Economic aspects of the recycling of industrial wastes: an inquiry into the treatment given the economics literature to activities involving the recovery and re-use of industrial wastes and its relevance, in terms of explanation and policy prescription, for those activities as they are carried on in the Illawarra region

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ECONOMIC ASPECTS OF THE RECYCLING OF INDUSTRIAL WASTES:

AN INQUIRY INTO THE TREATMENT GIVEN BY THE ECONOMICS LITERATURE TO ACTIVITIES INVOLVING THE RECOVERY AND RE-USE OF INDUSTRIAL WASTES AND ITS RELEVANCE, IN TERMS OF EXPLANATION AND POLICY PRESCRIPTION, FOR THOSE ACTIVITIES AS THEY ARE CARRIED ON IN THE ILLAWARRA REGION

by

Gregory J. Cunningham

A thesis submitted in partial fulfilment of the requirements for the degree of Bachelor of Commerce (Honours) in the University of Wollongong.


Degree awarded with first class honours.
The past few years have seen the development of considerable interest in activities involving the recovery of materials and by-products from the waste streams of industrial firms and their utilisation, by either the waste-producing firms themselves or other firms, as raw material inputs into production processes. This interest derives, of course, from community concern in the developed nations regarding the problem of environmental pollution. The use of waste recovery and re-use techniques actually reduces the volume of industrial wastes requiring discharge, in one form or another, into the environment and thus avoids the environmental pollution problems which tend to accompany the waste disposal activities of industrial firms. It would appear however, that waste recovery and re-use techniques have not yet received wide application, with economic considerations apparently playing an important role.

This study focusses on the Illawarra region as an example of a region in which waste recovery and re-use activities have not yet received wide application and investigates the treatment given in the economics literature to these activities, with this investigation being carried out with a view to assessing the contribution that has been made by economists to both the understanding of the particular nature of waste recovery and re-use activities and the stock of policy prescriptions appropriate as a means of inducing an increase in the level and extent of those activities and thus achieving a significant and sustained improvement in environmental quality. A subsidiary aim involved in carrying out this literature review is that of outlining and assessing the current state-of-the-art in respect of the treatment of recovery and re-use activities by economists.
The thesis is divided into six chapters. Chapter I introduces the study by briefly outlining some of the background of, and justification for, the literature review carried out. Chapter II expands on this brief introduction by considering, and explaining, both the interest which has been expressed in waste recovery and re-use activities in the Illawarra region in recent years and the observation that these activities appear to be 'restricted and fragmented'.

Chapters III and IV present a detailed examination of the economics literature concerned with the analysis of waste recovery and re-use activities. The first of these chapters considers the literature concerned with the inclusion of these activities in analyses relating to the problem of environmental pollution. These analyses have been carried out within the theoretical framework provided by modern welfare economics. The economy-wide perspective of the static and dynamic general equilibrium analysis carried out within this framework reveals that the factors underlying the restricted and fragmented nature of waste recovery and re-use activities basically relate to the existence of a defective system of economic incentives arising out of deficiencies in the operation of market processes.

The second chapter referred to above examines the work of those economists who have analysed waste recovery activities by including them within a framework which deals explicitly with that entity known as 'the firm'. The theoretical and quantitative analysis carried out within this framework indicates that economic factors are seen by economists as playing an extremely important role in the behaviour of firms in relation to waste generation, abatement and discharge activities.
The emphasis placed on economic factors in the literature is accompanied by the prescription of policies, particularly the effluent charge strategy, which seek to induce an increase in the amount of materials and by-product recovery carried on through market related means. In view of this Chapter V considers, and evaluates the importance of, problems and difficulties likely to be encountered in any practical implementation of the effluent charge strategy.

It is concluded (Chapter VI) that the economics literature has made an important contribution to the understanding of waste recovery and re-use activities as they are carried on in the Illawarra region. The factors making for the particular nature of these activities, however, operate on an economy-wide scale, so that the policies advanced by the literature represent an approach that might be taken by governments at a state or national, rather than regional, level.
I would like to record my appreciation of the help, encouragement and guidance extended by a number of people during the preparation of this thesis.

In particular I would like to thank Professor Ken Blakey for his assistance, patience and supervision of my studies. Professor Blakey patiently read a large section of the final draft and in so doing provided many helpful suggestions and comments and detected a number of errors. My thanks are also due to the other members of staff, both academic and non-academic, of the Department of Economics at the University of Wollongong for the interest and encouragement expressed throughout the development of this work.

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CHAPTER I

INTRODUCTION
An aspect of the operations of industrial firms that has received a considerable amount of attention in the developed nations since the early 1960's is the fact that the production of one or a few main products is necessarily accompanied by the generation of various non-product outputs. These non-product outputs, generally referred to as 'wastes', are generated because it is not possible to design production processes "for 100 per cent conversion of inputs into desired outputs." It is, of course, the discharge into the environment of wastes generated in industrial production processes that is in large part responsible for the environmental pollution problems which have been experienced in an acute form in the developed nations during the past 15 years or so.

Firms do not, however, always discharge the total amount of wastes generated in production processes into the environment, for it is often profitable, or perhaps necessary where firms are subject to governmental pollution control actions, to recover the original materials or new materials (termed 'by-products') from waste streams, with these materials and by-products being either re-used in production by the waste-producing firms themselves or sold to other firms as inputs into their production processes. It is also possible, of course, for firms to subject their wastes to treatment processes prior to discharge into the environment, although it must be

1. The term 'industrial firms' may be taken in this study as referring to firms operating production processes of the manufacturing type rather than to firms operating mining, logging or agricultural production processes.
4. The activities identified here may be referred to by use of the term 'recovery and re-use activities'.

recognised that the use of such processes, unlike the use of waste recovery processes, does not enable firms to discharge less wastes than are actually generated in production, for waste treatment processes dilute or transform, rather than reduce, wastes. Given the possibility of materials and/or by-product recovery from wastes and the waste treatment option, the materials flow within an individual firm might reasonably be represented by the scheme illustrated in Figure 1.

The process by which materials and by-products are recovered from industrial wastes and subsequently used, either by the waste-producing firm itself or by other firms, as raw material inputs into production processes is an interesting phenomenon, particularly in respect of the possibilities it implies for the avoidance of environmental pollution. As noted above the recovery of materials and by-products enables firms to reduce the amount of wastes requiring disposal in the environment and thus avoid the detrimental effects which tend to be exerted on the environment when it is used as a receptor of wastes. The implication, then, is that an increase in the amount of recovery and re-use activity carried on by firms would contribute much towards the elimination of the problem of environmental pollution.

The concern of economists with the explanation of the occurrence of environmental pollution and the prescription of policies appropriate for its prevention has resulted in activities involving the recovery and re-use of industrial wastes receiving considerable attention in the economics literature, with these activities having been included

5. The assertion that the use of recovery processes actually reduces the volume of wastes requiring disposal assumes, of course, that recovery processes themselves "do not result in the generation of more [wastes], on balance, than the use of virgin raw materials." Russell, C.S., Residuals Management in Industry: A Case Study of Petroleum Refining. (Baltimore: The Johns Hopkins University Press, 1973), p.5.
**FIGURE 1** Material flows in a 'typical' production activity

as an integral part of analyses relating to environmental pollution problems. More specifically, it is possible to refer to two distinct approaches that have been taken by economists in this regard.

The first of these approaches involves the consideration of recovery and re-use activities from an economy-wide viewpoint. Emphasis is placed on the role played by these activities in the process of interaction between economic activity and the environment, with the state of both environmental quality and the stock of non-renewable natural resources being an important consideration. An important feature of the analyses carried out along these lines is the interdependence identified between the problem of environmental pollution and the problem of depletion of non-renewable natural resources.

The second approach which has been taken in the literature involves the inclusion of the possibility of recovering materials and by-products from wastes within a framework which deals with the behaviour of individual firms in respect of the generation, abatement and discharge of wastes. Analysis carried out in this regard relates to either the neo-classical theory of the firm or an analytical framework which attempts to take the actual decision-making processes of firms into account.

In broad terms, the literature referred to here is concerned with both the explanation of the nature of activities involving the recovery and re-use of industrial wastes and the prescription of policies aimed at inducing an increase in the extent to which these activities are carried on in an economy. It would appear that this literature may be of some help in adding to the understanding of waste recovery and re-use activities as they are carried on in the Illawarra region of New South Wales and, in the process, contribute
policy prescriptions appropriate as a means of inducing an increase in the level and extent of these activities in the region. While considerable interest has been generated in recent years in the Illawarra region with regard to the advantages likely to accrue to the regional community, in terms of the avoidance of the environmental pollution problems which characterise the region, through increased use of waste recovery and re-use techniques, it would appear that these techniques have not yet received wide application.

It is with the assessment of the contribution that can be made by the economics literature to the understanding of, and policy approaches to, the nature of waste recovery and re-use activities in the Illawarra region that this study is in large part concerned. In order to achieve this aim, the justification of which will be outlined in detail in the next chapter, it is intended to examine the literature referred to earlier. The proposed examination of the relevant literature will also serve another, equally important, purpose - it will enable assessment of the current state-of-the-art of the economics literature in respect of the treatment of waste recovery and re-use activities.
CHAPTER II

SOME COMMENTS ON THE NATURE OF, AND INTEREST IN, WASTE RECOVERY AND RE-USE ACTIVITIES IN THE ILLAWARRA REGION.
The past few years have witnessed the development of an increased awareness on the part of the general community in the Illawarra region of the advantages inherent in materials and by-product recovery from industrial waste streams. Activities involving the recovery or salvaging from waste streams of materials and by-products which may be reused in production by the waste producing firm itself or sold to other firms as raw materials for production have come to be regarded as an important means of environmental pollution control. Such activities reduce the volume of wastes discharged into the environment by firms and thus prevent the environmental deterioration and degradation which tends to accompany industrial waste disposal practices. In addition, recovery activities produce a valuable source of low cost raw materials for firms faced with increasing prices in the market for newly extracted raw materials. Use of recovered materials and by-products as substitutes also contributes much towards the conservation of exhaustible natural resources.

The advantages identified here have been recognised by local government, regional organisations and various community groups. These organisations and groups have lent their support to, and sometimes initiated, efforts on the part of industry and governmental research organisations to find new uses, and expand existing markets, for the recovered form of industrial wastes whose disposal in the environment contributes to environmental quality deterioration.

Industry has responded to the conditions outlined above and has demonstrated some interest in recovery techniques and methods. Yet uncertainty exists as to whether or not this expressed interest has been translated into actual behaviour. Apart from the efforts of one
large firm to expand the market for its slag wastes and the participation of six Illawarra firms in the 'Industrial Waste Exchange' set up by the Metropolitan Waste Disposal Authority (M.W.D.A.) in Sydney, there exists little evidence to suggest that industry in general in the Illawarra region, defined as "the area more or less delimited by the administrative boundaries of the City of Wollongong and the Municipality of Shellharbour", has been attempting to expand and extend the utilisation of materials and by-products which are potentially recoverable from the wide range of gaseous, liquid and solid wastes generated. This lack of evidence of any tendency towards an increase in the amount of recovery activity carried on suggests that this kind of activity in the region remains "restricted and fragmented." Before dealing with the basis for, and implications of, the assertions made here regarding industry recovery behaviour it would seem desirable to outline the nature of local government, regional organisations and community group interest in this area. Such an outline might be expected to provide an appropriate background against which the behaviour of industry in respect of materials and by-product recovery might be viewed.

Increased community awareness of, and interest in, the recovery of usable materials and by-products from industrial waste streams seems to have its roots in a general concern for environmental quality and avoidance of its deterioration, or further deterioration, through

industrial waste disposal practices, i.e. avoidance of environmental pollution. This is, of course, a concern which the community in the Illawarra region shares with the community in other parts of Australia and with the communities of the developed nations in general. This widespread environmental consciousness within the communities of the developed nations is a relatively new phenomenon, having developed rapidly during the past decade or so. An outline of the nature and development of this phenomenon seems warranted, given the role played by it in stimulating interest in industrial waste recovery activities.

General community concern with environmental quality and avoidance of its deterioration began to develop in the developed nations during the mid-1960's in response to a number of factors. Chief among them was the readily observable degradation which the natural environment - watercourses, the atmosphere, land and the large ecological systems - was undergoing at that time. Rapid economic expansion in the developed nations, which was accompanied by a high rate of growth in total production, was resulting in a considerable increase in the throughput of raw materials and energy, and hence, through operation of the laws of conservation of mass and energy, a huge increase in the volume of wastes generated and disposed of in the environment. Excessive use of the environment as a waste receptor was causing a readily observable decline in environmental quality. This caused an impairment of the ability of the environment to provide a hospitable habitat for human and other forms of life, "the amenities that make life more enjoyable" and the resources used in production.

Environmental quality deterioration or, what refers to the same thing, environmental pollution, is not synonymous with the act of discharging wastes into the environment. The environment possesses "an enormous capacity to accept, absorb and assimilate" most kinds of wastes which flow into it, a capacity which derives from the operation of "natural processes which transform and/or disperse wastes into harmless areas or harmless and sometimes valuable products." This capacity to absorb and assimilate wastes is, however, limited. Environmental quality deterioration occurs when this particular capacity of the environment is exceeded. Concentrations of wastes build up, causing a diminution in the ability of the environment to provide the services referred to above.

Continuing deterioration in environmental quality has characterised environmental conditions in the developed nations during much of the past two decades or so, a situation which contrasts greatly with the improvement in environmental conditions which is said to have occurred during the first half of the 20th century, and, as noted above, is an important factor in explaining the development of widespread environmental consciousness in the communities of those nations. Several other factors have also contributed to the development of this environmental consciousness. Technological innovations have provided means to better detect and measure alterations to the environment. In addition

further population concentration in large urban areas has added greatly both to the problems and the awareness of them. Finally, it is apparent that more people are demanding higher quality surroundings in response to high levels of economic well being.9

It would appear, then, that environmental quality and avoidance of its deterioration has become an extremely important concern of communities in the developed nations of the world. Environmental awareness of the general community in the highly industrialised Illawarra region seems to provide a fairly representative example of this phenomenon.

The 1976 Commonwealth Census indicated that the Illawarra region possessed a population of 202,45910. Growth in the region, in terms of population, has been essentially a post-war phenomenon, with population having trebled between 1947 and 1971. Only slow growth in population (5.3 per cent) was evident during the five year period 1971 to 1976.11 The rapid rate of growth in population during the 1947 to 1971 period was based on continued development of the region's large manufacturing industry sector, although rapid development of the Finance, Wholesale and Retail Trade, Public Authority and Community and Professional Services sectors also played a significant role.12 The Illawarra region is in fact dominated by its manufacturing industry sector, which is in turn dominated by the heavy industries - the A.S.I.C. 'Basic Metal Products' classification. Approximately 42 per cent of the total workforce in the region is employed in manufacturing

9. Ibid.


11. Ibid.

industry, with 75 per cent of that manufacturing work force being employed in the heavy industries located in the Port Kembla area.\textsuperscript{13}

The regional dominance of the basic metal products industries, and their location in the Port Kembla area, is an important factor in explaining the environmental consciousness of the community in the Illawarra region. The six major heavy industrial firms generate huge volumes of liquid, gaseous and solid wastes and their waste disposal practices in the past have resulted in the Port Kembla area being regarded as a serious source of environmental pollution.

Gaseous emissions from these firms, particularly those from the Australian Iron and Steel Pty Ltd (A.I.S.) integrated steelworks complex, have exerted a readily observable detrimental effect on the atmosphere of the region. "When temperature inversions occur in the morning during Autumn and Spring the pall of pollutants from the [A.I.S. steelworks] is obvious on the Illawarra horizon ... During Summer with prevailing north easterlies there is a distinct drift of smog over Lake Illawarra and up the escarpment towards Jamberoo Valley."\textsuperscript{14} Water pollution deriving from the discharge of liquid industrial wastes is also a major problem in the Port Kembla and surrounding areas, the media in the region having made frequent reports of fish kills in Port Kembla Harbour during recent years. It has been reported that four major industrial firms have been discharging large volumes of contaminated waste fluid into Port Kembla Harbour each day, with one of these firms also discharging a substantial volume of other liquid wastes directly into the sea on a daily basis.\textsuperscript{15}

\textsuperscript{13} Ibid. A.S.I.C. refers to the 'Australian Standard Industrial Classification'.

\textsuperscript{14} State Pollution Control Commission, N.S.W., \textit{Annual Report} - year ended June 30, 1976, pp.100-101.

There also exist a number of other pollution sources in the region, the most important being the gaseous emissions emanating from three coke producing firms located in the northern part of the region and water pollution which has arisen from coal mining operations. It is also important to note that there has been a considerable amount of opposition to the establishment of landfill sites for coal washery refuse in bushland areas in the region.

It is against a background of community concern with the environmental pollution emanating from the sources referred to above that the increased interest on the part of local government, regional organisations and community groups in the recovery of usable materials and by-products from industrial waste streams has developed.

Local government interest in this area has been expressed most clearly through Ald. F. Arkell in his capacity as Lord Mayor of the City of Wollongong and as chairman of the Illawarra Regional Organisation of Councils (I.R.O.C.). In addition to organising a special I.R.O.C. meeting in May 1977 to examine uses which might be made of industrial and mining wastes, Ald. Arkell has, during 1977, attended (and officially opened) the annual conference of the Illawarra Branch of the Australian Institution of Engineers,16 which was concerned with the disposal and re-use of industrial wastes, and a slag products marketing seminar17 intended to promote greater use of blast furnace slag waste. In speaking at these meetings Ald. Arkell has been concerned both to express the interest and support of the City of Wollongong and the I.R.O.C. in activities involving the recovery and


re-use of industrial wastes and highlight the role that such activities, if carried out on an increased scale, could play in solving the region's environmental pollution and industrial solid waste disposal problems, and thus avoid further environmental damage.

Ald. Arkell has also pointed out that local government possesses the ability to influence and encourage industries to make productive use of wastes, using as an example the pressure which the City of Wollongong has exerted on the region's mining companies to make use of, and support, research being carried on by the Commonwealth Scientific and Industrial Research Organisation (C.S.I.R.O.) to derive useful products from coal washery refuse. The City of Wollongong has been able to exert this pressure through its consideration of applications made by these companies to establish or extend coal washery refuse dumps. 18

The Illawarra Regional Advisory Council (I.R.A.C.), a regional body of the N.S.W. Department of Decentralisation and Development, has also expressed interest in, and support for, efforts to find new uses for industrial wastes and their recovered derivatives. This interest and support derives from the I.R.A.C.'s concern with "the short and long term implications of the disposal of material, currently classified as waste, that is generated within the region." 19 Mr. K. Bond, at the time chairman of the I.R.A.C., presented a paper dealing with the topic of waste disposal and re-use to the engineering conference referred to earlier.

The regional daily newspaper - 'The Illawarra Mercury' - has played an important role in generating community interest in materials


and by-product recovery as a method of environmental pollution control. Several articles dealing exclusively with this topic have appeared in this newspaper during 1977, together with reports on the various conferences and seminars which have taken place.  

It would appear, then, that there exists a high degree of awareness in the community of the contribution that increased recovery of material and by-products from industrial waste streams could make to environmental pollution control and to solving the region's emerging industrial solid waste disposal problem. Accompanying this community awareness, interest and support has been a resolve on the part of some firms to find new uses to which their wastes, in their recovered form, might be put, as well as an effort to increase the size of already existing markets for these by-products. The advantages accruing to

20. Relevant articles which have appeared in *The Illawarra Mercury* during 1977 include:


such firms are twofold - they are able to reduce their volume of waste discharge, thus going some way towards satisfying the discharge standards imposed by the State Pollution Control Commission (S.P.C.C.), and receive revenue from the sale of the recovered by-product, perhaps offsetting the costs involved in the recovery process or yielding a profit. In addition, several firms which utilise, or are potential users of, materials and by-products derived from industrial wastes have supported those waste producing firms who have endeavoured to increase the amount of recovery activity they carry on. Several examples of the kinds of behaviour referred to here may be cited.

The prime example of the kind of behaviour noted above is the effort which has been made by A.I.S., in conjunction with Blue Metal and Gravel Ltd., Specified Concrete and Blue Circle Southern Cement to market through a series of seminars,\textsuperscript{21} blast furnace slag waste generated at its integrated steelworks complex at Port Kembla. This effort has involved an attempt both to expand the already existing market for the waste and extend its use into new areas.

A.I.S. produces about 1.7 million tonnes of blast furnace slag waste each year, of which only 700,000 tonnes is used by concrete manufacturing firms and governmental roadmaking authorities.\textsuperscript{22} In the past the balance (about 1 million tonnes) has been utilised by reclaiming "large areas of what were practically useless or marginally useful land areas"\textsuperscript{23} within the A.I.S. sites at Port Kembla and Springhill. The ability of the company to utilise slag waste in this manner has,

\begin{enumerate}
\item Slag Products Marketing Seminar, \textit{op. cit.}
\item \textit{Ibid.}, p. 14.
\end{enumerate}
however, been exhausted and it faces a considerable problem in the near future in disposing of the amounts that it cannot sell or donate. It is in response to this emerging solid waste disposal problem that A.I.S. and three firms which make use of blast furnace slag waste have been attempting to widen the market for the waste in the Illawarra and surrounding regions.

Also important in terms of efforts which have been made by firms to increase their amount of by-product recovery or utilise the by-products of other firms is the participation, noted earlier, of six firms located in the Illawarra region in the Industrial Waste Exchange set up by the M.W.D.A. in the Sydney region. The operation of this waste exchange is similar to that of the waste exchanges which have been set up in the United States and European countries such as Germany, Italy and Sweden in recent years to deal with wastes originating from manufacturing processes. The Industrial Waste Exchange maintains a register which lists, for a small fee, wastes offered for sale and specific wastes sought. The exchange seeks to "put potential users of wastes in touch with industries producing waste" but deals only in materials and chemicals for which no market now exists and thus does not compete with established markets. The fact that several firms located in the Illawarra region participate in the Industrial Waste Exchange is important for it indicates that there exist firms whose resolve to find uses for their wastes or find waste-derived substitutes for newly extracted raw materials is strong enough to stimulate them to attempt to achieve these ends in the Sydney region, even though the nearest major industrial area in that region - the Mascot, Sydenham, Alexandria area - is some seventy kilometres to the North.


25. Ibid.
The type of behaviour dealt with above does not, however, seem to be a widespread practice amongst the firms making up the manufacturing industry sector in the Illawarra region. Apart from the examples cited it is difficult to find further evidence of attempts by firms which contribute to the environmental pollution problem in the region to promote and market materials and by-products recoverable from their waste streams, nor is there any other evidence to indicate that the many firms which utilise newly extracted raw materials are making any concerted effort to substitute, where possible, waste derived materials and by-products for these virgin materials. Waste recovery and re-use activities thus seem to be restricted and fragmented in the Illawarra region. This observation is to some extent surprising given the changes which have occurred in recent years in the conditions faced by manufacturing firms in respect of governmental pollution control strategies and in markets for newly extracted raw materials, although it must be recognised that there exist important obstacles within industrial organisations which militate against any changes occurring in response to factors such as those noted here (e.g. the high costs involved in making changes to management structures, capital equipment and work patterns). The changes which have occurred in the conditions faced by industry are important and thus require brief elaboration.

As noted earlier, environmental pollution and its avoidance has become an extremely important concern of the communities of most developed nations during the last decade or so. Most nations have accepted the view that some kind of governmental control over waste

26. The existence of obstructions to change in industry, which is likely to be an important factor making for the restricted and fragmented nature of recovery and re-use activities, was pointed out to me by Professor Ken Blakey.
disposal activities is essential and have set up pollution control authorities through which a variety of policies aimed at achieving a reduction in environmental pollution have been implemented. The N.S.W. Government responded to "a great upsurge in the late sixties of public awareness of the need for controls over pollution and the environment" by introducing in 1970 several Acts of Parliament aimed at environmental quality control. Included were the Clean Waters Act and Acts setting up the State Pollution Control Commission and the Metropolitan Waste Disposal Authority. An Act dealing with the control of air pollution - the Clean Air Act - had been enacted some eight years earlier (1962). The S.P.C.C. was established during 1971 but its functions in relation to pollution control were only of an "advisory, supervisory and co-ordinating character. [In May 1974 the S.P.C.C.] commenced administration of the Clean Waters Act and the Clean Air Act," whose administration had hitherto been the responsibility of the N.S.W. Department of Health (now known as The Health Commission of N.S.W.). The strategy implemented by the N.S.W. Government through the S.P.C.C. (and its administration of these Acts) is essentially one which seeks to achieve standards of environmental quality through direct regulatory control of waste disposal activities. The past four years have seen the S.P.C.C. apply the regulations of the Clean Air and Clean Waters Acts with increasing stringency.
While the introduction of legally enforceable regulations concerning the disposal of wastes in the environment, and the increasing stringency with which these regulations have been applied, seems to have stimulated an increase in the amount of recovery activity carried on in the Illawarra region, it would have seemed reasonable to expect that the recovery activity generated would have been more widespread amongst industry in the region rather than being confined to only a few firms.

Similarly, some tendency towards increased substitution of recovered materials for newly extracted raw materials in manufacturing processes might have been expected in response to the changes which have occurred in the prices and availability of newly extracted raw materials during the last five years or so. As is well known the mid-1972 to early 1974 period saw a boom in the prices of industrial raw materials (and commodities in general) in international trade. Prices of most materials began to fall from peak levels during late 1973 - early 1974 but these prices have tended to be unstable in an upward direction since that time. There have been a number of causal explanations advanced to account for the events which have occurred in the markets for newly extracted industrial raw materials during the past five years, with some commentators, such as Lesher and Kaldor, suggesting that growth in world industrial activity has outrun materials availability and others maintaining that these markets have been subjected to a combination of unusual circumstances that are not

likely to be repeated. Irrespective of the causes of these events it is necessary to recognise that the years since 1974 have been characterised by prices for newly extracted raw materials which are higher, in both nominal and real terms, than those experienced during the post-war period up until 1972. What is more, this situation is likely to continue, for these higher prices and accompanying shortages seem to have been derived in part from structural changes which have occurred in the relationship between the raw materials producing developing countries and the industrialised developed nations in response to the commodity price boom, such things as attempts by various raw material producers to emulate the O.P.E.C. example, a desire on the part of developed nations to stabilise export prices and earnings of primary commodity producers and a general strengthening of the bargaining position of the developing countries in the so-called North-South dialogue in world politics, being important in this respect.

The neglect of recovery activities by industry in general in the Illawarra region becomes more apparent when it is noted that there seems to exist no shortage of technical information and know-how in the area of recovery of useful products from industrial waste streams. Recovery and re-use technology seems to have been advancing steadily in both Australia and overseas nations since the early 1960's, with a marked upsurge having occurred during the 1970's in research activity

32. See the following:
relating to the search for new products which might be derived from industrial wastes, new uses to which wastes and their recovered derivatives might be put, and suitable recovery processes.

In Australia several research divisions within the C.S.I.R.O. - the Divisions of Chemical Engineering, Building Research and Process Technology - have been involved in research of this kind. The United States Bureau of Mines seems to be the major governmental research organisation involved in the United States, carrying on a wide variety of research activities in this area. In England the Building Research Establishment has for some years possessed a research programme involving the evaluation of waste products for use in construction activities. Research activity carried on by universities and individual firms has also made an important contribution to the stock of technical knowledge in this area.

Recognition of the fact that technological developments which yield new processes and products seem to be proceeding at a rapid rate, thus providing waste producers with the technical information required to effect recovery of many materials and by-products and information regarding the nature of potential uses of these products, is not intended to minimise the influence exerted by technical considerations.

34. See the following:


in the decision by potential users to either utilise or reject materials and by-products derived from industrial waste. In fact it is important to note that technical considerations may be an important factor in explaining the lack of widespread recovery activity amongst industry in the Illawarra region. As Gutt has noted, "the by-product must fulfill engineering requirements in terms of physical properties and must not contain excessive amounts of deleterious components ... While these requirements apply equally to natural materials they are more difficult to fulfill with wastes which tend to be inhomogeneous and which may contain deleterious matter." 37 While there exists a tendency for potential users to view waste derived products as being inferior to natural materials for the reasons identified here, it may be noted that this kind of attitude towards these products is not always justified, as has been indicated by "experience in the construction industry and in particular with the manufacture of concrete in several countries." 38

It is possible to make reference to several other factors which may be important in explaining the limited role played by materials and by-product recovery in the Illawarra region. Important here is the possibility that recovery activities may themselves generate undesirable wastes for which a method of disposal has to be found. The water pollution problems emanating from the recovery of by-products from gas produced in coke ovens operations at the A.I.S. integrated steelworks complex is an important example of this problem. 39 On the other side of the coin utilisation of materials and by-products

37. Ibid.
derived from wastes can also give rise to waste generation and disposal problems, thus militating against utilisation of such products. Air and water pollution which has arisen out of a Port Kembla fertiliser plant's utilisation of spent sulphuric acid from an oil refinery is an example of the problems which can occur through use of waste derived products. As the S.P.C.C. commented, "it is certainly an efficient use of resources for one industry to utilise another industry's waste but, as the unfortunate side effects illustrate in this case, it is not always desirable."40

While technical considerations and the possibility of secondary waste generation are likely to exert an important influence on firm behaviour, it would seem that the most important factors making for the limited use being made in the Illawarra region of recovery methods, and the materials and by-products so derived, are economic in nature, for decisions made by firms in this area seem to be based largely on the criterion of profitability. This situation derives, of course, from the tendency for firms in our capitalist-oriented market economy to place a premium upon profit. It is possible to make reference to several economic considerations inherent in materials and by-product recovery and utilisation activities.

Recovery activities involving "the use of sophisticated technology to recover materials from mixed wastes"41 are likely to involve the waste producer in a considerable initial capital outlay, due to the nature of the equipment or plant required. In addition significant costs may be incurred in the actual operation of the recovery process.

40. State Pollution Control Commission, N.S.W., Annual Report (1976), op. cit., p. 91.
But while the costs incurred may be high, firms involved in recovery activities tend to be restricted in the price they feel able to ask for materials and by-products. As noted earlier, recovered materials sometimes vary considerably with respect to quality and form, since other impediments, some of which may be technically infeasible or prohibitively costly to remove, have usually been added in manufacturing, this having contributed to the development of an attitude amongst potential users of products derived from wastes which sees them as being inferior to natural materials. Firms having ready access to newly extracted materials thus tend to accept utilisation of materials and by-products "only when accompanied by a financial benefit, usually a lower material cost." This combination of high cost factors inherent in the recovery of many materials and by-products and a perceived necessity to charge low prices for them thus acts in such a way as to make recovery operations uneconomic to many firms producing wastes.

The attitude, noted above, of user firms toward materials and by-products derived from industrial wastes, and its implications for the price that these firms will pay for waste derived products, often impairs the ability of those products to compete with newly extracted materials. Also of much importance in this regard are transportation costs incurred by firms which utilise materials and by-products. Transportation costs pose a formidable barrier to the increased utilisation of waste derived products, for their magnitude often


43. Munn, loc.cit.
restricts the potential market for these products to the region in which they are produced. The importance of transportation costs may best be illustrated by reference to Munn's comments regarding the problems faced by A.I.S. in promoting increased use of blast furnace slag waste in the concrete industry: "Demand [for blast furnace slag products] in the concrete and bituminous concrete markets is unlikely to consume more than a fraction of total annual production unless the supply of the product to markets located at considerable distance from the source becomes feasible. At the present time market opportunities appear limited to areas in proximity to the source." 44

The ability of materials and by-products to compete with newly extracted raw materials will also be reduced if additional costs are incurred in response to their actual utilisation in production. It may be necessary for users to modify their production processes, thereby incurring considerable costs, if successful use of the materials and by-products is to be achieved. Further, it is possible that additional running costs, such as more careful quality control, may be incurred in utilising these products. Additional costs such as those identified here may be such as to offset the initial savings which accrue through acquisition of material and by-products in preference to newly extracted raw materials.

It would appear, then, that economic considerations play an extremely important role in determining the extent to which recovery activities are carried on by those firms producing wastes whose disposal in the environment contributes to environmental quality deterioration and also the extent to which raw materials consuming firms are prepared to make use of the products recovered. Recognition

44. Ibid., p.10-11.
of the economic nature of waste recovery and re-use activities is, of course, widespread and no novelty in this regard is claimed. But while representatives of local government, regional organisations and community groups, along with the chemical and industrial engineers working in industry, governmental research organisations and the universities, continually make reference to the importance of economic factors in this area, there seems to be too little attention paid to the substantial treatment given to this aspect of economic activity by the economics discipline. This neglect of the contribution made by the economics discipline, deriving as it does from the tendency by "other disciplines to offer totally uninformed criticism of economics as they see it", must be counted as being unfortunate for it means that a body of knowledge which may be of great help in adding to the understanding of the behaviour of firms in the area of recovery and re-use of useful products from industrial wastes and in providing detailed prescriptions for policy is being largely ignored.

It is the specific task of this work to examine in detail the treatment given by the economics and economics-related literature to industrial waste recovery and re-use activities with a view to assessing both the contribution made by this literature to the understanding of these activities as they are carried on in the Illawarra region and the extent to which the policies advanced by the literature offer any operational solution to the problem of inducing widespread materials and by-product recovery and utilisation activity in the region.

CHAPTER III

EXPLANATION AND POLICY PRESCRIPTION IN THE LITERATURE - THE ECONOMY-WIDE APPROACH.
An important section of the economics literature has included activities involving the recovery of useful products from industrial waste streams, and their utilisation in other industries, within the theoretical framework provided by modern welfare economics. Analysis within this framework is carried-out on an economy-wide scale (regional/national) and focusses on the potential role of recovery and re-use activities in preventing environmental quality deterioration as well as considering the interrelationship between that particular role and the one which can be played by such activities in avoiding the exhaustion of stocks of non-renewable natural resources. While much of the literature to be considered here is characterised by abstract theorising, "often too abstract to be practically useful", it does provide an important insight into the nature of recovery and re-use activities from the point of view of the economy as a whole as well as advancing policies which have the goal of inducing an increase in the extent to which these activities are carried on.

Before proceeding with an examination of the relevant literature it would seem desirable to outline, as a background, the nature and characteristics of modern welfare economics. Much of the theoretical analysis which appears in this section of the literature derives from that used in welfare economics.

The term 'welfare economics' refers to a body of theoretical analysis and scientific method which is concerned with the well-being of society as a whole. Assuming that the objective of society is the maximisation of total welfare, and at the same time abstracting from problems relating to the addition of individual utility functions, the

aim of welfare economics is essentially one of identifying that state of allocation of resources which fulfils that objective. The analysis involved is carried out with a view to the prescription of policies which will influence real world economic variables in such a way that maximum social welfare is achieved.

On a theoretical level modern welfare economics is dominated by Paretian welfare economics, which rests on the assumed value judgement that if one person is better off, and no-one worse off, welfare has increased. In Paretian terms an optimal (or socially efficient) state will be achieved when the allocation of resources is such that it is not possible to make anyone better off without making someone else worse off. A particular Pareto optimum cannot necessarily be equated with a position of maximum social welfare, however, for there exists an infinite number of Pareto optimal states, each corresponding to a different distribution of income. Only when a social welfare function, which provides "the ethical justification for the distribution of income"\(^2\), is specified is it possible to delineate the unique Pareto optimum which maximises social welfare.

The achievement of a position of maximum social welfare in a static context is, however, subject to the proviso that there exists efficiency in both production and exchange. (i.e. first order or marginal conditions)\(^3\) and that all functions are convex (i.e. second order condition). Maximisation of social welfare in an intertemporal context is also dependent upon first and second order conditions being met, with the first order conditions being modified so that efficiency in both production and exchange over time is required. Reference to production

3. Efficiency in production and exchange requires: (a) that it must not be possible to increase the production of one good without decreasing the production of another and (b) that it must not be possible to redistribute goods among consumers so that one consumer is better off without making another worse off.
and exchange over time, however, also necessitates consideration of saving and investment factors. Given fulfilment of first and second order conditions welfare of society over time will be maximised when the anticipated return from current investment (i.e. the marginal productivity of capital), yielding consumption goods in some future time period, is equal to the rate at which society as a whole is willing to sacrifice present consumption, through saving, for consumption in that future time period. (i.e. the marginal social rate of time preference). An important assumption underlying all this is that there exists no public goods, external effects, production functions exhibiting decreasing average costs, uncertainty or imperfections in production and exchange.

This outline of Paretian welfare criteria has thus far made no reference to the existence of a market economy, for it is possible to derive an infinite number of Pareto optimal situations "without the use of a market mechanism." Paretian welfare theory demonstrates, however, that the equilibrium states of the perfectly competitive market model, which provides both an explanation of the basic functioning of a market economy and a benchmark against which the performance of actual market economies may be evaluated, are Pareto optimal and that, in turn, all conceivable Pareto optimal situations correspond to equilibrium positions of the model. The tendency for the economic units in the perfectly competitive market economy to carry out economic activity to the point where the price in each market coincides with the producer's marginal cost taken together with the fact that production

6. The assumptions underlying this model include those of competitive markets, rational individual decision making to maximise utility or profit, inability of economic units to influence market prices and the formation of prices that are simultaneously in equilibrium.
and utility functions are convex ensures that the first and second order conditions for static Pareto optimality are satisfied by the perfectly competitive equilibrium. If the capital market is perfectly competitive, so that the market rate of interest equates the marginal rate of time preference of savers with the marginal productivity of capital, the condition for dynamic optimum will also be satisfied.

It must be noted, however, that the equilibrium of the perfectly competitive market economy will only correspond to the unique, welfare maximising Pareto optimum "if the initial distribution of factor ownership is considered equitable [in the sense that] the initial distribution of factors is such that the distribution of utilities resulting from competitive equilibrium is considered equitable." According to Winch this will occur only by coincidence.

While demonstration of the Pareto optimality and welfare maximising properties of the perfectly competitive market economy is interesting in itself, the significance of this demonstration in the present context lies in the implications which can be drawn regarding real world deviations from the conditions underlying the perfectly competitive market model. The real world deviation of concern is the existence of external effects. The presence of this phenomenon implies, as does the existence of public goods or production functions exhibiting decreasing average costs, that the equilibrium positions of the perfectly competitive market economy cannot be Pareto optimal, thus suggesting that there exist inefficiencies in the allocation of resources. External effects relevant from a Paretian point of view are those effects of economic activity which are external to the market mechanism - costs imposed

9. Ibid.
on others which are not paid for or benefits bestowed for which no payment is received.

The above discussion has outlined the framework within which activities involving the recovery of materials and by-products from industrial waste streams, and their utilisation by other industries, have been analysed in a section of the economics literature. The background provided by this outline is important to any examination of this literature, for the analyses carried out draw heavily on the basic theoretical constructs and concepts employed in Paretian welfare economics.

Recovery and re-use activities have been analysed in both static and dynamic terms. The static partial equilibrium approach to the explanation of environmental pollution externalities, although giving little formal treatment to recovery and re-use activities, can be modified so as to include them, while variables representing these activities are an integral part of analyses carried out in static general equilibrium terms. Extension of this general equilibrium approach to a dynamic framework corrects some of the deficiencies inherent in static analysis by considering recovery and re-use activities, and their interrelationship with the problems of both environmental pollution and the exhaustion of non-renewable natural resources, on an intertemporal welfare basis.

As noted above the existence of external effects constitutes an important real world deviation from the Pareto optimality and welfare maximising properties of the perfectly competitive market economy. There exists a substantial body of economic theory dealing with the implications of, and solutions to, the existence of external effects. This body of theory, which may be termed 'externality theory', derives,
in the main, from the treatment of the concept of external effects by Pigou\textsuperscript{11} in the 1930's. Following the Pigovian tradition much of the analysis of external effects has been carried out within a static partial equilibrium context, the important assumption being that the conditions (and assumptions) necessary for the achievement of Pareto optimality and maximum social welfare are met in all sectors of the economy other than that generating the external effect.

Industrial waste disposal activities involving the disposal of liquid, gaseons and solid wastes in the environment are an important example of an unfavourable external effect or external diseconomy. This kind of activity, it is argued, imposes costs on the individuals making up society by causing health problems, a decline in the aesthetic and amenity value of the environment, inconvenience in everyday life etc. That is, these side effects of the production activities of industrial firms cause a deterioration in the quality of environmental services (or, what is the same thing, environmental pollution), thus reducing the utility derived from the consumption of those services. The (social) costs imposed, however, are not part of a market transaction - industrial firms make no payment to affected members of society for the diminution in utility they experience. The fact that no costs are incurred by firms as a consequence of their waste disposal activities means that such costs will not be taken into account in the decision regarding output levels. The industry as a whole will thus produce too much of the activity generating wastes. In the terms used by externality theory, the marginal social cost of production will exceed the marginal private cost of production in this competitive industry, with the result that equilibrium output of the industry will be in excess of the Pareto optimal output level implied by equality between marginal social cost and marginal private cost. This basic characterisation of the external

\textsuperscript{11} Pigou, A.C., \textit{The Economics of Welfare} (London: Macmillan, 1932).
diseconomy known as environmental pollution may be modified so as to explicitly include activities involving the recovery of useful materials and by-products from industrial waste streams.

The choice faced by firms making up a competitive industry in respect of the disposal of wastes generated in production processes may be viewed as one between unchecked disposal of wastes into the environment or application of recovery techniques to those wastes so as to yield materials and/or by-products. The former alternative will be chosen, and an external diseconomy generated, when there exists no market for the wastes in their recovered form. This external diseconomy will be internalised into the market economy "if a market for a product not previously sold comes into being."12 That is, if commercial uses are found for the wastes in their recovered form and if the demand for these materials and by-products grew so that a market for them came into being, then the wastes would in effect become intentionally produced and jointly marketed with the main product. 13 Assuming that recovery processes are costless, the demand prices of both together would be equated to the marginal cost of production of the main product. Equality between marginal social cost and marginal private cost of production would be achieved in the competitive industry. Necessary conditions for Pareto optimality will thus be met and, given an equitable initial distribution of factor ownership in the economy, social welfare maximised. This conclusion is based on the assumption that the new relative price structure remains unaltered in the presence of an exogenous change which moves the economy to

13. Ibid.
Several straightforward policy implications can be drawn from this view of environmental pollution externalities. Research involving both the search for new uses to which wastes in their recovered form might be put and the development of recovery techniques should be initiated, encouraged and financially supported through explicit governmental policy measures. The establishment of industrial waste exchanges as a market for the recovered form of wastes currently disposed of in the environment also emerges as a highly desirable facet of government policy.

The externality literature has not, however, paid much attention to the view of environmental pollution externalities outlined above or to the policy prescriptions implied, preferring instead to concentrate on theoretical aspects of, and solutions to, the divergence between marginal social costs and marginal private costs of production. The solutions which have been advanced in this context, including Pigovian taxes, outright prohibition, regulation of production and voluntary agreement between those generating the external diseconomy and those affected by it, aim almost exclusively on output correction. That is, the policies advanced in the externality literature seek to eliminate the divergence between marginal social cost and marginal private cost of production through a reduction in output of those goods whose production generates an external diseconomy to a level which is Pareto optimal, so that the pollution (formerly the external diseconomy) generated is consistent with optimal output. The role which can be

14. Ibid.
15. Ibid., p. 15.
played by recovery and re-use activities in eliminating the external diseconomy is thus ignored.

Overall, then, it may be asserted that the static partial equilibrium approach to the explanation of environmental pollution externalities adds little to the understanding of the nature and extent of recovery and re-use activities in an economy. Nor does this approach yield much in the way of policy prescriptions relevant to the goal of inducing an increase in the extent of these activities. The inappropriateness of the static partial equilibrium approach derives in part from its tendency to view environmental pollution externalities as an exceptional case - "a comparatively minor aberration from Pareto optimality in competitive markets". Analysis of environmental pollution externalities within a general equilibrium framework, which views environmental pollution as a pervasive phenomenon, avoids the deficiencies noted here and tends to include recovery and re-use activities as an important variable.

The view of environmental pollution as a pervasive phenomenon has been based upon recognition of the importance of the operation of the Law of Conservation of Mass in combination with the fact that the use of the environment for waste disposal carries a zero price. According to the law of conservation of mass, the extraction of materials from the environment and their use in production and consumption involves no alteration in mass, so that wastes generated in those activities must be about equal in mass to those materials initially extracted from the environment. The discharge of these wastes into the environment is, however, free-of-charge, since environmental resources - the air mantle, watercourses, landscapes, large ecological systems etc. - "cannot, or

18. Ibid., p. 254.
can only imperfectly, be held in private ownership ... and therefore cannot be exchanged in markets like ordinary commodities". Unpriced use of the environment as a receptor of wastes will lead to its continual overuse for that purpose, resulting in the discharge of large masses of materials into the environment and thus, given the limited capacity of the environment to absorb and assimilate wastes, environmental quality deterioration or, what is the same thing, environmental pollution.

Recovery and re-use activities enter this characterisation of environmental pollution, which essentially derives from the work of Ayres and Kneese20 in the late 1960's, as the only alternative to the discharge of wastes into the environment. This involves recognition of the fact that waste treatment processes, which aim at reducing environmental pollution, do not destroy the waste materials but instead only purify and dilute them, perhaps for discharge into an alternative environmental medium. No reduction in the amount of materials involved occurs, only alteration in their form. In fact, it is probable that mass will be increased, "because the treatment process itself requires inputs whose mass is also conserved."21

Recognition of the pervasiveness of environmental pollution enables the interdependence of this phenomenon with activities involving the extraction of natural resources from the environment to be observed. The zero price attached to the use of the environment as a receptor for wastes gives rise to a distortion in the price structure relating to the throughput of newly extracted materials in the economy - "the price of extractive resource commodities, which are exchanged in markets, will deviate substantially from the actual social costs of their use."22

19. Ibid.
22. Ibid.
The 'social costs' neglected by the market include the environmental pollution emanating from production and consumption activities as well as environmental degradation, in the form of despoiled landscape and environmental pollution, caused by the actual process of extracting natural resources. The failure of market prices to reflect the social costs generated in extraction, production and consumption activities suggests that there exists a systematic bias in market processes which subsidises the extraction of virgin raw materials from natural resource stocks. "The larger the impact on environmental resources in extraction, production and consumption activities, the larger the subsidy."23

The effect of this subsidy accorded by the market is, according to the criterion of efficiency, to stimulate a throughput of newly extracted raw materials which is too rapid, recovery and re-use activities on a smaller scale than is desirable and excessive environmental quality deterioration.24 That is, there exists a deviation, making for inefficiency in the allocation of resources, from the standard provided by the perfectly competitive market model. Provided that conditions necessary for Pareto optimality are met, the operation of market forces in that model leads to a certain flow of materials through the economy, thus providing a socially acceptable balance between depletion and conservation of natural resources, and recovery and discharge of wastes.25

It may also be noted that there exists a further factor making for a state of inefficiency in the allocation of resources. The factor referred to is the tendency for governments in the developed nations to implement policies which stimulate, in the interests of rapid economic growth, the extraction of virgin raw materials. These policies, which

23. Ibid.
24. Ibid., p. 256.
have usually taken the form of special tax treatment of extractive industries vis-a-vis other industries, have been, and continue to be, important in Australia. The preferential treatment accorded extractive industries through the tax system re-inforces the bias of the market referred to above and thus contributes to a situation in which there exists too much extraction of virgin raw materials, too rapid throughput of those raw materials and not enough recovery activities.\(^26\)

The identification of inefficiencies in the operation of market processes has been accompanied in the literature by policy prescriptions which aim at eliminating them. In general it has been suggested in the literature that the market inefficiency involving the failure of the price system to include the social costs of waste disposal activities should be rectified by the introduction of an effluent charge strategy,\(^27\) and that the inefficiency created by preferential treatment of extractive industries via the tax system should be dealt with through repeal of such special and discriminatory tax treatment.\(^28\) It has also been suggested that severance taxes on virgin raw material extraction should be introduced both to encourage improved material durability and maintenance and induce an increase in the scale and extent of activities involving the recovery of useful products from wastes.\(^29\) This measure, it is hoped, would counter any tendency the market may have "to discount the future at too high a rate [as well as] discourage the generation of waste materials which damage the environment."\(^30\)

Institution of these policies, each of which promises to induce an increase in the scale of recovery and re-use activities, would, it is argued, "make the economic incentive system a powerful and all pervasive force for environmental improvement." 31

Advocacy of the introduction of an effluent charge strategy is backed by a substantial body of economic theory, with the goal of inducing more widespread recovery and re-use activities amongst industrial firms figuring prominently in that theory. The effluent charge strategy is essentially a modification of the Pigovian tax solution to the existence of environmental pollution externalities. In its basic form the Pigovian tax solution involves the imposition of a tax on the firm generating this kind of externality equal to the difference between marginal social costs and marginal private costs of production. The effect of this tax, in theory is one of inducing the firm to reduce its output below its competitive equilibrium to a level which is Pareto optimal and thus socially efficient. The effluent charge strategy, on the other hand, involves the imposition of financial charges in proportion to the concentration, above a certain level, of various residuals contained in the waste streams of industrial firms. The reasons underlying the modification of the Pigovian solution in this form relate to the fact that implementation of the optimal structure of Pigorian taxes is infeasible.

The effluent charge strategy basically represents an attempt to charge firms for the use of the environment to dispose of wastes with the expectation that they will respond to this price in the same

31. Ibid.
way as they respond to the prices of other resources. While the introduction of an effluent charge strategy cannot be shown to lead to Pareto efficient levels of production in a perfectly competitive economy, it does possess an efficiency property which is important to any real world application of the strategy - it is, on both an individual firm and economy-wide basis, the least-cost method of realising environmental quality standards. Economic theory suggests that the existence of effluent charges will encourage firms to make reductions in, or modifications to, the volume of wastes that they dispose of in the environment through use of that combination of end-of-pipe treatment, internal process change, material and by-product recovery etc. which is least costly to them and, given that pollution control absorbs scarce resources, least costly to society as a whole. In terms used in the theory, each firm disposing wastes will equate marginal costs incurred in reducing and/or modifying their discharge of wastes with the effluent charge set by the pollution control authority.

This brief sketch of the rationale behind the arguments of those who advocate the introduction of effluent charges suggests, then, that materials and by-product recovery activities will play an important role in firms' attempts to avoid paying the charge. The imposition of effluent charges might thus be expected to stimulate firms to increase the amount of recovery activity they carry on, as

35. More substance is added to this sketch in Chapter V.
well as inducing increased expenditure on waste treatment processes and changes in input or factor proportions, process changes, alterations in output specifications etc. Introduction of this strategy in combination with the repeal of tax privileges accorded to extractive industries and introduction of severance taxes on virgin raw material extraction might be expected, according to economists such as Kneese and Page, to significantly check the pace of flow of virgin raw materials through the economy. This would be achieved through the effect that these policies would have in increasing the extent of recovery and re-use activities and in slowing down the rate of raw materials extraction from natural resource stocks.

The view of environmental pollution as a pervasive phenomenon and the perceived interdependence of that phenomenon, through the inefficiencies in market processes, with economic activity in the extractive industries sector suggests that environmental pollution and recovery and re-use activities might best be analysed within a general equilibrium framework. That is, within a framework which takes account of the interrelationships between economic activity in the various sectors of a market economy. A number of economists have used a static or dynamic general equilibrium approach to the analysis of the factors giving rise to environmental

pollution, although only a few of the models advanced have included recovery and re-use activities as a variable important to the avoidance of that phenomenon. The discussion which follows will be concerned with these latter models.

Ayres and Kneese have advanced a model which formalises the ideas relating to the pervasive nature of environmental pollution by including them within the mathematical framework of Walrasian general equilibrium analysis. This model traces the flow of materials through the economy, paying much attention to materials flows not generally included within the Walrasian model because of their unmarketable nature - the disposal of wastes, generated in production and consumption activities, in the environment. Industrial waste recovery and consumption waste recycling activities enter the model, which is

37. The models referred to appear in the following references:—


Müller, op. cit.


38. Ayres and Kneese, op. cit.
characterised by specification of materials balance relationships, as the only alternative to the disposal of wastes into the environment. External diseconomies arising out of waste disposal activities are included through the specification of variables representing the associated negative prices. The inclusion of prices associated with the disposal of wastes in the environment is intended to subject normally unmarketed flows of materials "to the moderation of a market or a surrogate thereof."\textsuperscript{39} It is suggested by Ayres and Kneese that there exists a set of prices, charged to producers and determined by the appropriate Pareto reference criteria, that will in effect ration the output of wastes and provide revenue for compensation to consumers.\textsuperscript{40}(i.e. the negative prices for disservices imposed).

Mäler has built upon and improved the general equilibrium approach used by Ayres and Kneese in his construction of a static general equilibrium model which both accounts for environmental pollution externalities and incorporates a system of effluent charges as a means for correcting those externalities. While the initial formulation of this model excludes recovery and re-use activities, it is later modified so that these activities become important in determining the flow-of-wastes into the environment from production processes.

The model advanced by Mäler includes variables representing both environmental quality and the price at which society values that environmental quality. A tax-transfer system is incorporated in the

\textsuperscript{39} Ibid., p. 291.

model, essentially involving the imposition of a set of effluent charges, collected by an environmental management agency, on the discharge of wastes into the environment and the transfer, in effect, of the revenue so collected to consumers. Måler proves, on the basis of numerous simplifying assumptions and through use of sophisticated mathematical techniques, that the perfectly competitive market economy which his model describes possesses, in the presence of the specified tax-transfer system, an equilibrium in which profits, utilities and "the net social benefit from using the environment for waste disposal" are maximised. In addition, it is shown that this equilibrium is socially efficient (i.e. it is a Pareto optimum) and that each socially efficient state can be represented by an equilibrium in the model.

The basic operation of the Måler model may be outlined by reference to Figure 2. The model essentially consists of a process of interaction, underlying which is the concept of materials balance, between production, consumption and environmental management activities and the environment. Each of these activities exerts an effect, favourable or unfavourable, on the quality of the environment. Any production and consumption wastes disposed of in the environment, rather than being recovered or recycled, will cause a deterioration in environmental quality. The environmental management agency will attempt to counter the detrimental effect of waste disposal activities by treating the environment so that its waste assimilation capacity is increased. It is assumed that this treatment of the environment is

43. Capital accumulation activities are excluded by Måler because of the static nature of the model.
44. This may be achieved through re-aeration of water bodies, low flow augmentation etc. Måler, op. cit., p. 4.
FIGURE 2 Schematic representation of the working of a decentralised market economy

paid for by consumers and that the total profit of the environmental management agency is transferred to consumers as a lump sum."\textsuperscript{45} Quality of the environment in the model is thus dependent on the amount of wastes disposed of in the environment and the extent of treatment of the environment by the environmental management agency. Materials balance is achieved through the assumption that no stocks of goods are built up in production, consumption or environmental management activities, so that flows of materials (in tons) to and from these activities must balance.

The options and preferences of the decision makers in the economy - producers, consumers and the environmental management agency - are clearly defined by Mäler. All producers possess a production set comprising the possible activities the producer may choose among - "inputs of labour, energy, raw materials, intermediate products, outputs of goods and services and outputs of wastes."\textsuperscript{46} Consumers possess a preference set relating to their consumption activities, these activities utilising consumption goods as inputs and generating, income satisfaction and wastes as output. Satisfaction is also derived from the flow of environmental services purchased from the environmental management agency. This agency is involved in two other activities - the sale of waste disposal services, through the effluent charges, to producers and households and the purchase of goods from producers for use in treating the environment.

Modification of the model allows activities involving the recovery of materials and by-products from waste streams to be included as an implicit option in the production set.\textsuperscript{47} In the

\textsuperscript{45} \textit{Ibid.} The fact that consumers pay for the treatment of the environment means, in effect, that the total profit of the environmental management agency will consist of the effluent charges collected.

\textsuperscript{46} \textit{Ibid.} p. 49.

\textsuperscript{47} Waste treatment processes are included as a production activity but do not affect the materials balance relationship.
initial formulation of the model all goods and services except environmental services were partitioned into regular goods and services (i.e. consumption goods and services, intermediary commodities, raw materials etc.) and wastes. Recognition was given, however, to the fact that the distinction between regular goods and services and wastes is dependent upon "technological possibilities and relative prices... One good may, therefore, be regarded as a regular good at one price configuration, while it may be a residual at another."\(^48\)

An important factor in this respect is, according to Mäler, demand. If, to take the example given by Mäler, a production process utilises as an input a good classed as a waste and "if demand for the outputs of that process increase, then it may happen that the demand for the residual increases to such an extent that producers are willing to pay a positive price for the possession of this good."\(^49\)

Identification of the restriction introduced by the a priori distinction between regular goods and services and wastes leads Mäler to modify his model by dropping that distinction and then defining wastes as goods and services which, in equilibrium, are in positive excess supply and whose discharge "causes a fall in the value of environmental services."\(^50\) This modification does not alter either the equilibrium property of the model or the social efficiency of that equilibrium.

While yielding some insight into the relationship between economic activity and environmental quality and the place of recovery and re-use activities within that relationship, the static general equilibrium models advanced by Ayres and Kneese

\(^{49}\) *Ibid.*
and Mäler are deficient in one important respect - by definition they take no account of the passage of time and thus are only applicable to economic activity in a given time period. No consideration is given to the effects that action in one time period can exert upon economic activity and environmental quality in subsequent periods.

A static, timeless approach to model building may be appropriate for some purposes but the use of such an approach to analyse, with a view to policy prescription, economic activity and its relationship to the emergence of the problem of environmental pollution is inappropriate. This assertion may be justified on several counts.

It might reasonably be suggested that environmental pollution is by its very nature a dynamic phenomenon. As has been noted environmental pollution arises when the capacity of the environment to absorb and assimilate wastes is exceeded, the resulting build-up of wastes causing a diminution in the ability of the environment to provide services. The build-up or accumulation of wastes in one period will influence environmental quality in subsequent periods, for the quantity of wastes disposed of in the environment in these periods will be added to the already existing stock of wastes, thereby increasing the probability that the capacity of the environment to absorb and assimilate wastes will be exceeded. It may be asserted, then, that environmental quality in the future will be dependent not only upon the wastes disposed of in the environment at that time but also on the volume of wastes currently being disposed of in the environment.\footnote{Victor, op. cit. p. 31.}
The intertemporal relationship between environmental quality and waste disposal practices involving use of the environment in turn implies the existence of an intertemporal relationship between environmental quality and economic growth. The process of economic growth, with its tendency to be accompanied by increases over time in the throughput of raw materials in the economy, might be expected to exert, over time, an increasingly detrimental influence on environmental quality, for the operation of the Law of Conservation of Mass will, in the absence of any increase in the extent of recovery and recycling activities, ensure that much of this material returns to the environment in the form of wastes. The increase in the flow of materials through the economy referred to here necessarily requires an increase in the rate of extraction of virgin raw materials, this having given rise in recent years to considerable concern regarding the prospect of exhaustion of finite, non-renewable natural resource stocks. Rapid economic growth will thus tend to be associated with the depletion of natural resource stocks as well as with environmental pollution.

It would appear, then, that it is necessary to take explicit account of the passage of time in any consideration of the relationship between economic activity and the occurrence of environmental pollution. Dynamic general equilibrium analysis of this relationship is thus desirable. Several models have been advanced which analyse, using optimal control techniques, the dynamic processes of waste accumulation and natural resource depletion and their relationship in the economic system to production, consumption and natural resource extraction activities. 52

industrial wastes and/or recycling of consumer wastes enter these models both as a possibility for waste reduction and a means for avoiding constraints imposed on growth by the availability of a finite stock of natural resources.

A model which seems to be fairly representative of the dynamic models referred to here is that advanced by Måler.\textsuperscript{53} While this model, like most of these dynamic models, includes only recycling of consumption wastes in its formal structure, it is apparent, from both the context within which the model is presented\textsuperscript{54} and the implications drawn from the results derived, that Måler's concern is with the dynamic implications not only of consumption waste recycling activities but also of those activities involving the recovery and re-use of industrial wastes.

In essence, the model advanced by Måler derives, through use of optimal control techniques, the time path of the set of variables representing total consumption, capital accumulation and environmental quality which maximises intertemporal social welfare in a specified market economy during a finite planning period. This result is achieved in the presence of desired values of capital accumulation and environmental quality at the end of the planning period (i.e. 'terminal values' of these variables) as well as a constraint specifying that the assumed finite natural resource stock cannot be exhausted during the planning period. It is shown that this optimal time path tends to approach the steady state in

\begin{thebibliography}{99}
\bibitem{53} Måler, \textit{op. cit.}, Chapter 3, pp. 58-106.
\bibitem{54} \textit{Ibid.}, p. 84.
\end{thebibliography}
long run, thus making the turnpike property, and its implications for planning, valid for the model. 55

Structurally the model is based upon the working of the market economy incorporated within Måler's static general equilibrium model discussed earlier 56 and portrayed in Figure 2. There are, however, important differences. Economic activity is characterised by the production of a 'composite' commodity which can be used for either consumption or capital accumulation, 57 with the total capital stock being partitioned into that allocated to consumption waste recovery activities and that employed in production of the composite commodity itself. The production process utilises capital, labour and natural resources as inputs, with the labour force (and total population) assumed to be constant over time. Materials balance is achieved through the assumption that the volume of natural resources extracted from the environment corresponds to the volume of wastes deriving from consumption activities 58 and depreciation of the capital stock plus the

55. The steady state solution is a time path characterised by the fact that all essential variables (total consumption, capital accumulation and environmental quality in this case) change at the same rate and, in the process, satisfy the necessary conditions for optimal growth. Validity of the turnpike property for the model means that the optimal time path or the set of essential variables will, given a long enough planning period, approach the neighbourhood of the (optimal) steady state, stay in that neighbourhood for most of the time and move so that terminal requirements of the essential variables are met. Ibid., p. 104

56. Supra, p. 47-50.

57. Måler, op. cit., p. 59.

58. It is assumed by Måler that there are no wastes generated in production - all material inputs are embodied in output - and that consumption goods are transformed immediately into wastes upon consumption. Ibid., p. 62-63.
Existing environmental quality is specified to be a function of current waste discharges and wastes discharged in all previous time periods.

An important feature of the model is the specification of a special requirement regarding the allocation of capital goods to recovery activities. The capital requirement function for recovery activities indicates that an increase in the flow of wastes will, given constancy in the proportion of the waste flow recovered (i.e. a constant recovery rate), result in a proportionate increase both in the volume of wastes recovered and in the minimum capital stock allocated to consumption waste recovery activities. This implies that the real average cost of recovery is constant, given a constant recovery rate. Variation of the recovery rate in an upward direction will, it is assumed, be accompanied by rapidly increasing marginal costs of recovery, reflecting the observed tendency for recovery techniques to be applied initially to those wastes that are cheap to recover and thereafter to more expensive recovery propositions as the desired rate of recovery is increased. "Complete recovery will, however, never be optimal because it requires too large an investment in recovery processes." 60

The intertemporal nature of the model basically derives from the interdependency over time, achieved through various assumptions made in its specification, between consumption and capital accumulation activities and environmental quality. The overall objective of the economy described in the model is the maximisation of social

welfare over the planning period, that is, maximisation of the present value of future utilities of the individuals in society. Utility at each moment is assumed to depend "on the flow of consumption and on the flow of environmental services."Achievement of the objective is subject to a number of constraints describing the processes of capital accumulation, the nature of waste flows, the state of environmental quality and initial and terminal conditions.

Demonstration of the validity of the turnpike property for the model is important, for one of Måler's aims in formulating the model was that of illuminating "the future consequences of an optimal decision today on present allocations amongst consumption, capital accumulation and environmental quality." The implication of the existence of the turnpike property for the model is that it is possible, if the steady state is known, for the governmental planning authority to implement, in the first planning phase, an approximation of the optimal policy that will steer the economy to the steady state in the shortest time. If, for example, present environmental quality is less than that in the steady state, waste discharge should be decreased.

Overall, operation of the model outlined here reveals that the existence of opportunities for the recovery and re-use of consumption wastes (and, by implication, recovery and re-use of industrial wastes) allows the variables representing total

61. Ibid., p. 12
62. Ibid., p.
63. Ibid., p. 72.
64. Ibid.
consumption and capital accumulation to avoid the constraints imposed by the availability of a finite amount of natural resources during the planning period. These opportunities would also allow a continuation of economic activities should complete exhaustion of available natural resources occur. In such a situation raw materials would be provided through the recovery of wastes emanating from the depreciation of the capital stock, although a progressive decline in the quality of life, as measured by total consumption, would accompany such a situation. Environmental quality, on the other hand, would be high.65

The picture which emerges from the dynamic model advanced by Mäler is one that severely discounts prospects for the achievement of continually high rates of economic growth in the future in the developed nations. The model thus lends support to those who contend that "natural resource constraints impose on insuperable obstacle to [economic] growth."66 This model is, however, based on the important assumption that technological knowledge is constant over time. History has shown, however, that "economies possessed of a high degree of technological versatility have adapted to changing patterns of resource scarcities."67 Thus, although "no amount of historical analysis can provide an adequate basis for optimism concerning future prospects",68 technological change seems likely to prove, in the long run, a powerful mechanism of response to, and solution for, any natural resource scarcities

65. Ibid., p. 43.
67. Ibid.
68. Ibid.
that arise. In response to ideas such as these, Måler has modified his dynamic model, on an informal basis, to include technological change.

Included in this modification carried out by Måler are possibilities such as new discoveries of natural resources in response to systematic exploration and inventions which make profitable to use previously unutilised resources. Technological changes of this kind will most likely be related to economic incentives, in the form of natural resource rents, arising out of scarcities of those resources. Of more importance in the present context are possibilities of technological change involving inventions which make it possible to increase output without increasing raw material input, thus enabling an increase in production to occur without a corresponding increase in waste flow, and the development of new techniques for waste recovery. Developments enabling increases in the efficiency of existing recovery processes will also be important. The incentives for these kinds of technological change will, according to Måler, derive from considerations of resource scarcity and environmental quality deterioration.

Måler suggests, however, that the incentives for technological change arising out of natural resource scarcity and environmental quality considerations are likely to be insufficient to ensure an adequate rate of development of new technology, giving rise to the need for government policy action to establish systematic incentives for the development of this new technology. According to Måler, governments of the developed nations seem to have been

69. Ibid.
ignorant of the need for such systematic incentives. For instance, despite the widespread concern regarding environmental pollution, there exists "no systematic incentives for producers to develop new methods of recovering and recycling, in spite of their importance for both environmental quality and the supply of raw materials." The policy measure considered most appropriate by Maler to provide these incentives is the effluent charge strategy.

Orr has given substance to Maler's assertions regarding the appropriateness of effluent charges as a means of providing systematic incentives for the development of new technology aimed at both avoidance of environmental pollution and an increase in the effective long term supplies of natural resources. Orr argues that "the greatest advantage of effluent charges relative to alternative environmental control mechanisms is in their provision of decentralised incentives for technological change." Furthermore, Orr suggests that there may exist significant advantages, in terms of practical implementation, of designing the effluent charge strategy specifically for the purpose of inducing long run technological change, rather than with the aim of effecting changes in resource allocation.

Overall, then it might be suggested that the analysis carried out within a welfare economics framework contributes much towards the understanding of activities involving the recovery of saleable materials and by-products from industrial waste streams.

70. Maler, loc. cit.
71. Ibid. p.203
73. Weinstein and Zeckhauser, op. cit., p. 67.
74. Orr, op. cit., p.
as they are carried out in actual market economies. It is apparent that these activities have the potential to play an extremely important role in the process of interaction between economic activity and the environment, for their use on a more extensive scale would militate against the detrimental effects exerted on environmental resources by economic activity through the biases which exist in the operation of market processes.

There is also much to be gained through consideration of the policy prescriptions advanced with the aim of inducing an increase in the amount of recovery and re-use activity carried on. The advancement of policy prescriptions aimed at achieving an increase in the extent of recovery and re-use activities through elimination of market biases represents an important contribution. Advocacy of these policies, including introduction of an effluent charge strategy for environmental pollution control, elimination of special tax privileges accorded to extractive industries and imposition of severance taxes on virgin raw material extraction, appears to be backed by sound arguments, although it must be recognised that there may exist some problems in, or barriers to, their implementation in practice. While the literature considered pays much attention to these kinds of policies another important, though not conflicting, approach to policy prescription was evident.

Included in this second approach are policies aimed at stimulating the development of technology involving new recovery techniques or new uses to which wastes in their recovered form might be put. Government initiation and financial support of this
kind of research is thus seen as being highly desirable, as is the introduction of the effluent charge strategy, regarded by some economists as an important means by which systematic incentives for the development of new technology in this area may be established. Also important in this second approach to policy prescription is the advocacy of the establishment of industrial waste exchanges as markets for the recovered form of wastes currently disposed of in the environment.
CHAPTER IV

THE INCLUSION OF WASTE RECOVERY ACTIVITIES WITHIN MICROECONOMIC ANALYSES OF 'THE FIRM'.
Analysis of materials and by-products recovery activities within the framework provided by welfare economics is, as was outlined in the previous chapter, concerned with those activities, and the contribution they can make to the avoidance of both environmental pollution and the depletion of non-renewable natural resources, on an economy-wide scale. Attention is essentially directed towards the inclusion of industrial waste recovery activities within the process of interaction between the various economic units and the environment, with the main aim being one of considering the effect of that process of interaction, through its effect on the allocation of resources within a market economy, on the welfare of society. Analyses of this kind are carried out with a view to the prescription of policies appropriate to the goal of maximising that welfare. Given the insights and policy prescriptions yielded by this economy-wide approach it would seem desirable to consider the analyses of those economists who have considered recovery activities on a microeconomic level by including them, along with the process by which industrial wastes are generated and disposed of in the environment, within a framework which deals explicitly with the behaviour of that entity known as 'the firm'. This chapter has the purpose of outlining, on the basis of consideration of the relevant literature, the nature and characteristics of such analyses.

It is possible to delineate two approaches which have been taken in microeconomic analyses dealing explicitly with the behaviour of firms in relation to the generation of wastes in production. The first of these involves inclusion of the process
of waste generation, along with opportunities for reducing the volume of wastes so generated and/or the volume of wastes disposed of in the environment, within the framework provided by the neo-classical theory of the firm. The alternate approach involves the advancement of a conceptual framework within which a view of the decision-making processes of firms in relation to waste generation, abatement and disposal in the environment is specified. Although no formal theoretical model is constructed by those taking this latter approach, the conceptual framework provided enables construction of a quantifiable linear programming mode, thus allowing quantitative studies to be carried out. Activities involving recovery of materials and by-products from wastes enter the analyses carried out under both these approaches as an important means by which waste discharge limits imposed on the firm may be met or payment of effluent charges on waste discharge avoided. The identification of these differing approaches to the behaviour of firms in the area of waste generation and management permits a convenient division to be made in the consideration of the relevant literature.

The term neo-classical theory of the firm basically refers to the hypothetical construct known as 'the firm' in the perfectly competitive market model.¹ In this model, the main aspects of which were outlined briefly in the previous chapter,² the firm operates in an environment characterised by perfectly competitive markets.

2. Supra, pp. 32-34.
for factor inputs and goods and services, thus implying that supply functions for inputs and demand functions for outputs are given. In addition, the stock of natural resources is fixed and the firm produces according to a given production function. Given this operating environment, and the perfect information which emanates from it, the firm acquires inputs and produces output, as explained by the principles of marginal analysis, so as to achieve its sole objective - the maximisation of profits. This objective is achieved by production of that level of output at which market price obtained for that output equals the marginal cost of producing it. The neo-classical firms behaviour, then, is deduced from the assumptions describing its operating environment.

This brief outline of the neo-classical theory of the firm reveals a basic lack of empirical content. The neo-classical firm possesses no organisational problems or internal decision-making processes. "In fact, all of the empirical content in this neo-classical model lies in the description of the environment within which the firm must operate." Cyert and Hedrick have suggested that there exist two ways in which empirical content may be added to the neo-classical model of the firm - a change in the assumptions and/or the specification of "some aspects of the firm's behaviour directly." While the latter method of including empirical content appears to be the most interesting, having led to the development

5. Ibid., p. 398.
6. Ibid., pp. 398-399.
7. Ibid., p. 399.
of the behavioural and managerial theories of the firm, it is
the first mentioned method which is of most interest in the
present context, for it has been employed to include that part
of the operations of real world firms involving waste generation,
abatement and disposal within the framework of the neo-classical
theory of the firm.

The effect on the behaviour of the neo-classical firm of a
change in the assumptions regarding the firm's operating environ-
ment may be illustrated by brief reference to Langham's modifica-
tion of those assumptions so as to induce waste abatement behaviour
by a firm which, in utilising two variable inputs to produce one
product, generates a single waste and disposes of it in the
environment. 8 Langham's modification of the firm's operating
environment involves introduction of the assumption that society
imposes a tax or limit on the level of waste discharges into the
environment by the firm.

Given the neo-classical assumption that "the decision-maker
knows the technical transformation that creates the [wastes] of
concern to society",9 Langham demonstrates that a tax imposed
on a waste created in fixed proportion with output will result
in a reduction in output produced, with a limit on the amount of
the waste which can be discharged also inducing a reduction in
output. In the latter case output will be reduced in fixed
proportion to the limit imposed.10 Langham's analysis also involves
consideration of the case in which only one of the two inputs is
responsible for generation of the waste. The result implies that

9. Ibid., p. 315.
10. Ibid.
either a tax or a limit on waste discharge will be met, given certain conditions, by a decrease in the use of the offending input and/or an increase in the use of the other input.

While Langham later adds a degree of complexity to his analysis of the neo-classical firm through consideration of risk factors and non-convexities such as the introduction of new production technology and reciprocal external diseconomies, he neglects to consider opportunities for waste abatement other than output reduction and/or changes in the use of factor inputs. Fan and Froehlich\textsuperscript{11} and Ethridge\textsuperscript{12} have advanced neo-classical models of the firm which avoid this particular deficiency by explicitly including materials and by-product recovery as the main or only waste abatement option. These models will now be considered.

The neo-classical analysis presented by Fan and Froehlich involve consideration of the profit maximising position of a waste generating multi-product firm in the presence of governmental pollution control measures consisting of the imposition, simultaneously, of a legal limit on the volume of wastes which can be discharged into the environment and an effluent charge on the amount of wastes actually discharged. Reduction in the discharge of wastes is assumed to be achieved, together with accompanying costs, through recovery of materials and by-products (termed 'recovered effluents' by Fan and Froehlich). While there exists a market for the wastes in their recovered form this market


does not necessarily absorb all the recovered products. The firm incurs a disposal cost for the materials and by-products not sold in the market. 13

With total revenue specified as the sum of revenue from the sale of output and 'recovered effluents' and total cost consisting of those costs incurred in production and recovery processes and the effluent charge on waste discharge, Fan and Froehlich suggest that it is possible, through use of the Lagrange technique, to derive the optimal, profit maximising output of the firm. The reduction in waste discharge implied by this optimal position would, however, exceed that required under the discharge limit imposed by the governmental pollution control authority, a possibility which is seen by Fan and Froehlich as being in conflict with the observed tendency for firms to reduce their discharge of wastes into the environment only by that minimum amount necessary to enable them to meet the discharge limits imposed. Specification of the model is altered to accomodate this observation so that the firm is required to meet the waste discharge limit exactly. Profit maximising output positions, although recognised to be sub-optimal in terms of the original specification, are then derived, employing the Lagrange technique, for the firm under perfectly competitive and, given a change in the assumptions relating to the nature of the markets in which the firm operates, imperfectly competitive conditions. The fact that prices may not be regarded as given in the case of the imperfect competitor necessitates consideration of "the various demand elasticities" 14 in the latter situation.

14. Ibid., p. 266.
The results derived by Fan and Froehlich indicate that the perfectly competitive firm will maximise profits at the output level at which the market price of the ith output equals the marginal cost of production plus the net marginal cost of recovery and disposal. The imperfect competitor, on the other hand, will maximise profits at that output level at which marginal revenue is equated with the marginal cost of production plus the sum of net marginal recovery and disposal costs.¹⁵

It might reasonably be suggested that the model of the firm constructed by Fan and Froehlich, and the analysis accompanying it, is deficient in several respects. The firm is allowed no flexibility regarding the means used to achieve a reduction in waste discharge, thus revealing a perspective which is too narrow, being concerned only with the derivation of profit maximising positions rather than with deriving interesting theoretical insights into the control actions. In addition the pollution control policy imposed on the firm in a confusing combination of the effluent charge and direct regulatory control strategies. The rationale behind the imposition of the effluent charge does not appear to be that of inducing the firm to reduce its discharge of wastes - this is achieved through a legal limit - but instead seems to be one of exacting revenue from the firm in the name of waste disposal costs.

The neo-classical analysis of the firm advanced by Ethridge represents a significant improvement on that presented by Fan and Froehlich. Ethridge is concerned with the derivation of the profit maximising positions of the firm in the absence and presence of a governmental pollution control measure - in this case an effluent charge. The main aim of this exercise is that of demonstrating, given a fair degree of flexibility in terms of the achievement of waste reduction, the means which the neo-classical firm will respond to

a measure designed to induce it to reduce its discharge of wastes into the environment.

The theoretical analysis advanced by Ethridge is based on a distinction between the various products produced by firms. Ethridge suggests that firms can be viewed as producing three types of products - the main, or primary, products, by-products and waste products. The distinction between by-products and waste products (which together make up the 'side-products' accompanying production of the primary products) is seen as being economic in nature. "By-products are those side products for which firms find it economically feasible to recover until the marginal returns from recovery equal marginal costs of recovery. Waste products are those for which marginal costs [of recovery] exceed marginal returns".

In constructing his model Ethridge considers a firm producing one primary product and a side product consisting of by-products and waste products. The side product includes "all the physical resources not embodied in [the primary product]." In the absence of any governmental pollution control policy the costs of the firm will vary with the level of both primary product production and by-product recovery. If it is assumed that the side product is generated in fixed proportion with production of the primary product it is possible to set out the firm's cost relationships in a three-dimensional diagram. This is carried out in Figure 3. The firm faces a total, average and marginal cost relationship for its primary product at each level of side product produced and also faces a total, average and marginal cost relationship for its recovery of by-products at each level of production of the primary product. The combination

17 Ibid., p. 1431.
of these two sets of relationships yields an average cost surface ('AC surface')\textsuperscript{19} Given the marginal cost of producing $Y_p$ ($MC_{Y_p}$) at each level of $Y_o$ and the marginal cost of $Y_b$ ($MC_{Y_b}$) at each level of $Y_p$, variation of $Y_p$ and $Y_b$ at the same time gives rise to a marginal cost path ('MC path') which goes through the low point of the AC surface. This path shows the marginal cost of

\textsuperscript{19} Ibid., Note that the assumption of fixed proportionality between the generation of side product and production of the primary product is included in Figure 3 in the form of the line designated '$Y_o = KY_p$', where $k$ = constant, $0 < k < 1$. 
"producing $Y_p$ and $Y_b$ in their optimum proportions." The firm will maximise profits by producing that combination of $Y_p$ and $Y_b$ which corresponds to the point of intersection between the MC path and the marginal revenue surface (not shown). This ensures that $MC_Y$ equals price obtained for $Y_p$ and that $MC_Y$ equals price obtained for $Y_b$, these being the conditions which must be met simultaneously for an optimum to exist.

Having derived the optimum, profit maximising position of the firm under conditions in which no charge or restriction on the discharge of wastes into the environment exists, Ethridge introduces the requirement that the firm pay an effluent charge for its use of the environment as a waste receptor. Given the existence of this governmental pollution control measure Ethridge derives, in some cases by altering or adding to the specification of the model and the assumptions underlying it, the effect that this measure will exert on important parameters within the model.

In the first place, the existence of an effluent charge implies that an extra cost will have to be taken into account in the determination of the optimal output level of the primary product, for the generation of waste products is, by virtue of the fixed proportion generation of the side product, a positive function of primary product production. This will cause a decrease in the optimal level of primary product output.

The second of the effects referred to above is that exerted on the recovery of by-products. The imposition of an effluent charge on the discharge of wastes into the environment will make by-product recovery processes more attractive to the firm, for the costs

20. Ibid.
21. Ibid.
22. Ibid. p. 1434.
incurred by these processes will decrease, in effect, in response to the fact that payment of the effluent charge is avoided by their use. The optimal level of by-product recovery will increase as a result of this decrease in effective costs.23

The combination of a decrease in the optimal level of primary product production and an increase in the optimal level of by-product recovery implies a significant reduction in the amount of waste products discharged into the environment by the firm. The changes identified here also hold if the firm operates in imperfectly competitive markets, although the optimal outputs of the primary product and by-products "would be different under imperfect competition than under perfect competition".24

Ethridge also demonstrates that the imposition of an effluent charge on the discharge of wastes will affect the level and mix of factor inputs used by his neo-classical firm. This demonstration is achieved through appropriate modification of the specification and assumptions of the model.

By specifying the relationship of both primary product production and by-product recovery to the input of factors Ethridge is able to show that the effluent charge will induce a change in the level and mix of factor inputs utilised by the firm. The magnitude and direction of these changes will depend on the marginal productivities of the factor inputs and on the level of the charge.25 Ethridge is also able to show that an effluent charge will exert an influence on factor input mix if the assumption of fixed proportionality between production

23. Ibid.
24. Ibid. p. 1437.
25. Ibid. p. 1435.
of the primary product and the generation of the side product is dropped.

The absence of the fixed proportionality assumption allows the firm to reduce its generation of waste products, and thus avoid payment of the effluent charge, by reducing the amount of side product accompanying each unit of primary product production. Making changes in factor input mix is one method by which the firm can achieve this objective. Thus if an increase in the use of one input causes a decrease in side product generation per unit of primary product production, its use will be increased. Should an input increase the generation of the side product by more than it increases by-product recovery use of that input will be curtailed. Under these conditions changes in factor input mix allows the firm to decrease its primary product production by a smaller amount than was the case under the fixed proportionality assumption. The objective sought in the absence of this assumption might also be achieved by "a change in production methods, waste treatment etc".

The model constructed by Ethridge thus allows the firm to respond to the imposition of an effluent charge on its discharge of wastes by achieving waste reduction through a combination of increased by-product recovery, decrease in primary product production and changes in the level and mix of factor inputs used. Waste treatment and changes in production processes, although given no formal treatment in the model, may also be included as waste reduction options according

26. Ibid. p. 1435.
27. Ibid. p. 1436.
28. Ibid.
to Ethridge. The particular combination of waste reduction measures chosen will depend upon the costs incurred by these measures as well as the level of the effluent charge.

The firm will endeavour to minimise the combined cost of operating the waste reduction measures and paying the effluent charge. It will achieve this aim by reducing waste discharge to that level at which the marginal cost of waste reduction, assumed to be a continuous and increasing function of waste reduction achieved, is equated with the particular effluent charge imposed. At each level of waste reduction below this level "the firm can reduce its waste load at a lower cost than it can pay to discharge it; for levels of [waste reduction beyond this level] the firm can pay to discharge the wastes at a lower cost than it can reduce [them]." The combination of waste reduction measures chosen by the firm will be that combination which is implicit in the level of marginal costs of waste reduction equated with the effluent charge.

While the neo-classical analysis advanced by Ethridge yields theoretical results which appear important in terms of prediction, this type of analysis is characterised by several deficiencies, particularly in its application to the behaviour of firms in relation to waste generation, abatement and disposal. For instance, the fact that the behaviour of the firm in the Ethridge model is deduced from the assumptions describing its operating environment points to the existence of an important deficiency, for this characteristic means, as was noted earlier, that parameters describing the internal

29. Ibid.
30. Ibid.
31. Overall cost minimisation will be achieved because the marginal costs of waste reduction are assumed to be calculated according to minimum cost combinations of waste reduction measures at the various levels of waste reduction.
organisational and decision-making processes of the firm are excluded. These parameters are, however, likely to be important to any consideration of the effect of policies aimed at inducing an increase in the extent of materials and by-product recovery, and other waste abatement activities, carried out by real world firms.

The inappropriateness of the neo-classical approach employed by Ethridge becomes more apparent when the basic orientation of this mode of analysis is considered. The neo-classical approach to the theory of the firm is basically concerned with the explanation and prediction of the direction of change in important parameters in response to a specified variation in the firm's operating environment, the aim being one of ascertaining the effect of that change in conditions upon the aggregate behaviour of large groups of firms. It must be recognised, however, that it is often desirable for purposes of policy prescription in relation to environmental pollution problems to have knowledge regarding the actual magnitudes, including costs, involved in the response of particular firms to changes in external conditions. The desirability of this kind of information derives from the tendency for large firms within several important industries to be the most serious sources of environmental pollution. The particular orientation of the neo-classical approach to the theory of the firm does not allow the possibility of generation of such information, however.

Russell has advanced a conceptual-analytical framework appropriate for the study of the behaviour of firms in the area of waste generation and management which avoids some of the deficiencies inherent in Ethridge's neo-classical theory of the firm approach. It must be recognised, however, that the approach taken by Russell does not involve adherence to the objectives involved in theoretical research within the 'theory of the firm' framework and is thus not strictly comparable, in the terms employed by Cyert and Hedrick, with the analysis advanced by Ethridge. Russell's intention is instead one of providing a conceptual framework within which the construction of a quantifiable model for investigation of the response of individual firms to governmental pollution control actions may be carried out. It is thus within the context of microeconomic investigation of the behaviour of firms in the area of waste generation and management that the comparison between the work of Russell and that of Ethridge is relevant.

The conceptual framework advanced by Russell is concerned with the decision-making process of firms in relation to the generation, control and discharge of wastes. It is suggested that the decision-making process of a firm may be viewed as consisting of two levels. On one level decisions relating to the production activities of the firm are made, while at the second level managers are concerned with minimising any costs associated with wastes generated as a result of at the first decision-making level. This perceived split-level decision-making process is important and requires further elaboration.


36. Ibid., p. 136.
The idea central to Russell's conception of the decision-making process of the firm is that the wastes generated in production, net of any materials and by-product recovery carried out at prevailing prices in the absence of governmental pollution control action, \(^{37}\) "may be considered as an input to the production process and treated symmetrically with other inputs". \(^{38}\) At the first level of decision-making, then, managers determine parameters such as scale of activity, product type and quality, production technology and input mix "such that the plants contribution to profit is maximised", \(^{39}\) taking account of the relative costs of capital, labour and raw materials as well as any costs incurred in disposing of the wastes generated. In the absence of any governmental pollution control measures these wastes can be disposed of in the environment free-of-charge, so that decisions relating to production will be made on the basis of a zero cost for the waste generation 'input'. Costs will, however, be incurred if a governmental pollution control authority places an effluent charge or legal limit on the discharge of wastes into the environment. The existence of such costs might be expected to exert an important influence on the production decision, for it means that there exists "a direct incentive to economise on the use of the waste generation input." \(^{40}\)

As noted earlier it is the specific task of management at the second level of decision-making in Russell's scheme to minimise the costs associated with supplying the quantity of wastes decided on at the first level of the decision-making process. \(^{41}\) In attempting

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37. Further reference to the generation of wastes in relation to Russell's conception of the decision-making process of firms may be taken as including this qualification.


to achieve its cost minimisation objective management at this second decision-making level will take into account the technology and costs associated with the options available for dealing with the wastes generated. These options are taken by Russell as including materials recovery, by-product recovery, preliminary treatment, transport within the plant, end-of-pipe treatment and discharge into the environment. 42 If effluent charges are imposed on the firm the cost of 'supplying' waste generation will be "the least-cost combination of discharge reduction measures and charge payments."43 Under a discharge limit, on the other hand, the costs of supplying this 'input' will be those incurred in reducing the amount of wastes generated "to the amount the firm is allowed to discharge."44

Russell envisages some kind of iterative relationship between the two decision-making levels he specifies. Assuming the existence of an effluent charge or limit on the discharge of wastes into the environment, planning of the next period's production activity by management at the first decision-making level would take account of some approximation of the costs likely to be incurred as a result of waste generation. Communication of the resulting plan, which would include an outline of the volume of wastes likely to be generated, to the second decision-making level will result in management at that level designing a least-cost waste abatement and disposal system to meet existing and expected charges or limits on waste discharge.45 The costs involved will then be taken by management at the first level as being the appropriate price for the waste generation 'input'.

42. Ibid.
43. Russell (1973) op. cit., p. 17.
44. Ibid.
45. Ibid.
and used in the construction of a modified production plan which maximises profits. The plan, in its modified form, might again be considered by management at the second level and so on. Russell suggests that in principle this process of interaction amongst the two levels "could continue until the costs of another round exceeded the likely increase in profits to be gained by further refinements." In practice, however, "the iterative procedure would probably be carried out only for a few steps."

In the present context the importance of Russell's conception of the decision-making processes of firms, which he regards as "probably a reasonable description of how ... decisions are actually made," lies in its inclusion of materials and by-product recovery activities as an important waste reduction option available to management at the second decision-making level in its attempt to minimise the costs associated with supplying the waste generation input. Although Russell does not develop these ideas analytically his use of the decision-making process he specifies as a conceptual basis for constructing a quantifiable model investigating the response of an individual firm to governmental pollution control actions enables some insight to be gained into the nature and extent of materials and by-product recovery activities carried on by real world firms.

As it stands, the conceptual framework specified by Russell is inappropriate as a basis for constructing a quantifiable model, for it implies a programming problem involving consideration of functions which, in being "inherently non-linear," are likely to give rise to complex and difficult problems in the derivation of a solution. Russell avoids these problems by taking account of only a small number of production alternatives and, at the same time, condensing

"the two-phase decision process into a single phase represented by a linear program." The working model constructed is thus of the linear programming type.

The linear programming model formulated by Russell takes maximisation of profits to be the objective of the firm in its operation of six 'activities' - primary products production, by-product production, materials recovery, treatment and transport of wastes, sale of products and discharge of wastes. The various cost and/or revenues associated with these activities make up the coefficients of the firm's objective function - the formal expression maximised by the model. The achievement of the profit maximisation objective is, however, constrained by the existence of requirements which must be met in relation to quantity of output produced, output quality and waste generation, as well as limits imposed on input availability. The requirement which must be met in relation to waste generation is important and thus requires brief explanation.

The specific requirement imposed in relation to waste generation is that all wastes generated "be accounted for by material recovery, by-product production, treatment, transport or discharge." This requirement, formally referred to by Russell as a 'continuity condition', applies not only to wastes generated in production processes (primary wastes) but is also applicable to any 'secondary' wastes arising out of waste recovery, treatment or transportation activities. An important feature of the model in relation to the requirements noted

51. Ibid.
52. Ibid.
53. Ibid.
54. Ibid.
here is the fact that it can accommodate the situation in which several waste streams containing "a number of residuals in different proportions ... are subject to several possible treatment [or recovery] stages each removing a particular proportion of each residual." The inclusion of this kind of situation is achieved by allowing the continuity conditions to apply to the individual waste streams rather than to individual residuals within those streams, with identification of the various quantities of individual residuals taking place at the point of discharge.

Investigation of the response of the firm described by the linear programming model to environmental pollution control action on the part of a governmental pollution control authority is achieved through the scope allowed for the inclusion of measures such as "effluent charges, discharge quantity constraints or even discharge concentration limits." It is important to note that from the point of view of the model effluent charges and discharge limits "are completely symmetric." It is also possible to investigate the effects of changes in parameters such as "process technology, requirements for output quality, available input quality and relative input prices" on the waste generation, abatement and discharge activities of the firm.

The ability of the model to handle investigation of the effect of governmental pollution control measures and changes in important parameters on the activities of a firm in relation to its generation

55. Ibid., p. 24.
56. Ibid.
57. Ibid., p. 27.
58. Ibid., pp. 133-134.
59. Ibid., p. 27.
and management of wastes is important, for it enables isolation of the effect of these factors on the extent of materials and by-product recovery carried on by the firm as well as the effect exerted on waste treatment, transport and discharge activities. Given this, the quantification of Russell's linear programming model to analyse waste generation, abatement and disposal in a petroleum refinery and an integrated steelworks complex might be expected to yield some insight into the actual extent to which real world firms will respond to governmental pollution control actions and other important influences by increasing by-product and materials recovery. These applications of Russell's model, and their explicit consideration of recovery activities, will now be considered.

It is important to note that the industry studies involving the quantification of Russell's linear programming model are not 'empirical' studies in the sense in which that term is normally used, for the focus is not on firms already in existence. Attention is instead directed towards the construction of linear programming models of new or 'grass roots' firms using technical, cost and price information derived from available literature, as well as detailed information obtained from experts in the relevant industries where necessary. The broad intention in the construction of these quantitative models was the representation of 'base conditions', this involving the determination of the nature and characteristics of production processes and other activities in the absence of governmental pollution control measures. Specification of the 'base conditions' thus allows the effects of government pollution control actions and of changes in factors such

60. Russell (1973) op. cit.
as input quality, product quality, process type etc. on the waste generation and control activities of the firm to be analysed.

The Russell-Vaughan linear programming model of an integrated steelworks complex incorporates the five major groups of operations carried on in the manufacture of basic steel products - coking, sintering, ironmaking, steelmaking and final rolling and finishing. The inputs and outputs associated with these operations are included in the model as are the various solid, liquid and gaseous wastes which arise, these being accounted for by the by-product recovery, waste treatment, recirculation and discharge options for dealing with wastes. This model is solved by Russell and Vaughan under different combinations of prices, costs and constraints on waste discharge with a view to analysing the response of the hypothetical firm, in terms of waste generation, abatement and discharge, to changes in factors such as by-product prices and production process and to the introduction of a legal limit on the amount of wastes that may be discharged into the environment. While the analysis and description of this response is interesting the orientation of the present study dictates that concern be with the extent to which use of the by-product recovery option for dealing with wastes is involved in this response.

The major source of by-products recovered from wastes in the model is coke making operations. The production of coke gives rise to a volatile gas which is cooled by use of waster sprays and processed to remove marketable by-products such as ammonium sulphate and phenol. The process of removing these by-products gives rise to solid, liquid and gaseous wastes. The liquid wastes generated in by-product recovery processes, known as 'liquor streams', may also be subjected to phenol and/or ammonia recovery, as well as waste treatment processes, evaporation in coke cooling, or unmodified

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The level of by-product recovery in the Russell-Vaughan model, as in actual practice, is dependent upon "the cost of recovery, the market price and the existence or absence of residuals discharge limits on the [waste] from which the by-product can be manufactured."  

Russell and Vaughan make variations in the market price of by-product phenol. Analysis of the firm's response reveals that it takes only a small increase in price over that assumed in the 'base conditions' to make recovery of most of the phenol from the coke ovens liquor stream profitable. A further increase in price is shown to stimulate recovery of nearly all phenols. The increase in the level of by-product phenol recovery stimulated by these price increases results in a significant decrease in the volume of liquid residuals emanating from the hypothetical firm's coke ovens operations, thus indicating that "by-product prices can have a very large effect on [waste] discharges."  

The imposition of a legal limit on the discharge of BOD waste emanating from coke making and final rolling and finishing operations is also shown by Russell and Vaughan to exert an important effect on the level of by-product recovery. The reduction achieved by the firm in the discharge of BOD is accompanied by a decrease in the discharge of other wastes, this latter effect arising out of an increase in the recovery of phenols and ammonium sulphate from liquor streams in the coke ovens and recovery of oil from the liquid wastes of the cold rolling mill.

64. Ibid., p. 23-24.
65. Ibid., p. 23.
66. Ibid., p. 35.
67. Ibid.
Operation of the Russell-Vaughan linear programming model of an integrated steelworks complex thus indicates that by-product recovery activities can play an important role in reducing the discharge of liquid and gaseous wastes generated in the day-to-day operations of such a complex. The results achieved by Russell in this application of linear programming techniques to a hypothetical petroleum refinery are similar in kind to those yielded by the integrated steelworks complex application. The petroleum refinery study was, however, carried out on a more extensive basis, and Russell is thus able to consider the effect of a variety of factors on the level of by-product recovery.

The petroleum refinery modelled by Russell is basically concerned with "the production of gasoline from original crude stocks" and thus consists of three kinds of production processes - separation of the crude oil fraction appropriate for gasoline by boiling; splitting, combining or re-arranging crude oil molecules to increase the proportion of crude oil suitable for gasoline; and removal of impurities present in the crude oil. Russell organises data relating to these production processes into his linear programming framework.

The model pays particular attention to the sulphur impurity present in the crude oil input. This impurity is translated into liquid and gaseous wastes, a marketable by-product and product impurities by"a complicated set of processes." Under base conditions some 45 per cent of sulphur entering the refinery leaves as product contaminant, with 30 per cent being recovered and sold.

at prevailing prices and 24 per cent discharged into the environment as waste. The analysis and description presented by Russell involves explicit consideration of the effect of changes in conditions faced by the firm on the amount of by-product sulphur recovered from the various waste streams arising out of the refinery's operations.

Russell demonstrates that the existence of various restrictions on the sulphur content of some products and changes in output mix towards less gasoline output will both result, for various reasons, in a significant increase in the amount of sulphur recovered by the refinery. The utilisation of crude oil higher in sulphur content than that assumed to be used under base conditions will induce a similar result. In addition the market price of by-product sulphur is shown to be an extremely important variable. The operation of the model is such that a fall in the price of by-product sulphur to a level below that assumed in the base conditions will result in a substantial decrease in the amount of sulphur recovered. This leads Russell to assert that the price of by-product sulphur is clearly "an important parameter in terms of its environmental quality implications."[71]

The imposition of an effluent charge on the discharge of sulphur into the environment does not have much effect on sulphur recovery in Russell's petroleum refinery model, however. The hypothetical firm reacts to the charge by way of changes in the sulphur content of purchased fuel and by the sale, as opposed to burning, of coke. Only if the market price of sulphur is very low will an effluent charge stimulate an increase in sulphur recovery.

Overall, consideration of the industry studies carried out by Russell alone and in collaboration with Vaughan has indicated that there exist a number of important factors influencing the behaviour

71. Ibid., p. 130-131.
of firms in relation to the recovery of materials and by-products from waste streams. While these studies of hypothetical firms point to the importance of governmental pollution control actions in this regard they also indicate that changes in factors such as product quantity and quality requirements, quality and prices of inputs and the market prices of recoverable materials and by-products will exert an important influence on the extent of recovery activities and thus on environmental quality. The implication here is that governmental policy seemingly unrelated to environmental quality considerations might, through its effects on input prices and quality, output quality requirements etc., be able to induce an increase in the amount of recovery activity carried on by firms and through this influence exert a favourable influence on environmental quality.

It was suggested earlier that the approach taken by Russell in respect of the behaviour of firms in relation to the generation of wastes avoids some of the deficiencies inherent in the neo-classical theory of the firm approach taken by economists such as Ethridge and Fan and Froehlich. The discussion carried out above lends much support to this contention, for Russell specifies a conceptual framework consisting of the decision-making process of an individual firm in relation to waste generation and management - a feature which is by definition absent from the neo-classical approach. In addition, Russell's incorporation of this decision-making process into a linear programming model which, being quantifiable, is able to generate information regarding the actual magnitudes involved in the response of an individual firm to governmental pollution control actions avoids other deficiencies.
present in the neo-classical approach - its interest in direction, as opposed to magnitude, of changes and the emphasis placed on the aggregate, rather than individual, behaviour of firms.

It is necessary to recognise, however, that Russell's modification of the decision-making process he specifies in the form of a linear programming model contains important features of neo-classical analysis, for linear programming techniques maximise through the equalisation of marginal values i.e. they operate according to the concept of substitution at the margin. Thus while it is possible to identify two differing approaches to the study of the behaviour of the microeconomic unit known as 'the firm' in regard to waste generation and control of its discharge, these approaches, in the final analysis, do not differ on a fundamental basis.

This chapter, then, has considered that part of the economics literature concerned with the analysis of waste recovery activities within a framework which deals with the behaviour of the microeconomic unit known as 'the firm'. While this is clearly an area requiring further research, particularly in respect of theoretical research within the context of the theory of the firm, the literature considered does provide an insight into the behaviour of firms in respect of materials and by-product recovery and, in the process, supports some of the policy prescriptions referred to in the previous chapter.

Of particular importance is the emphasis placed by this section of the literature on the role played by economic considerations in the behaviour of individual firms in relation to the recovery of materials and by-products from wastes. While this essentially involves only the addition of a theoretical dimension to the intuitive
notion that the level of waste recovery activity carried on by firms will be dependent upon both the market price obtainable for the recovered products and the costs incurred in the recovery process, it is important, for it enables the investigation, in both theoretical and quantitative terms, of the effect that imposition of effluent charges on the discharge of wastes will have on the level of recovery activity - an investigation which predicts a substantial increase in this activity and, by implication, a significant improvement in environmental quality.

As was noted above, the emphasis placed on economic considerations in the modelling of the behaviour of individual firms also reveals the important effect that can be exerted by changes in factors such as the market prices obtainable for recovered materials and by-products, input prices, output quality requirements etc. This suggests that governmental policy initiatives distinct from comprehensive pollution control strategies can influence recovery activity and thus environmental quality.

Finally, it might also be suggested that the inclusion of recovery activities as a means of reducing waste discharge is in itself an important feature of the analyses considered in this chapter. This assertion may be justified by noting that there exists a tendency for economic analyses related to environmental pollution control to neglect the various options available to firms in their effort to reduce waste discharge, preferring instead to concentrate, in the main, in pollution control in the context of end-of-process treatment of wastes.
CHAPTER V

AN EVALUATION OF THE EFFLUENT CHARGE STRATEGY.
The literature considered this far in this study has been concerned with the inclusion of activities involving the recovery of materials and by-products from industrial waste streams as an integral part of analyses relating to the problem of environmental quality deterioration. It would seem reasonable to suggest that consideration of this literature has revealed, among other things, that the effluent charge strategy is considered by many economists as the policy measure most appropriate as a means of inducing an increase in the level and extent recovery activity. Advocacy of the effluent charge strategy in this context has, as was outlined in earlier chapters, been justified on several grounds. It appears, however, that the relevant arguments and analyses have paid too little attention to the fact that the effluent charge strategy is a comprehensive pollution control strategy and, as such, cannot be considered as being appropriate solely to one purpose. Recognition of this factor necessitates consideration of several important difficulties and problems which, it has been suggested, are likely to be encountered in the practical implementation of the effluent charge strategy. It is with the identification and evaluation of these problems and difficulties that this chapter is in large part concerned.¹

Before proceeding, a brief review of the main aspects of the arguments and analyses of those who have advocated introduction of the effluent charge strategy in the context of inducing increased materials and by-product recovery from wastes would seem desirable.

¹. This chapter consists of a modified version of an essay presented for the 400 level course 'Economics of Social Welfare I'. 
On an intuitive level, the imposition of an effluent charge on a firm's discharge of wastes into the environment might be expected to make the operation of previously unprofitable recovery processes economic if the price obtainable in the market for the recovered materials and by-products plus the saving from not having to pay the charge exceeds the costs of operating the recovery processes. In these terms, then, the effluent charge is seen as inducing an increase in the amount of materials and by-product recovery carried out by firms.

Theoretical investigation of the intuitive reasoning referred to here using the techniques of neo-classical analysis has revealed that the optimal level of materials and by-product recovery of a neo-classical firm would, under certain conditions, increase in response to the imposition of an effluent charge on its waste discharge. This response derives from the decrease in effective costs incurred in operating recovery processes as a result of the fact that operation of those processes avoids payment of the effluent charge. The increase in materials and by-product recovery was shown to be accompanied by the use of other waste reduction measures - decreased production, waste treatment, change in production processes and changes in the level and mix of factor inputs. The particular combination of waste reduction measures chosen by the hypothetical firm was indicated to be that which minimises the combined cost involved in operating waste reduction activities and paying the effluent charge on wastes still discharged.2

Other economists have translated these microeconomic predictions on to an economy-wide scale, suggesting that effluent charges,

2. Supra, pp. 74-75.
imposed with a view to the correction of the market bias emanating from the fact that use of the environment for waste disposal is unpriced, would induce an increase in both the level and extent of materials and by-product recovery activities, as well as causing an increase in the use of other waste reduction measures. The resulting improvement in environmental quality would, it is argued, be achieved at minimum possible resource cost to the economy. The increase in recovery of materials and by-products, and their utilisation by other firms, is seen as effecting a slowdown in the rate of flow of newly extracted raw materials through the economy.\textsuperscript{3} It has also been suggested that the introduction of an effluent charge strategy might also stimulate firms to carry out research aimed at the development of new recovery processes or new uses to which wastes in their recovered form might be put, this research being carried out with a view to reduction of waste discharge sometime in the future.

It is apparent from this brief review that the rationale behind advocation of the effluent charge strategy in the context of inducing increased materials and by-product recovery by firms derives in large part from the basic theoretical demonstration that each individual firm faced with effluent charges on its discharge of wastes will respond by equating its marginal cost of waste reduction with the charge and thus make reductions in waste discharge by using that combination of waste discharge measures which minimises cost, both to the firm itself and to the economy as a whole.\textsuperscript{4} Recognition of this implies that it is more appropriate to consider arguments in

\textsuperscript{3} Supra., pp. 41-44.

\textsuperscript{4} Aggregate waste reduction achieved will correspond to that necessary to achieve the desirable level of environmental quality if the pollution control authority's estimate of the aggregate marginal cost of waste reduction is accurate, implying that accurate information concerning the waste reduction costs likely to be incurred by firms exists. If this information were inaccurate the appropriate effluent charge may be taken as having been determined through an iterative process by which appropriate adjustments are made to the level of the charge if the target level of waste reduction, and environmental quality, is not achieved initially.
favour of the effluent charge strategy in relation to its effect on recovery activities as making up part of the more general arguments in favour of the strategy as a comprehensive environmental pollution control strategy. These arguments tend to be based upon demonstration of the perceived advantages possessed by it in comparison with the direct regulatory control approach to pollution control currently employed in most developed nations.

It is not intended, however, to enter into discussion of the work of economists who have been concerned to point out what they believe to be the superiority of the effluent charge strategy over the direct regulatory control approach, 5 apart from noting that these economists regard their arguments as being strong on both theoretical and practical grounds. Attention is instead directed towards consideration of a number of deficiencies which have been identified in the arguments and analyses of such economists, these deficiencies relating to problems and difficulties which are likely to be encountered in the practical implementation of the effluent charge strategy. Of particular interest in this respect are doubts which have been expressed regarding the appropriateness of this strategy in situations characterised by features such as rapid economic growth, spatial differences in the environmental effect of firm's waste disposal activities and a response by firms which contradicts that assumed in theoretical analyses. Also of importance is the criticism which has been directed towards advocates of the effluent charge strategy in respect of their failure to take account of the effect that existing institutions would have on any practical implementation of the strategy.

The broad aim involved in considering the factors referred to here is that of assessing the efficacy, feasibility and efficiency of the effluent charge strategy in its application to real world situations and thus its appropriateness as a technique of achieving improvements in environmental quality. The conclusion reached will be of direct relevance to the arguments and analyses of those economists who have advocated the effluent charge strategy in the context of inducing an increase in materials and by-product recovery from industrial waste streams.

Of particular importance to the successful implementation of an effluent charge strategy is a response by individual firms that is consistent with that assumed in theoretical analyses. The response assumed involved individual firms varying their waste reduction according to the level of the effluent charge imposed, the important underlying assumption being, of course, that firm's incur incremental costs of waste reduction which are a continuous and increasing function of the amount of waste reduction achieved. This may be illustrated by reference to Figure 4.

**FIGURE 4** Variation of waste reduction by firm in response to different levels of effluent charge

![Diagram](image-url)
An increase in the level of the effluent charge from $p/unit to $P_o/unit will induce the firm, equating its marginal cost of waste reduction with the charge, to increase its waste reduction to $q_o\%$. Several economists have suggested, however, that the marginal cost of waste reduction curves of firms in the real world may be characterised by discreteness (and thus discontinuities), the implication being that the pollution control authority may not be able to achieve a target reduction in waste disposal by imposing a particular effluent charge.

More specifically, it has been suggested that the marginal cost of waste reduction curve of certain firms may be characterised by sections of constant marginal costs of reduction—measures employed to reduce the volume of wastes disposed may be characterised by constant returns to scale over a range of waste reduction levels. This possibility, and its implications, may be explained more clearly by reference to Figure 5.

In this diagram it is assumed that the firm possesses only one or two options in its effort to reduce waste discharge, these options being characterised by constant returns to scale over significant ranges of possible waste reduction levels. The marginal cost of waste reduction curve in this example is characterised by three discrete steps. It is unlikely that the governmental pollution control authority will be able to induce firms to reduce wastes by, say 50%, since the firm will be indifferent between 35% waste reduction and 50% waste reduction when the effluent charge is set at $P_1/unit, the likelihood being that it will prefer to reduce wastes by only 35%.

FIGURE 5  Effect of effluent charge when waste reduction measures used by firm are characterised by constant returns to scale

Cost of waste reduction ($/unit)

Waste reduction (%)


The theoretical observation outlined above has been given empirical content by Dorsey in his case study of water quality management on the Wisconsin River. Dorsey found that the response of firms to the introduction of effluent charges would be dominated by the alternative treatment plants that might be constructed, with plants embodying both primary and secondary treatment technologies being characterised by constant average and marginal costs.


The analysis carried out by Darcey, then, implies that an effluent charge "set equal to marginal costs prevailing among polluters could not determine a unique waste treatment level." 9

Russell and Vaughan 10, however, have suggested that any occurrence of the kind of situation dealt with above is likely to be rare in reality, this assertion being justified by reference to the complexity of the large industrial operations that tend to be "the most serious point pollution sources". 11 These authors suggest that even if only one or two waste reduction options are available to a firm the fact that industrial plants are usually composed of several different production processes, each generating a waste stream made up at different concentrations of various residuals, will mean that a precise reaction to various charge levels is generally possible if the firm is in a position to sewer each waste stream separately. 12 In any case, it is argued, firms usually possess a number of waste reduction options "sometimes in combination with waste streams of varying composition." 13 This will mean that, even if some waste reduction options are characterised by constant returns to scale, "marginal cost of reduction curves will have many steps, so that many different levels of discharge are attainable through effluent charges." 14

The implication, then, is that the efficiency of an effluent charge strategy in real world situations is not likely to be hindered to any significant extent by discontinuities in the marginal cost of waste reduction curves of firms, for these discontinuities,

9. Ibid.
11. Ibid., p. 249.
12. Ibid., p. 246.
13. Ibid.
where they exist, are not likely to be extensive. It is important to recognise, however, that there may exist situations, usually in the case of water pollution control achieved solely by the use of treatment plants, where the problem identified by Byrne and Spiro may be significant.

Another consideration which has been identified as being potentially significant in the practical application of the effluent charge strategy is the fact that the environmental effects of industrial waste disposal activities differ spatially. The extent to which industrial waste discharges are translated into pollutant concentrations is sensitive to source location. For instance, "sources downwind or downstream of the receptor tend to make less of a contribution to the degradation of air and water quality than sources upwind or upstream." While those who advocate introduction of effluent charges recognise this point they tend to place little emphasis on it. Their arguments and analyses are usually based on the imposition of a single charge on all firms discharging a particular residual (the charge differing according to the type of residual) with an accompanying qualification implying that the system of charges could be modified to take account of spatial variations in stream flow and atmospheric temperature inversion. The implications stemming from the fact that the effect of waste disposal activities on the environment differs over space are much more significant than this kind of qualification would suggest, however.


Should the pollution control authority, in implementing an effluent charge strategy, ignore the consideration identified above and set a uniform effluent charge for individual residuals, it will most likely find that it is unable to achieve the desired environmental quality standards. Further, the resulting level of environmental quality may be achieved in a manner which is less efficient than that which could be induced by a direct regulatory control strategy.  

Taking account of the differential spatial effect of waste disposal activities, on the other hand, means that it is necessary to institute a system of zonal effluent charges, with charges for individual residuals varying across these zones. The pollution control authority would thus be required to collect, and evaluate, much more detailed information (both quality and quantity) than is usually considered necessary to administrate an effluent charge strategy. Additional information required would relate to the nature of relevant environmental processes in the various zones and the effect of these processes on the concentration of residuals in the environment of these zones. In addition to the costs involved in generating this kind of information it is likely that the process of setting appropriate zonal effluent charges will be costly due to its time consuming nature.

Some economists have pointed to other aspects of information requirements which may cause problems in the administration of an effluent charge system. As was noted earlier, the pollution control

17. Rose-Ackerman, op. cit. p. 516.
18. Tietenberg, loc. cit.
authority responsible for the administration of the effluent charge system will, in setting initial effluent charge levels, utilise information concerning the costs likely to be incurred by firms in reducing their discharge of wastes. It is likely, however, that there will exist a number of imperfections in this information, imperfections which may cause problems for the authority in its administration of the effluent charge system.

Figure 6 may be used to illustrate one problem which may arise out of the existence of imperfect information:

FIGURE 6 The use of the effluent charge strategy when there exists information imperfections

In the case illustrated the pollution control authority, as a result of information imperfections, has underestimated the waste reduction costs incurred by firms, where $MC_E$ and $MC_A$ are estimated and actual marginal costs of waste reduction respectively. An effluent charge of $p_2$/unit will induce firms to reduce their volume of waste discharge by only $q_2\%$ instead of the anticipated $q_3\%$. As information relating to the performance of firms in response to the charge becomes available the pollution control authority may be expected to make an upward adjustment in the charge to, say $p_3$/unit. (converse in the case where overestimation of cost occurs). The ability of the pollution control authority to experiment in this manner in practice, however, "will be limited by the capital intensity of pollution control ... Since there is a time lag between the decision to invest and the completion of the project, environmental quality resulting from any given charge will not be known for several years." 19

The mere existence of the possibility of changes being made to effluent charges over time may result in the presence of significant imperfections in information acquired by the pollution control authority. If the number of firms discharging wastes is small, and collusion effectively prevented, there may exist a tendency towards overstatement of costs incurred in waste reduction, in the hope that other waste dischargers will overinvest in pollution control equipment. Where the number of waste dischargers is large, however, this is unlikely to occur. Should an incentive to collude exist, deriving from the recognition that the pollution control

authority "has poor information concerning pollution abatement costs",21 over reduction may be carried on by firms with a view to persuading the authority to make a downward adjustment in the effluent charge.

The successful implementation of an effluent charge strategy will, then, be dependent to a large extent on information considerations. It is necessary to recognise that the pollution control authority will need to collect much more information than is generally assumed if it is to take account of variations over space in the effect of waste disposal activities. Further, the fact that we do not live in a world of perfect information will have an important effect on the efficiency with which the pollution control authority is able to implement the strategy.

Discussion thus far has been carried out in static terms, thus neglecting important dynamic considerations. This emphasis on static analysis derives from the fact that arguments and analyses which have been advanced in favour of the introduction of effluent charges have been presented in a non-dynamic framework. Ferrar and Whinston22 have suggested that this neglect of dynamics is an extremely important deficiency. They suggest that in a non-dynamic, non-growth oriented economy (or region) an effluent charge strategy may be successful in achieving acceptable standards of environmental quality.23 The most acute environmental quality problems, however, "occur in the most vigorously developing metropolitan regions... In this more dynamic setting the concept of a static equilibrium effluent charge is meaningless."24

21. Ibid., p. 524.
23. Ibid., p. 309.
24. Ibid.,
Ferrar and Whinston suggest that in growth-oriented regions there will exist a perpetual 'adjustment lag' in the setting of effluent charges to achieve environmental quality standards. The establishment of new firms, for example, will most likely cause a deterioration in environmental quality due to the likely increase in the total volume of wastes discharged. This will occur in spite of the fact that the new firm makes the appropriate (desired) response to the existing effluent charge. Information generated about environmental quality would signal the pollution control authority that an upward adjustment in the effluent charge is required, with subsequent action being taken to increase the charge to "that level which would restore desired environmental quality." This process of adjusting effluent charges will, however, take time. Meanwhile it is likely that more firms will be established, making the new charge inadequate to achieve the required environmental quality standard. It would thus seem reasonable to anticipate the existence of a perpetual adjustment lag, which under an effluent charge strategy would imply perpetual violation of environmental quality standards.

The observation made by Ferrar and Whinston has important implications for the effectiveness of an effluent charge strategy. Acceptable standards of environmental quality, it would seem, are virtually unattainable in a growth oriented society if effluent charges are used as the major instrument to control pollution.

Economists who have argued in favour of the introduction of effluent charges as a means of pollution control have often suggested that this strategy possesses the virtue of being less subject to political processes than the current direct regulatory control approach. The strategy of direct regulatory control

25. Ibid.
of the waste disposal activities of firms, it is argued, has a tendency to become "a political process entailing bargaining between parties of unequal power." The effluent charge strategy, on the other hand, is seen as a market oriented technique and its introduction would "reduce the scope for administrative discretion and bargaining." Majone, however, has disagreed with this latter characterisation of the effluent charge strategy and has been concerned to point out that the same institutional influences which distort the regulatory control approach will also, in practice, distort the operation of an effluent charge strategy.

Freeman et al have probably been the most vocal of whose who have denounced direct regulation as being subject to political processes while at the same time pointing to the virtues of the effluent charge strategy in comparison. These authors have asserted that every aspect of direct regulatory control - the setting of standards, the question of whether violations have occurred, the steps that need to be taken to correct infractions and even the judicial process (when convictions are sought) is characterised by bargaining "between pollution control authorities and the interests they regulate...At every stage... those being regulated have a lot at stake, while the public interest is diffuse, poorly organised and poorly represented... predictably, the bargains struck favour those being regulated."

27. Ibid., p. 106.
29. Freeman, Haveman and Kneese, op. cit., p. 106.
30. Ibid., p. 105.
The effluent charge strategy, in contrast, is seen as requiring only one major decision - the level of the charge to be imposed. This decision, it is argued, is less subject to 'administrative discretion and bargaining' because it is a "significant and highly visible one." In addition there are two other characteristics of the strategy which are important in this respect: there is a performance criterion by which to judge the correctness of the decision on the level of the charge (i.e. the resulting environmental quality); and the effect of the charge is likely to be durable, the zeal and effectiveness of the pollution control authority tending not to diminish over time.

In fact there exists much evidence to support the contention that industrial interests have exerted an important influence on the activities of authorities concerned with controlling pollution through direct regulatory control. The importance of this influence in the United States has been outlined by Grad, who noted that industrial interests possess substantial representation on air quality standard setting boards, with the result that "air pollution control agencies were for a long time industry protection oriented and would not recommend air pollution control measures that were costly or otherwise objectionable to industrial polluters." Grad also noted that a similar situation exists in the drawing up of legislation designed to control water pollution.

31. Ibid., p. 106.
32. Ibid.
35. Ibid.
It is apparent, however, that a similar disease has inflicted the pollution control systems of those countries that have introduced effluent charges. France (1964) and the Netherlands (1971) have introduced pollution charges into water quality legislation, the charge system being used "as part of a machinery of direct controls." In France, effluent charges were introduced under the 1964 law on water management and pollution control. Industrial interests are strongly represented on both a national and regional level, this representation tending to act in such a way as to significantly influence the level of the effluent charges.

The existence of this situation has led Majone to emphasise the important role played by existing institutions in the implementation of any pollution control strategy. The model of policy making implicit in the analyses of those who advocate introduction of an effluent charge strategy is seen by Majone as being inadequate, this inadequacy deriving from the "artificial separation of the behaviour of individual actors in the market place, where the institutional constraints are given, from their behaviour in the political arena, where those constraints are established." Of particular importance in this respect is the role played by individuals and groups pursuing their self interest, "not only within given rules but also by investing resources to change the rules to their own benefit..." In the case of pollution control policies it is necessary to take into account the actions of leaders of industrial interest groups, as well as the actions of legislators,

37. Ibid., p. 590.
38. Ibid., p. 593
citizen groups and party leaders. It is the interaction, through a process of "bargaining and partisan mutual adjustment,"\textsuperscript{39} between these actors which determines the form in which policies will be implemented in practice.

A realistic appraisal of the appropriateness of introducing an effluent charge strategy must thus take account of the way in which the strategy would be modified in response to the structure of existing institutions, for the actual results achieved will be affected substantially by these institutional-political arrangements. "The actual outcome of environmental policies are affected more by institutional arrangements emerging from the political process than by the technical characteristics of the instruments employed."\textsuperscript{40}

It would seem likely, then, that the administration of an effluent charge strategy would be much more affected by bargaining behaviour and political influences than Freeman et al would have us believe. Legislation would most likely dictate that the pollution control authority establish charge levels in consultation with those having an interest, for various reasons, in the control of pollution - industrial interests and citizen groups. Industrial interests might be expected to have a dominating influence, since they will be able to devote more time and effort to negotiation than citizen groups. These interests might be expected to be concerned both to "keep the charge as low as possible ... [and ensure that]... increases in the charge would be delayed as long as possible."\textsuperscript{41} Taking these considerations together with the likelihood that the pollution control

\textsuperscript{39} Ib\textit{id.}, p. 603.
\textsuperscript{40} Ib\textit{id.}, p. 593.
\textsuperscript{41} Dorcey, op.\textit{cit.} pp. 127-128.
authority will be uncertain as to the appropriate level of the charge it would seem unlikely that "effluent charges would achieve desired environmental quality standards within a reasonable length of time." 42

One qualification needs to be added here. It is conceivable that the widespread and increasing environmental consciousness which has developed in the community during the past decade would stimulate the pollution control authority to 'get tough' with firms discharging wastes by setting the effluent charge at a high level. Experience with public regulation in general, however, would suggest "that periods in which regulatory agencies are 'tough' upon the regulated are temporary phenomena." 43

It must be recognised, then, that existing institutional and political arrangements would effect a significant modification in the form that an effluent charge strategy would take in practice. It might reasonably be suggested that such modification is likely to significantly affect the efficacy of the strategy.

Consideration of the problems and difficulties likely to be encountered in any practical application of the effluent charge strategy would suggest, then, that the argument in favour of the strategy is nowhere near as strong as is often assumed. The effectiveness of the strategy may be significantly impaired if the pollution control authority is unable to obtain reliable information and if it is unable to induce a precise reaction by firms to the

42. *Ibid.*, p. 128
effluent charge set. Growth oriented economies will also cause problems for the pollution control authority, for the existence of rapid economic growth will mean that the authority will have to determine dynamic effluent charges. The impracticability of doing so will mean the attainment of acceptable standards of environmental quality is not possible. But perhaps the most important problem likely to be encountered in the practical application of the effluent charge strategy is the effect that modification of the strategy to fit into the existing institutional and political arrangements will have on the efficacy of the strategy. It might reasonably be suggested that the strategy is likely to be quite sterile under such arrangements.

It is worthwhile noting that Orr\textsuperscript{44} has suggested that some of the problems and difficulties noted here in relation to the implementation of an effluent charge strategy might be avoided if the strategy is designed specifically for the purpose of inducing long run technological change rather than with the aim of effecting changes in resource allocation.\textsuperscript{45} Concern, Orr argues, should be with the establishment of a long run framework for technological adaption to problems of environmental quality deterioration, with technological developments aimed at decreasing waste generation and/or discharge accompanying a given level of economic activity being of most importance. This involves placing emphasis on the


\textsuperscript{45} Ibid. pp. 444-445.
direction and rate of change in environmental quality over time rather than on the achievement of specific environmental quality standards within a particular time period.

The effluent charge scheme envisaged by Orr is one involving the gradual implementation of effluent charges in predetermined steps over a period of several years. This kind of scheme is seen as avoiding any problems that may be associated with the possibility that iterative adjustments may be made to the charge level by the pollution control authority to achieve the desired level of environmental quality. A "stable profile of charges extending several years into the future" would be set, with adjustments being made infrequently in response to situations in which "the charge structures fail to elicit adequate response or where burdens are clearly onerous and not justified by actual or anticipated response." In addition the fact that Orr envisages implementation of nationwide, rather than zonal or regional, charge structures means that some of the information difficulties and political problems likely to be associated with regional or zonal charge structures would be avoided.

While the effluent charge scheme advanced by Orr represents an important approach to the problem of environmental quality deterioration, in that it promises to yield an improvement in environmental quality over the long run through technological developments in the area of waste recovery treatment activities, it is not of the type

46. Ibid., p. 445.
47. Ibid.
48. Ibid.
49. Ibid., p. 446.
normally envisaged by those who advocate the effluent charge strategy as the appropriate means of dealing with this problem. The demonstration that there exists a variety of problems and difficulties likely to be encountered in any practical implementation of the strategy thus remains of considerable importance, for it suggests that this strategy may be ineffective in dealing with the problem of environmental quality deterioration.
CHAPTER VI

CONCLUSION
The preceding chapters have been concerned to examine the approaches that have been taken to the inclusion of industrial waste recovery activities within analyses relating to waste generation, abatement and disposal, and to outline, and in some cases evaluate, the various policy prescriptions which have been advanced with the intention of inducing an increase in the level and extent of such activities and, by implication, an improvement in environmental quality. This review of the literature was carried out with a view to the eventual assessment of the contribution which has been made by the economics literature both the explanation of the 'restricted and fragmented' nature of waste recovery and re-use activities in the Illawarra region and the stock of policy prescriptions appropriate to the goal of inducing an increase in the level and extent of such activities. This concluding chapter has the specific purpose of carrying out this assessment.

Reduced to its basics the literature reviewed in earlier chapters suggests that the restricted and fragmented nature of waste recovery and re-use activities in the Illawarra region may be explained from two points of view - economy-wide and micro-economic. These two approaches may be regarded as being complementary rather than in conflict, for taken together they yield an important insight into the nature of recovery and re-use activities in the Illawarra region.

From a microeconomic viewpoint the literature suggests that the choice faced by firms in the region in respect of the fate of wastes generated in production may be viewed as one between the discharge of those wastes, subject to any discharge limits imposed by the N.S.W. State Pollution Control Commission (S.P.C.C.), into the environment or application of recovery techniques to the
wastes to yield materials and by-products. The alternative chosen is seen as depending upon the operation of several important factors - the existence of technology appropriate for the recovery of materials and by-products, the identification of uses to which these materials and by-products might be put, the revenue obtainable through their sale to user firms and the costs involved in operating the recovery processes.

Economic theory suggests that firms will carry out recovery activities when the marginal revenue derived from the sale of materials and by-products exceeds the marginal costs incurred by recovery processes, so that wastes discharged into the environment, and thus contributing to environmental pollution, will be those for which the marginal costs of recovery exceed the marginal returns from sale.\(^1\) This latter category will include those wastes for which no recovery technology and/or potential use exists. The theoretical result referred to here may be regarded as theoretical expression of the observation that firms tend to carry out recovery activities only when the revenue obtainable for the materials and by-products so derived is well in excess of the costs incurred in recovery.\(^2\)

On a microeconomic level, then, the literature suggests that the environmental pollution problem which exists in the Illawarra region is in large part an economic phenomenon, with the wastes being discharged into the environment by firms


being those for which no profitable use can be found. The restricted and fragmented nature of recovery activities in the region may thus be viewed as deriving from the importance placed on profit by firms.

The microeconomic explanation outlined above underlies the explanation of the nature of waste recovery (and re-use) activities which may be gleaned from consideration of the literature concerned with the analysis of such activities on an economy-wide scale. This literature suggests that the restricted and fragmented nature of recovery and re-use activities in the Illawarra region may be viewed as deriving from both the existence of deficiencies in the operation of market processes in the Australian economy as a whole and the presence of a set of governmental policies, implemented at state or national level, which either fail to recognise the existence of these deficiencies or aggravate them.

The most important market deficiency referred to here is that which arises out of the fact that the use of the environment by firms for waste disposal is unpriced. This allows firms to discharge wastes which are unprofitable to recover into the environment, subject to any waste discharge limits imposed by the S.P.C.C., free-of-charge of any costs incurred by the regional community (i.e. in terms of diminished utility derived from the consumption of environmental services) as a result of any environmental pollution that may be generated by such activities. Also of importance are the (uncompensated) costs imposed on the Australian community in general as a result of the detrimental effect exerted on the environment by the actual process of natural resource extraction.
Taken together, the two factors referred to may be viewed as making for the existence of a situation characterised by the fact that the price at which newly extracted raw materials are purchased by firms fails to reflect the actual social costs of their use. The implication is that newly extracted raw materials are underpriced and are thus able to compete much more favourably with materials and by-products recovered from wastes than they would be if the social costs referred to above were reflected in their price. The overall result, in the terms used by the literature, is a flow of newly extracted raw materials through the regional and national economies which is too rapid according to the criterion of social efficiency, waste recovery and re-use activities carried out on a smaller scale than is desirable by reference to that same criterion and environmental pollution. 3

As noted in an earlier chapter 4 the literature suggests that government policies of the type which stimulate economic activity in the extractive industries sector of an economy through special tax treatment are likely to aggravate the distortion in the price structure arising out of the existence of deficiencies in the operation of market processes. Policies of this type have been, and continue to be, an important component of Commonwealth Government policy, and their use thus requires brief review.

During the late 1960's and early 1970's the extractive industries sector in Australia experienced a period of rapid growth - growth which is regarded as having been encouraged to a significant extent by special income tax treatment accorded to these industries.

by the Commonwealth Government during that period. The year 1974 saw the removal of the main features of this special tax treatment, which had included the exemption of some income from tax, provisions providing deductions to shareholders and accelerated write-off provisions. The past two years, however, have seen the Commonwealth Government, with a view to stimulating recovery from the current inflationary recession, move towards the restoration of special tax treatment of extractive industries through the introduction of measures such as accelerated depreciation allowances, accelerated write-off provisions and special allowances for development expenditure. In addition the Commonwealth Government has implemented allowances designed to stimulate economic activity in the economy as a whole—these might also be expected to exert an important influence on economic activity in the extractive industries sector.

8. It may be noted in passing that the six state governments also possess the ability to influence economic activity in the extractive industries sector of the Australian economy through their power to levy royalties and lease premiums and rentals. Although royalty rates have been increased by most state governments in recent years it seems that these governments "tend to favour development [of extractive industries] for its own sake." Ibid., p. 9.
It would seem reasonable to suggest, then, that the concessional income tax treatment of the extractive sector in the Australian economy during much of the past decade or so (in fact for most of the post-war period) has, by way of its indirect influence on the prices of newly extracted raw materials, contributed to the restricted and fragmented nature of waste recovery and re-use activities in the Illawarra region.

It is also important to note that the particular type of pollution control strategy employed by the S.P.C.C. in N.S.W. may be viewed as being an important factor in explaining the nature of recovery and re-use activities in the Illawarra region, for this strategy, in concentrating on the setting of waste discharge standards for firms generating liquid and/or gaseous wastes, is regarded by the literature as paying no attention to the fact that the use of the environment for waste disposal is unpriced. The strategy is thus viewed as failing to correct distortions in the price structure relating in the flow of raw materials through the economy and, as a result, offering little in the way of economic incentives for increased recovery of materials and by-products from wastes.

9. The main features of the S.P.C.C.'s pollution control strategy are as follows: (i) large-scale generators of air-borne wastes are required to apply annually for a licence which carries conditions relating to allowable waste discharge. These conditions are based on the kind and volume of wastes discharged at individual sources; (ii) the strategy used to control water pollution involves the setting of ambient water quality standards. These standards determine the conditions attached to licences granted to dischargers of waterborne wastes. Butlin, N.G. (ed), *Sydney's Environmental Amenity 1970-75*, The Botany Bay Project Reports: No.1., (Canberra: Australian National University Press, 1976), p. 38, 44.

The kind of criticism referred to here is an important feature of the comments made by Butlin in the first report of the Botany Bay Project\textsuperscript{11} on the pollution control strategy employed by the S.P.C.C. Butlin suggested, in the context of liquid waste management, that the direct regulatory control strategy of the S.P.C.C. is oriented towards organisation of the treatment and/or disposal of liquid wastes, "leaving many problems to re-emerge in a different form or location."\textsuperscript{12} This strategy, it is argued, does not pay much attention to techniques of waste management involving the control of liquid waste at source, the systematic re-use of waste components or the control of the assimilation process in the environment.\textsuperscript{13}

The above discussion, then, has outlined the manner in which the restricted and fragmented nature of waste recovery and re-use activities in the Illawarra region may be explained from the point of view of the economics literature. This literature also offers, of course, a number of policy prescriptions aimed at inducing an increase in the level and extent of activities involving the recovery of useful materials and by-products from industrial wastes. The relevance of these policy prescriptions to the Illawarra situation will now be considered.

The policy prescriptions advanced in the literature, and outlined and evaluated in earlier chapters, included the effluent charge strategy, the elimination of special tax treated accorded extractive industries, introduction of severance taxes on virgin

\textsuperscript{11} Butlin, (ed.) \textit{op. cit.}
\textsuperscript{12} \textit{Ibid.}, p. 126.
\textsuperscript{13} \textit{Ibid.}, p. 125.
raw material extraction by those same industries, the setting up of an industrial waste exchange and government initiation, encouragement and financial support of research aimed at "developing new ways of recovering and re-using waste materials." Advocation of these policies has been backed by a variety of arguments which derive from, and relate to, the kind of explanation, reviewed above in the context of the Illawarra situation, offered by the literature for the nature of waste recovery and re-use activities. The question which must be asked of these policy prescriptions is that of their appropriateness as a means of inducing recovery from wastes on a larger scale in the Illawarra region.

It is necessary to recognise that most of the policy prescriptions referred to here can be implemented only at State or Commonwealth levels of government, with the reasons relating to the particular nature and scope of the policies themselves and/or the possession of appropriate powers allowing their implementation. Included in this category are the effluent charge strategy, the policies aimed at the extractive industries sector and increased governmental involvement in research relating to the development of new recovery techniques and new uses to which wastes in their recovered form might be put. Perhaps the only policy prescription possessing a specifically regional character is that advocating the setting up of an industrial waste exchange.

The implication which can be drawn here is that the major policy initiatives directed towards achieving an improvement in environmental quality through increased recovery of usable materials and by-products from industrial waste streams will need to come from State and/or Commonwealth levels of government. In this context, then, consideration of the economics literature has yielded a set of policy prescriptions which appear to be inappropriate for implementation on a specifically regional level.

This inappropriateness of the policy prescriptions advanced in the literature derives, of course, from the recognition given to the economy-wide dimensions of the factors making for the restricted and fragmented nature of waste recovery and re-use activities. The problem identified in relation to the Illawarra region is, it would seem, common to most industrialised regions in the developed world, for the factors making for its existence operate on a national rather than regional scale. The policy prescriptions referred to must thus be regarded as an approach to the problem of environmental quality deterioration that might be taken by the top two levels of government in Australia.

Taking all things into consideration, then it might be suggested that the examination of the economics literature carried out in this study has yielded an important insight into the nature of that part of economic activity involving the recovery of materials and by-products from industrial waste streams and their utilisation, either by the waste-producing firms themselves or other firms, as raw material inputs into production processes. The policy prescriptions on the basis of this explanation represent a policy approach which promises to induce an increase in the level and extent of these activities and thus achieve a significant and sustained improvement in environmental quality.
It is important to note, however, that the treatment of waste recovery and re-use activities has, as was outlined in earlier chapters, been carried out within "the theoretical framework of conventional economic theory"\(^\text{15}\) - a framework which is regarded by Kapp as being "perhaps too narrow to offer the required analytical tools for the exploration of the causal process of environmental disruption and for the determination of adequate instruments of control designed to mitigate the deterioration of the environment."\(^\text{16}\) The reasons underlying Kapp's criticism relates to his more general aversion to conventional economic, which he sees as having been pushed, in response to both the orientation of the theoretical framework itself\(^\text{17}\) and the attitudes of those conventional economists who utilise it, "more and more in the direction of a formal, self-contained, closed mechanical analytical system [which does not allow] the assimilation of new perspectives and new paradigms developed by other disciplines."\(^\text{18}\)

Kapp sees the solution to the inappropriateness of the approach of conventional economists to environmental problems as lying in the development of study and research undertaken in collaboration with scientists in other relevant disciplines.


\(^{16}\) *Ibid.*

\(^{17}\) According to Kapp the approach of conventional economists to economic theory is characterised by the following features: emphasis on the use of mathematics, reasoning by analogy to mechanics, the search for levels of stable equilibrium and "an implicitly normative insistence that economic theory is concerned with the explication of the logic of rational action under conditions of scarcity." Kapp, K.W., "The Nature and Significance of Institutional Economics," *Kyklos*, Vol. 29, (Fasc.2.), p. 210.

There appears to be considerable merit in the kind of 'institutionalist' criticism advanced by Kapp. It is, however, beyond the scope of the present study to evaluate the validity or otherwise of this particular criticism. It will suffice to say that the examination of the literature carried out in this study has indicated that despite an obvious need for further research the economics discipline has made an important contribution, in respect of its treatment of waste recovery and re-use activities, to the understanding of "the problem of environmental disruption and environmental control." The view of some professional economists that "conventional economists would render the greatest service to posterity if they remained silent" thus appears unjustified.


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