK} \left(\frac{K}{Q} \right)^2
\end{aligned}$$

which is the expression for the labor input-output equation shown in V-8.

VITA

Deborah Vaughn Nestor was born in Waterloo, Iowa on March 19, 1965. After graduating from Dunkerton Community High School in 1983, she attended the University of Northern Iowa where she received a Bachelor of Arts in Economics and Mathematics in May 1987.

In September 1987, she accepted a graduate assistantship at The University of Tennessee and began study towards a Ph.D. in Economics. She received this degree in August 1991.

Deborah is married to Michael D. Nestor of Pittsburgh, Pennsylvania.