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A Dissertations or papers submitted for the degree of Doctor of Philosophy of the Australian National University by submission of published work

September 1975
STUDIES IN THE APPLICATION OF PUBLIC ECONOMICS TO
AGRICULTURE AND THE NATURAL RESOURCE SECTOR

by

Anthony Chisholm

A collection of papers submitted for the Degree of
Doctor of Philosophy of the Australian National University
by submission of published work

September 1975
In compliance with the requirements relating to Examination for the Degree of Doctor of Philosophy of the Australian National University, I affirm that, with the exception of the joint research work reported in Chapter Seven, the work which follows is entirely my own.

We affirm that the papers on pollution and resource allocation reported in Chapter Seven are genuinely joint research work.

[Signatures]
I have been fortunate to have done most of my research in the stimulating academic environment of the Australian National University. During 1974 I was on sabbatical leave at the University of California at Davis, for the first half of the year, and at Berkeley for the second half of the year. This period of leave freed me from teaching duties and provided a welcome opportunity to complete work on two of my research papers and initiate work on another.

The nature of my research has been such that for the most part it was done independently and did not entail close supervision. I would like to express my thanks, however, to Professor Russell Mathews for formally acting as a supervisor throughout the entire period of research and also to Professor Clem Tisdell, who was a joint supervisor over the early period of research until taking up his current position at the University of Newcastle.

During the course of my research I have benefitted from discussions with many individuals. Those individuals who helped with discussions and comments on preliminary drafts of particular papers are acknowledged separately in each paper. I appreciated working with Geoffrey Brennan and Cliff Walsh on the joint research project on pollution and resource allocation and also thank them for many constructive tearoom discussions.

I am grateful to the typists who have competently and patiently typed successive drafts of my papers, and especially wish to thank Isobel Everitt who was responsible for most of the typing.
Finally, I acknowledge my greatest debt to my wife, Kristen, who has not only given me continuous encouragement throughout a long period of research, but who also has helped with the proof reading of my papers. My wife and children stoically bore the negative externalities which authorship of a project of this nature inevitably imposes on one's family.
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Appendix 7.1 The Parameter Subject to Tax (unpublished)
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CHAPTER 1

INTRODUCTION

The research reported here is mainly comprised of a collection of papers published over the period 1971-79. There is an inevitable temptation to include in a discussion of this book a few relevant but more accessible to the published studies, particularly those written during a period of several years has elapsed since the date of publication of a paper. However, with only two exceptions which are discussed below, I have chosen not to modify or edit the papers which have been published or are in the course of publication.

Overall, the papers cover a wider range of subject material than would be found in a traditional thesis composed primarily of manuscript work. This is consistent with my interpretation of the spirit of the new rules of the Australian National University for the Degree of Doctor of Philosophy by admission or published work. These rules state in part:

"... on the grounds of a substantial contribution by learning of the highest eminence University standards, revealing a capacity to relate his work to the broader framework of the discipline within which it falls and related disciplines contained in published work of which he is the author or joint author."
INTRODUCTION

"Whoever hopes a faultless tax to see,
Hopes what ne'er was, or is, or e'er shall be".


The research reported here is mainly composed of a collection of papers published over the period 1971-75. There is an inevitable temptation in a submission of this type to supplement and make additions to the published studies, particularly in those instances where a period of several years has elapsed since the date of publication of a paper. However, with only two exceptions which are discussed below, I have chosen not to modify or add to the papers which have been published or are in the course of publication.

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"...on the ground of a substantial contribution to learning at the highest contemporary University standards, revealing a capacity to relate his work to the broader framework of the discipline within which it falls and related disciplines contained in published work of which he is the author or joint author".
The central unifying theme running through the set of papers is their concern with public economics, especially as it relates to agriculture and the natural resource sector and, in particular, their concern with various aspects of taxation. Taxation is a subject which for a number of reasons assumes a place of special importance for agriculture and the natural resource sector. In the first place, in Australia and also in some other countries, the agricultural and forestry sectors have been major recipients of various forms of income tax-concessions. And it seems likely that these income tax-concessions have significantly influenced production and investment decisions within these sectors.

In the second place, there are some difficult conceptual problems relating to how taxable income should be defined for economic activities that involve long-lived assets - such as developing and improving farm land, growing fruit trees and vineyards, and timber-growing - so that the tax will not distort optimization decisions.

In the third place, there has been increasing concern in recent years with the consequences of various forms of market failure in the natural resource area, and especially with the problem of pollution. A central problem has been how to evaluate the relative merits of alternative methods of pollution control, particularly the use of tax measures versus the use of direct regulations and other legal instruments. The conceptual issues raised within the context of the pollution problem, and the feasible forms of government intervention, appear to apply quite generally to a wide array of environmental problems, including, for example, the choice of 'optimal' policies for the preservation and utilization of wildlife species.
There are ten papers, including several shorter notes, in the submission. These are classified into six chapters, each chapter comprising either a single paper or one major paper together with one or more supplementary papers as appendices. Whilst each of the major papers is a self contained study, it is helpful to classify the papers into three subgroups. The focus of the three main papers in the first subgroup is on intertemporal aspects of income taxation and investment decisions. In the author's view, this is the most difficult and intellectually challenging area of research pertaining to the study of the economic effects of income taxes. It is an area of study which has been the subject of a large number of papers in the economic literature. Many of the conclusions reached in these studies are difficult to reconcile and some, at least on the surface, appear to be quite contradictory.

The first paper in the subgroup, which forms Chapter Two, is the main unpublished paper and was presented at the Australian Fifth Conference of Economists, in August 1975. It combines some of my earliest thinking on the subject of income taxes and investment behaviour with my most recent thinking, and forms a natural background chapter for the papers which follow. The paper is a theoretical one which examines the fundamental question of how income and in particular, tax-deductible depreciation, should be defined so that an income tax will not distort investment decisions. Following a detailed analysis of the concepts of immediate expensing (instantaneous depreciation) and true economic depreciation, the paper analyses the economic effects of a progressive income tax which, through various forms of tax-concessions, favours some investment activities relative to others.
Chapter Three comprises a paper in which a model is developed to analyse the effects of income tax policy on the optimal timing of replacement for farm machinery. The model is then applied to examine the effects of changes in the Australian income tax legislation made in 1973, relating to tax depreciation allowances and investment allowances for farm machinery. The effects of the United States income tax legislation on optimal replacement were also examined, albeit more briefly, and compared with the effects of the Australian income tax legislation.

Chapter Four consists of two papers and forms a natural extension to the research contained in Chapters Two and Three. A supplementary paper is given as an appendix, though its subject matter logically precedes that of the main paper and it should be read first. This paper analyses the problem of choosing an appropriate criterion for determining the optimal replacement pattern for long-lived appreciating assets, such as a growing forest, in the absence of tax effects. An earlier version of the main paper was presented at the annual meeting of the American Agricultural Economics Association, in August 1974, and the revised paper is scheduled to be published in the December 1975 issue of the journal Economic Inquiry.

The paper develops a tax incidence model to analyse the economic effects of alternative methods of taxing income derived from products with long-lived production processes, of which timber-growing is the classic example. Compared with a 'neutral' income tax, it is concluded that two other types of income taxes, which approximate those currently applying to the forestry sectors of Australia and the United States, bias production towards longer rotation cycles, increase land (site) values, and depress timber prices.
The main concern of the two papers which form the second subgroup is with problems which arise from, or can be related to, the nature of the progressive income tax rate scale. The focus of the first paper, which comprises Chapter Five, is on equity and efficiency questions, arising from the interaction of an annual tax accounting period and a fixed progressive rate scale when taxpayers have a fluctuating annual income. A comparison is made between a number of possible income averaging procedures on the basis of selected performance criteria. Several of the income averaging procedures considered are judged to have superior attributes to the current Australian income averaging procedure applying to primary producers.

In Chapter Six, the second paper in the subgroup examines the possibility of using the income tax system as a vehicle for making transfer (welfare) payments to low-income farm families as part of a rural reconstruction programme. That is to say, it is proposed that the progressive income tax rate scale would, below some specified level of income, become negative. At the time the negative income tax paper was written the rural sector in Australia, by contrast with the rest of the economy, was experiencing an extremely severe recession. And while a negative income tax was considered for low-income farm families only, the author strongly favours as a 'first-best' solution, the use of a comprehensive negative income tax, which would apply uniformly to all low-income families and which would be designed to replace the existing largely piecemeal system of welfare payments.

The papers contained in Chapter Seven comprise the final subgroup. The chapter is composed of one major paper together with three supplementary papers as appendices. Chapter Seven stands somewhat apart from the preceding chapters, in that the papers do not have some aspect of income taxation as their central focus. Rather, the Chapter is concerned with
problems attributable to various forms of market failure in the natural resource sector, and in particular with the problem of pollution. However, various types of tax instruments provide a major means of correcting for market failure and for controlling pollution. The main paper, after considering the relative merits of market and political decision-making processes in attaining socially optimal levels of pollution, focuses on the alternative policy options for pollution control. The major conclusion which emerges is that in general, tax (fiscal) instruments provide a more efficient means of controlling pollution than the widespread use of regulations or other legal instruments.

The paper on pollution and resource allocation was written jointly with Cliff Walsh and Geoffrey Brennan. The paper evolved mainly from a more wide ranging paper which Cliff Walsh and I presented at the 17th Australian Agricultural Economics Society Annual Conference, in February 1973, and also in part, from a somewhat more theoretically orientated paper which Geoffrey Brennan, Cliff Walsh and I presented at the 45th ANZAAS Congress, in August 1973. A copy of the former paper is enclosed at the back of the submission. Altogether the research on this topic extended over a period of approximately fifteen months and the three authors all contributed fully to the many discussions and to the preparation of various draft papers. Although Geoffrey Brennan was not a joint author of the first paper presented at the Australian Agricultural Economics Society Annual Conference, he helped with fruitful discussions and bore the main burden of preparing the paper presented at the 45th ANZAAS Congress. The published paper on pollution and resource allocation in all its aspects thus represents a genuinely joint research effort and the three authors equally share responsibility for the ideas and views expressed in the paper.
Appendix 7.1 contains a short unpublished note which complements the main paper by examining the major alternative parameters to which taxes (or regulations) aimed at controlling pollution may be applied. Appendix 7.2 is a reply to a comment by R.A. Richardson on our paper on pollution and resource allocation. A copy of Richardson's comment is enclosed with the submission. Richardson's comment, together with our reply, is to be published in the August 1975 issue of the *Australian Journal of Agricultural Economics*.

The final appendix comprises a paper reprinted from the Proceedings of the Third Workshop of the United States/Australia Rangelands Panel, Tucson, Arizona, in March-April 1973. The paper contains a section which considers the use of tax instruments, and related regulations, to correct for various forms of market failure associated with the preservation and utilization of wildlife, with particular reference to the kangaroo. The paper illustrates that the basic methodology and alternative policy options which apply to the pollution problem also have application to other environmental problems. For the purposes of this submission the relevant part of the paper is confined to the discussion on the preservation and utilization of wildlife. But to enable this discussion to be placed within the context of the paper as a whole, a copy of the complete paper is given in Appendix 7.3.

Finally, it should be observed that several major Australian taxation studies were published in 1975, subsequent to the completion of the major part of the research reported in this submission. No attempt is made here to relate some of the work in these studies to my own research. But it is of interest to note that some of the research in two of these studies, namely, The Industries Assistance Commission Report: Rural Income Fluctuations - Certain Taxation Measures, and the Report of the
Commission of Inquiry into Poverty (Henderson Report), is closely related to my research on alternative income averaging schemes and a negative income tax, respectively.
CHAPTER 2

PROGRESSIVE INCOME TAXES, TAX-FAVOURED INVESTMENTS, AND INVESTMENT BEHAVIOUR

Anthony S. Chisholm

There is one extensive body of economic literature which discusses questions relating to income taxation and investment decisions. A central problem, and one which is a major theme of this paper, is how neither, and the particular tax-favoured depreciation, should be defined so that a tax on income will not distort investment decisions. Among those who have contributed to the discussion on this matter are Gregor (1949), Gregson (1959), Smith (1960), Hall (1967), Hall and Jameson (1967), Hall and Jenson (1967), Ely (1971), Smidt (1972), and Cohn (1973). A useful point of departure is provided by the quotations given below:

...Furthermore, there appears to exist no administratively feasible way to specify neutral write-off rules except to define taxable income as gross income minus all cash outlays including investment. This process is permissible because to specify fully capital capitalized for the purposes and represents the maximum size of accelerated depreciation...

Fundamental theorem of tax law literature: "If, and only if, true line of economic value is permitted as a tax deductible expense will the present discounted value of a cash-inflow stream be independent of the rate of tax." (Kaminen, 1974, p. 604.)

In this writer's view, most of the apparent conflict and confusion surrounding the issue of capital expenditure (or instantaneous depreciation) versus true economic depreciation may be attributed to the fact that the formal proofs - if properly interpreted - which support the "neutrality" thesis...

* I wish to thank Ted Sayer and Peter Swan for helpful discussions and for comments on an earlier version of this paper. Views are, of course, entirely my responsibility. This paper is a slightly modified version of the paper presented at the Australian Fifth Conference of Economists, August 1978.
 Progressive Income Taxes, Tax-Favoured Investments, And Investment Behaviour

Anthony H. Chisholm*

There is now an extensive body of economic literature which focuses on questions relating to income taxation and investment decisions. A central problem, and one which is a major focus of this paper, is how income, and in particular tax-deductible depreciation, should be defined so that a tax on income will not distort investment decisions. Among those who have contributed to the discussion on this topic are: Brown (1948), Musgrave (1959), Smith (1963), Samuelson (1964), Wright (1964), Gaffney (1967), Hall and Jorgenson (1967), Johansson (1969), Thomson and Goldstein (1971), Sodersten (1972), and Coen (1975). A useful point of departure is provided by the quotations given below:

...Furthermore, there appears to exist no administratively feasible way to specify neutral write-off rules except to define taxable income as gross income minus all cash outlays including investment. This amounts to permitting businesses to expense fully capital expenditures for tax purposes and represents the maximum rate of accelerated depreciation. (Smith, 1963, p.90.)

Fundamental theorem of tax rate invariance: If, and only if, true loss of economic value is permitted as a tax-deductible expense will the present discounted value of a cash-receipt stream be independent of the rate of tax. (Samuelson, 1964, p.604.)

In this writer's view, most of the apparent conflict and confusion surrounding the issue of immediate expensing (or instantaneous depreciation) versus true economic depreciation may be attributed to the fact that the formal proofs - if properly interpreted - which support the 'neutrality' claims

* I wish to thank Ted Sieper and Peter Swan for helpful discussions and for comments on an earlier version of this paper. Errors are, of course, entirely my responsibility. This paper is a slightly modified version of the paper presented at the Australian Fifth Conference of Economists, August 1975.
for both types of tax depreciation are basically correct, but different assumptions underlie each.

The plan of the paper is to outline firstly, the case for immediate expensing and secondly, the case for true economic depreciation. It will be shown that a general 'income' tax which permits immediate expensing of all investment outlays is effectively a tax on pure profits. On the other hand, a general income tax that permits the write-off of true economic depreciation, taxes both 'normal' interest earned on investments plus any pure profits. That is to say, it is a genuine income tax and not a pure profits tax. In the next section of the paper a progressive personal income tax which approximates the 'Samuelson' type of income tax is assumed to exist. But it is assumed that some favoured investment activities (sectors) receive some form of tax-privilege, and the economic effects of a progressive income tax that is not uniformly applied are then examined.

I. IMMEDIATE EXPENSING

The analysis employs discrete rather than continuous time period models, since the author believes the results can be shown more simply and clearly using discrete models. The most important assumption underlying the analysis which follows is that of a perfect capital market enabling any individual (firm) to freely borrow and lend at a constant market rate of interest. The before-tax net present value, $P$, of an investment outlay that provides a flow of annual net receipts, $N_k$, over a time span of $n$ years is defined as,

$$ P = \sum_{k=1}^{n} N_k (1+i)^{-k} - C, $$

where $C = \text{the price of the capital good, and}$

---

1 The first two sections of the paper are not intended to be a review of the literature, nor is the primary aim to break new ground. Rather, using a simple analytical framework an attempt is made to interpret and clarify some issues relating to immediate expensing and true economic depreciation which appear to have generated a fair amount of confusion.
\( i = \) the market rate of interest.\(^2\)

Assume now that an income tax is imposed at a uniform rate, \( T \), and that initially there is a zero tax allowance for depreciation. The after-tax net present value, \( P^* \), is defined by relation (2).

\[
P^* = \left( \sum_{k=1}^{n} N_k (1+i)^{-k} \right) (1-T) - C.
\]

The above relation is expanded to incorporate a positive annual tax-deductible depreciation allowance, \( D_k \), in equation (3).

\[
P^* = \left( \sum_{k=1}^{n} N_k (1+i)^{-k} \right) (1-T) + T \left( \sum_{k=0}^{n} D_k (1+i)^{-k} \right) - C.
\]

It is helpful at this point to define a parameter, \( K \), where \( K \) defines the ratio of the value of the cumulative discounted depreciation allowance to the price of the capital good.

\[
K = \sum_{k=0}^{n} \frac{D_k (1+i)^{-k}}{C}.
\]

Using equation (1) we can now rewrite equation (2) in the following form:

\[
P^* = P(1-T) - TC.
\]

Now from equations (4) and (5), relation (3) may be rewritten as,

\[
P^* = P(1-T) - TC + TCK,
\]

which simplifies to

\[
P^* = P(1-T) - TC(1-K).
\]

\(^2\) It is assumed throughout the paper that the before-tax annual cash-receipts flows \( N_k \) are all non-negative. This ensures that all investments have a unique \( K \) internal rate of return.
The parameter \((1-K)\) provides a measure of the rate at which depreciation can be written off for tax purposes. If no depreciation write-off is permitted, the value of \(K\) equals zero and equation (7) simply collapses to equation (5). At the opposite extreme, when \(K\) has a value equal to unity, the discounted present value of the depreciation allowance equals the acquisition price of the capital good. One method of depreciation, for which the value of \(K\) is equal to unity, is 'immediate expensing', that is, a tax depreciation policy which permits the full price of a new capital good to be deducted from taxable income at the time of its acquisition. Immediate expensing thus represents the most extreme form of accelerated depreciation.

Under a general tax that permits immediate expensing of all capital outlays, only pure profits will be taxed. This important point is most easily explained by noting that with immediate expensing equation (7) reduces to

\[
P^* = P(1-T)
\]

Now for a truly marginal investment, pure profits and the net present value, \(P\), will be zero. Also, the net present value of tax payments associated with the investment will be zero, since the value of the tax savings made at the time the investment outlay is expensed equals the present value of the sum of annual tax payments associated with the cash-receipt flow, \(N_k\). Hence, investments that were marginal before tax will continue to be marginal after the imposition of a general tax that permits immediate expensing. However, for all investments that earn pure profits, and thus have a positive net present value, tax will be paid in proportion to the pure profits earned, and the after-tax net present value of these investments will equal \(P(1-T)\). A

---

3 It is assumed here that the investment outlay is made precisely at the end of a tax year and the tax-deductibility is therefore immediate. In addition, it is assumed that a system of 'full loss offset' applies if taxable income is negative in any period.

4 This is true regardless of whether the investment is financed from equity or debt capital, providing that interest payments on investment financed by borrowing are not tax-deductible. The implications of permitting immediate expensing plus tax-deductibility of interest expenses on debt capital are considered in the third section of the paper.
general tax which permits immediate expensing of all investment outlays is thus perfectly neutral on the criterion that the before-tax net present values of all investments are reduced in exact proportion to the tax rate.

The treatment of capital goods already in use when a general tax is imposed, that permits immediate expensing of all new investment, needs to be briefly considered. If no depreciation allowance is permitted for capital goods already in use at the time the tax is introduced, a capital levy at rate $T$ will be imposed on existing capital goods. That is to say, if the value of a capital good immediately prior to the imposition of the tax is $V_k$, its value immediately after the introduction of the tax will be $V_k(1-T)$. If for distributional reasons, this capital levy was considered to be undesirable, immediate expensing of the value of the capital stock in existence at the time of introducing the tax could be permitted. But it would seem highly unlikely that full loss offset could be successfully administered in these circumstances.

Finally, it is important to recognize that there are an infinite number of feasible methods of tax depreciation with the property that the value of $K$ is equal to unity, and which are thus equivalent to immediate expensing. For all these alternative methods, however, the sum of the undiscounted 'depreciation' allowances will exceed the value of the investment outlay. The most obvious alternative is to allow full tax deductibility of the cash-receipt stream $N_k$ for all marginal investments. It is shown in the following section that, for a marginal investment, $N_k$ equals the implicit rental price of capital services. For investments which have a positive net present value $P$, (i.e. inframarginal investments) only that part of $N_k$ which represents the normal market rate of return on investment would be tax-deductible.

5 Unless stated otherwise, it is assumed throughout the paper that when a tax is imposed - or a tax change is announced - it is expected to be permanent.
The major conclusion to emerge from the foregoing discussion is that a perfectly general 'income' tax that permits immediate expensing of investment outlays, is in fact a tax on pure profits, and as such it is a neutral tax. The opportunity cost of capital, that is, the market rate of interest in a perfect capital market, is effectively excluded from the tax base. But it is clearly intended, primarily on equity grounds, that the personal income tax base should include interest income earned on equity capital. Given this decision, it is of course impossible to specify a personal income tax base which does not distort individuals' saving-consuming choices. In other words, there is a bias against aggregate savings and associated capital formation which is inherent in taxing income, as compared with a consumption or a wealth tax, since the income tax lowers the effective interest rate on which rational individuals base their saving-consuming decisions.

In these circumstances, the important problem which remains to be answered - and the one which forms the central focus of Samuelson's (1964) paper - is how must income be defined if the present discounted valuations of all assets (cash-receipt streams), and therefore all optimal investment decisions, - is to be independent of the tax rate each individual is subject to? It is to this issue we now turn.

II. TRUE ECONOMIC DEPRECIATION

In a discrete time period model, true economic depreciation is defined as the difference between the present value of the net receipt stream.

6 There is a large public economics literature which focuses on the question of the appropriate base for the personal income tax. See, for example, Haig (1921), Simons (1938), Vickrey (1947), and Musgrave (1967).

7 It is also well known, of course, that the income tax distorts the work-leisure choice.

8 No attempt is made in this paper to analyse, within a macroeconomic framework, the effects that the imposition of a general income tax - and the associated government expenditure that it finances - may have on an economy's time path of aggregate private capital formation and the market rate of interest. The market rate of interest is tacitly assumed to remain unchanged.
generated by an investment outlay as at the beginning and end of an annual period. It can be shown that economic depreciation, in any annual period, is equal to annual net receipts minus interest on the value of the capital good as at the beginning of the year.

Denoting the present value of the expected future earnings stream at the beginning of the kth year as $V_k$, we have

\begin{equation}
V_k = N_k (1+i)^{-1} + N_{k+1} (1+i)^{-2} + \ldots + N_n (1+i)^{-(n-k+1)},
\end{equation}

and

\begin{equation}
V_{k+1} = N_{k+1} (1+i)^{-1} + N_{k+2} (1+i)^{-2} + \ldots + N_n (1+i)^{-(n-k)}
= V_k (1+i) - N_k.
\end{equation}

Economic depreciation is therefore defined as

\[ V_k - V_{k+1} = V_k - (V_k (1+i) - N_k) = N_k - i V_k. \]

Rearranging terms we obtain

\begin{equation}
N_k = V_k - V_{k+1} + i V_k,
\end{equation}

where $N_k$ now can be interpreted as the implicit rental price of capital services, that is, the sum of economic depreciation plus the market rate of interest on the value of the capital good at the beginning of the period. It is this rental value of capital services that is effectively excluded from the tax base when immediate expensing of investment outlays is permitted. It follows that, for an investment which is wholly financed by borrowing, an individual (firm) would be indifferent between an income tax of the Samuelson
type which allows tax-deductibility of true economic depreciation plus explicit interest payments, and a tax which permits immediate expensing but no tax-deductibility of interest payments. Consider now a perfectly general income tax which permits true economic depreciation as a tax-deductible expense. For a fully equity financed investment, taxable income, \( Y \), is defined as

\[
Y = N_k - (V_k - V_{k+1})
\]

\[= i V_k.
\]

Annual tax payments of \( TiV_k \) will be made and after-tax income, \( Y^* \), net of depreciation, will be:

\[
Y^* = (1-T) \left[ N_k - (V_k - V_{k+1}) \right]
\]

\[= i (1-T) V_k.
\]

From equation (14), it is apparent that when true economic depreciation is permitted as a tax-deductible expense, the present discounted value of a cash-receipt stream will be independent of the rate of tax each individual is subject to if, and only if, a private net-of-tax discount rate equal to \( i(1-T) \) is used to evaluate investments. Under a perfectly general income tax that permits the write-off of economic depreciation, the amount of the gross-of-tax rate of return siphoned off to the government as taxation, is exactly proportional to each individual's tax rate. And the

9 Equation (14) corresponds to Samuelson's \textit{op.cit.} equation (4). There is an apparent error in Samuelson's equation (4). Note first that Samuelson's \( T \) equals our \( (1-T) \). Then his equation (4) for after-tax income should read:

\[
Ti_t V_t = N_t - (V_t - V_{t+1}) - (1-T) [N_t - (V_t - V_{t+1})].
\]

10 Throughout the discussion on the progressive personal income tax it is assumed that a proper income averaging system ensures that the tax rate is uniform over time for each individual.
opportunity cost of capital to each individual - and hence the relevant private rate of discount - is therefore given by the net-of-tax rate of return \( i(1-T) \), since an individual has no opportunities to invest free of its burden. The structure of optimal investment decision rules is thus unaltered by the tax, since the present discounted valuations of all cash-receipt streams are independent of the tax rate to which each person is subject.\(^{11}\)

It is beyond the scope of this paper to discuss either problems associated with the administration of an income tax which allows the write-off of true economic depreciation, or problems raised by inflation.\(^{12}\) Some of these problems have recently been examined by Coen (1975), in a study which explores a new approach to the estimation of true economic depreciation.

It may be simply observed here that the time pattern of economic depreciation is a function of the time path of the flow of annual cash-receipts generated by an investment outlay. For instance, for a capital good yielding a constant annuity over its life span and having zero scrap value, true economic depreciation would begin at a relatively low annual rate and rise exponentially. The straight-line depreciation formula would be too rapid and would favour investment in long-lived capital goods. However, straight-line depreciation provides a reasonable approximation to true economic depreciation when the annual cash-receipts flow begins at a high level and becomes pro-

\(^{11}\) This applies to investment financed from both debt and equity capital. In the former case, with tax-deductibility of interest payments, net tax payments at the margin are zero, i.e. \( Y = N_k - (V_k - V_{k+1}) - i V_k = 0 \). Investment will thus proceed to the point at which the gross-of-tax rate of return is equated with the market rate of interest, regardless of whether investment is debt or equity financed.

\(^{12}\) The influence of inflation can be quite readily incorporated if the simplifying assumption is made that a uniform constant rate of inflation over the indefinite future is perfectly anticipated and the nominal rate of interest fully reflects the rate of inflation. In these circumstances, if the income tax is assessed on the basis of nominal income, the real net-of-tax rate of return will be uniformly lower on all investments than it would be in the absence of inflation, or if the tax were assessed on real income. Denoting the rate of inflation as, \( g \), and the nominal rate of interest as, \( i \), the real net-of-tax rate of return equals \( [i(1-T) - g] \). To convert the tax base from nominal to real income it would be necessary to allow an additional deduction in each period for the capital appreciation in the value of a capital good resulting from inflation.
gressively smaller over an asset's life. This type of time pattern of the
annual cash-receipts stream is probably quite common in practice, since a
progressively increasing annual repairs and maintenance outlay is typically
required to maintain an asset's output.

Generally speaking, existing income taxes which permit the write-off
of depreciation over the estimated economic (standard) life of a capital good,
via such formula as the straight-line method, provide a rough approximation
to the Samuelson income tax. Interest income on equity capital is effectively
included in the progressive personal income tax base. But the income tax is
not uniformly applied over all investment activities. The economic effects
of a progressive income tax which is not uniformly applied, that is, which
favours some investment activities relative to others, are examined in the
following section of the paper.

III. TAX-FAVoured INVESTMENTS AND
A PROGRESSIVE INCOME TAX

An appropriate starting point is to assume initially a 'neutral-tax'
world in which a perfectly general income tax of the Samuelson type exists.13
Competitive resource allocation and the absence of uncertainty ensure that,
in equilibrium, the gross-of-tax rates of return on all investment activities
will be equal at the margin to the market rate of interest.14 The private
net-of-tax rates of return on equity capital will vary between individuals
according to their marginal rate brackets, that is, for any individual taxpayer
\[ r = i(1-T) \].

The economic effects of introducing some form of tax-concession to
apply to a particular investment activity are now considered. The tax-

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13 The approach taken in this section of the paper has been considerably
influenced by the recent publication of a paper by Bailey (1974), and the
conclusions are broadly speaking similar to those reached by Bailey.

14 That is to say, all investments having a positive net present value will
be undertaken. For purposes of description and simplicity, the internal
rate of return, or yield concept, is used rather than the present value
concept, even though the former concept has some well known theoretical
limitations.
concession may take the form of permitting the tax write-off of depreciation at a rate which exceeds the rate of true economic depreciation whilst maintaining tax-deductibility of interest payments on debt capital; introducing an investment incentive - such as an investment allowance or tax credit - which is separate from and additional to the depreciation allowance; or making income from the tax-favoured source partially or wholly tax-exempt.

In Australia and the United States various forms of tax-concessions apply, for example, to investments associated with developing and improving land for farming, breeding livestock, growing fruit and nut trees, and timber-growing. The tax-concessions are also variously referred to as 'tax-privileges', 'tax-shelters', and 'tax-favoured' investments. They commonly take the form of permitting immediate expensing of investment outlays, or, at least, allowing a rate of depreciation write-off that substantially exceeds the rate of true economic depreciation, while continuing to allow tax-deductibility of interest payments on debt capital. For instance, many types of investment in developing and improving farm land effectively create, or substantially increase the productivity of, an asset that for all practical purposes is infinitely durable. With non-favoured tax treatment no tax-deductibility of these investment outlays would be permitted, since the rate of true economic depreciation is effectively zero. If the land was being developed for purposes of resale, rather than to be farmed by the developer, then with 'neutral' tax treatment the capital costs of land development would

15 The focus here is on the economic effects of tax-privileges as they apply to non-corporate investment, the income from which is subject only to the progressive personal income tax. It is pertinent to note, however, that Stiglitz (1973) has recently challenged the position taken by Harberger (1962) and many others, e.g. Bailey (1969; 1974); namely that the imposition of the corporate tax creates a distortion inducing a flow of capital from the corporate to the non-corporate sector. Stiglitz argues that in the absence of uncertainty all corporate investment will be financed at the margin from debt capital, and that existing interest deductibility provisions plus depreciation allowances are approximately equivalent to permitting immediate write-off of investments with no interest deductibility. In these circumstances, in the absence of any tax-privileges to either sector, corporate firms will, like non-corporate firms, invest up to the point where the pre-tax marginal rate of return on investment is equated with the market rate of interest.
be capitalized and deducted for tax purposes only at the time of sale of the improved land. Of course, if the capital gains made on the sale of the improved land are not taxed, there should be no tax-deductibility of development expenditures.

In addition to tax-privileges in the form of accelerated depreciation (including immediate expensing), some sources of income receive favoured capital gains treatment, or are otherwise taxed at an effectively lower rate because the tax is assessed on an income realization basis rather than an income accrual basis. A good example is timber-growing in Australia, where planting costs can be immediately expensed but income is not taxed until realized at harvestime.16

For expository purposes, it is now assumed that a tax-concession is introduced to a small area of investment activity, whilst a neutral income tax continues to apply elsewhere. The tax-concession takes the form of permitting immediate expensing of investment in the favoured sector plus tax-deductibility of interest payments on debt capital. For simplicity, consider an investment in land development and improvement which results in a permanent increase in the productivity of a block of farm land. In other words, the rate of true economic depreciation of the asset 'created' by the investment is zero, and the annual net receipt stream, $N_k$, is composed solely of the interest return on capital. In addition, it is conceptually convenient to initially consider a situation before any tax-induced changes in factor or product prices have occurred. Now for an investment which is fully financed from equity capital, the immediate expensing privilege gives rise to a tax refund which reduces the effective cost of the investment in proportion to the rate of tax. The annual net receipt stream will also be reduced in proportion to the rate of tax. Hence, the private net-of-tax rate of return on

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16 For a detailed discussion of the economic effects of alternative forms of income tax on timber-growing see Chisholm (1975).
the investment will precisely equal the gross-of-tax rate of return, and the effective rate of tax on the investment is in this sense zero.

Now for an investment financed fully from debt capital, the immediate expensing plus tax-deductibility of debt interest payment privileges will, as before, via the tax refund, reduce the 'effective cost' of the investment in proportion to the rate of tax. But as a result of the tax-deductibility of interest payments, there is now effectively no tax levied on the annual net receipt stream. The net-of-tax rate of return (gross of debt interest payments) on the favoured investment will thus exceed the gross-of-tax rate of return.

At this point two observations can be made. Firstly, regardless of whether the tax-favoured investment is financed from equity or debt capital, the value of the tax-privilege is greater for high-bracket taxpayers than for low-bracket taxpayers. In the former situation, high-bracket taxpayers receive lower net-of-tax rates of return on ordinarily taxed investments than do low-bracket taxpayers. And high-bracket taxpayers therefore obtain the largest benefits from investments which can be immediately expensed when the gross and net-of-tax rates of return are equated. In the latter situation, high-bracket taxpayers receive larger tax refunds when the investment is made than low-bracket taxpayers, whilst the effective tax levied on the net receipt stream is zero, regardless of the individual's tax-bracket.

Secondly, we have so far analysed the effects of introducing the tax-concession in the absence of any tax-induced changes in factor and product prices. Following the introduction of the tax-concession, the higher net-of-tax rate of return will attract capital from high-bracket investors into the tax-favoured activity. Investment will continue to take place under the 'tax-shelter', and factor and product prices will adjust, until in competitive equilibrium, the gross-of-tax rate of return for high-bracket investors equals the net-of-tax rate of return obtainable on ordinarily taxed investments.
In general, denoting the tax rate for high-bracket taxpayers as $T'$, competition between investors in this group will lower the gross-of-tax rate of return on the tax-favoured investment activity to $(1-T')$ times the gross-of-tax rate of return on ordinarily taxed investments. At this point, the net-of-tax rates of return on the tax-favoured investment activity and on ordinarily taxed investments will be equated for high-bracket taxpayers. For instance, if we take the polar case of $T'=1$, the competitive equilibrium gross-of-tax rate of return on the tax-favoured investment will be zero. In any time period, the cash-receipt flow will just cover true economic depreciation of the capital good. For the opposite polar case of $T'=0$, the equilibrium gross-of-tax rate of return on the tax-favoured investment will equal that obtaining on ordinarily taxed investments. Since $T'$ is zero, there is no tax-induced shifting of capital. And in equilibrium, the cash-receipt flow in any period will cover true economic depreciation plus the market rate of interest on the current value of the capital good.

As an illustrative example, consider the case where there are a large number of investors in the maximum tax-bracket of say 0.7. The market rate of interest - and the gross-of-tax rate of return at the margin on ordinarily taxed investments - is 10 percent. In this situation, competition between investors in the high-bracket group will lower the gross-of-tax rate of return on the tax-favoured investment to an equilibrium level of three percent. The net-of-tax rates of return at the margin, on the tax-favoured and non-favoured investments will be equated for high-bracket investors, regardless of whether they finance investment from debt or equity capital. Investment in the tax-favoured activity will be unprofitable for individuals in tax brackets below 0.7, since they can obtain a higher net-of-tax rate of return by investing in ordinarily taxed areas of investment, where the gross-of-tax rate of return is substantially higher. The tax-favoured investment activity will therefore come to be completely dominated by investors in the high-bracket group.
The lowering of the gross-of-tax rate of return on the tax-favoured investment activity will be caused by the tax-induced inflow of investment capital into that sector and an associated 'bidding-up' of factor prices and reduction of product price(s) as output expands. The extent to which the incidence of the tax-privilege is reflected in higher factor prices, versus a lower product price(s), is crucially dependent upon the relative magnitudes of the price elasticities of supply of factors and the price elasticity of demand of the product(s).

Immediate expensing, combined with tax-deductibility of debt interest payments, represents the most extreme form of accelerated depreciation and in so far as this is the only tax-privilege, the lower bound of the equilibrium gross-of-tax rate of return is zero. And in practice, this lower bound would not be attained, since the maximum rate bracket under a progressive income tax is always less than unity. However, immediate expensing may be combined with other forms of tax-concessions such as investment allowances and partial (or full) tax-exemption of income from the favoured source. In these circumstances, it is quite conceivable for the composite value of tax-concessions applying to the favoured investment activity to be so great that competition between high-bracket investors will cause the equilibrium gross-of-tax rate of return to be negative. A negative gross-of-tax rate of return occurs when the undiscounted value of the total cash-receipt stream \( \sum_{k=1}^{n} N_k \) is less than the cost of the investment outlay. The associated positive private net-of-tax rate of return for high-bracket taxpayers is attributable to the composite present value of tax-deductible allowances plus exemptions significantly exceeding the initial cost of the investment outlay.

Existing progressive income taxes, in countries like Australia and the United States, very roughly approximate the Samuelson model. But they are not uniformly applied to all sources of capital income and tax-privileges of varying magnitudes apply to favoured investment activities. In these circumstances, it is to be expected that competition between high-bracket taxpayers
for tax-sheltered investments will, in the long-run, reduce gross-of-tax rates of return on the most highly favoured activities to an equilibrium level at which they are unprofitable areas of investment for all individuals except those in the highest tax brackets.

The lower tax payments associated with tax-favoured investments do not, therefore, provide a true measure of tax incidence. The lower tax payments are offset, in equilibrium, by lower gross-of-tax rates of return which high-bracket taxpayers sacrifice when investing in tax-sheltered investments, in order to maximize their net-of-tax incomes. The tax-induced shifting of capital and resources into sheltered investments and the resultant lowering of pre-tax rates of return - via adjustment of factor and product prices - to an equilibrium level at which net-of-tax rates of return on favoured and non-favoured investments are equalised for high-bracket taxpayers, are all part of the real incidence of tax-privileges.

Harberger (1962), Baumol (1970), and others, argue that the gross-of-tax rate of return on an investment may be used as a measure of society's evaluation of the investment. If this measure is accepted, then it can be argued that tax-induced divergences in the levels of gross-of-tax rates of return between different investment activities are a direct manifestation of an inefficient allocation of resources. Since overall returns to society could be increased by transferring capital from activities yielding low pre-tax rates of return to those yielding high pre-tax rates of return.

Underlying the above line of argument, among other things, is the tacit assumption that a discriminatory income tax policy is not being used to correct for non-tax market distortions. A detailed discussion of this topic and the related theory of the second best is outside the scope of this paper.¹⁷

¹⁷ So also, is a discussion on government policies which seek to stimulate the general level of capital expenditures throughout the economy. If tax policy is used to achieve this goal, instruments should be selected which do not alter the structure of the effective relative costs of capital goods with varying economic lives, and which do not discriminate between low-bracket and high-bracket firms.
However, most appraisals of the income tax legislation generally dismiss the argument that the concessions and exemptions contained in existing legislation are explicitly designed to correct for specific non-tax market distortions. With regard to the United States income tax legislation Simons (1938, p.219) and Bailey (1974, p.1158) both argue, and in this writer's view persuasively, that the special concessions and exemptions contained in the legislation are essentially the product of covert political bargains and compromises between special interest groups, and that they have induced a gross misallocation of resources. It seems reasonable to presume that, at least in part, a similar explanation accounts for the extremely complex and piecemeal Australian income tax legislation. Be that as it may, when genuine non-tax market distortions do occur it is most unlikely that the progressive income tax will provide the most efficient and equitable policy vehicle for correcting them.

The major non-corporate sector is the farm sector, and both in the United States and in Australia this sector has received extremely favourable tax treatment, although the extent of the concessions varies markedly between different farming activities and many do not receive significantly favoured tax treatment. Whatever arguments may be put forward, that in the absence of offsetting policies to stimulate investment levels of investment and output in certain farming activities would be below the 'social optimal', the use of incentives (concessions) the value of which is directly linked to the size of an individual's marginal tax bracket cannot be justified in the author's view.

Such a policy gives rise to market forces which over the long-run will exert continuous pressure on low-bracket farmers to move out of those farming activities which receive substantial tax-privileges. To the extent

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18 In addition, some tax-concessions were almost certainly completely unforeseen at the time of drafting the income tax legislation. Indeed, some controversy still surrounds the definition of a 'neutral' income tax base with respect to economic activities like timber-growing, mining, growing vines for wine production, and growing fruit and nut trees. Moreover, it may be argued that for some economic activities it would be too costly to administer the 'ideal' income tax base.
that low-bracket farmers respond to these tax-induced economic pressures, their place will be taken by high-bracket farmers and so-called Pitt Street (Australia) and Wall Street (U.S.) farmers, that is, high-bracket investors whose primary sources of income are outside agriculture. Finally, it should be made clear that the above effects are due to the value of the tax-concessions being tied directly to the progressive rate structure of the personal income tax. There are, of course, tax instruments, such as an investment credit which provides a direct credit against the payment of taxes and which is therefore independent of a firm's rate bracket. Providing there is adequate provision for carry forward and for carry-back of losses, an investment credit will not discriminate between low and high-bracket taxpayers.

IV. CONCLUSIONS

In a pioneering paper Brown (1948) was the first to show that if all investment outlays were permitted to be immediately expensed, a tax on business income would not distort the structure of optimal investment decisions. The tax would clearly have enormous administrative advantages since it would avoid difficult problems of measuring depreciation. But the tax effectively excludes interest from the tax base and thus represents a tax on pure profits and if it were to be applied to all noncorporate investment it would radically change the base of the progressive personal income tax base. There is a widespread consensus that the most equitable definition of income on which to base an income tax, is that which defines it as being income from all sources. And on equity grounds it would be quite unacceptable to exclude interest income earned on capital from the tax base and thereby convert the personal income tax into a tax on labour income and on pure profits. Though it is well known that with interest income included in the income tax base individuals' saving-

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19 This assumes, of course, that tax-concessions can be written off against taxable income from any source. In practice, the constraints against doing this are fairly negligible.
consuming decisions will be distorted, since the tax lowers the effective interest rate on which individuals base these decisions.

If this distortion is accepted as being an inevitable price of imposing an income tax, then following Samuelson (1964) there is a reasonable consensus that both from an equity and an efficiency viewpoint the appropriate concept of capital income is that which defines it as being income net of true economic depreciation. If the concept of true economic depreciation (and appreciation) were universally applied under a general progressive personal income tax, optimal investment decisions would not be distorted, as they would be independent of the tax rate to which each individual is subject. Existing progressive income taxes, in countries like the United States and Australia, roughly approximate the Samuelson model, but only in so far as standard tax depreciation formulae provide an approximate measure of true economic depreciation and the tax is evenly applied. But in practice, the progressive income tax is not applied uniformly, particularly with respect to the treatment of depreciation, to all sources of capital income and some favoured areas of investment receive substantial tax-privileges that are directly linked to the size of an individual's tax-bracket.

In general, we would expect two major economic effects to arise from the application of a progressive income tax which discriminates between investment activities. In the first place, with competitive resource allocation, pre-tax rates of return on tax-favoured investment activities will tend towards equilibrium levels lower than those obtaining on ordinarily taxed investments. The lower pre-tax rates of return on tax-favoured investments is the 'sacrifice' made by high-bracket taxpayers in order to maximize their net-of-tax incomes. In the second place, because the tax-privileges are more valuable to high-bracket taxpayers than to low-bracket taxpayers, competition between investors in the former group for tax-sheltered investments will put constant pressure on low-bracket taxpayers to move out of those areas of economic
activity which receive substantial tax-concessions. Low-bracket taxpayers will obtain higher after-tax incomes by investing in ordinarily taxed investments which can be expected, ceteris paribus, to have higher pre-tax rates of return. This, of course, raises very serious equity issues. In addition, in the absence of non-tax market distortions which are being corrected by a discriminatory income tax policy, tax-induced divergences between pre-tax rates of return on different economic activities represents an inefficient allocation of society's capital, since overall returns could be increased by transferring capital from uses with low pre-tax rates of return to those with high pre-tax rates of return.
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CHAPTER 3

EFFECTS OF TAX DEPRECIATION POLICY
AND INVESTMENT INCENTIVES ON OPTIMAL
EQUIPMENT REPLACEMENT DECISIONS
Effects of Tax Depreciation Policy and Investment Incentives on Optimal Equipment Replacement Decisions*

ANTHONY H. CHISHOLM

A model is developed to analyze the effects of income tax policy on the optimal timing of replacement for farm machinery. The impact of some forms of tax investment incentives on optimal replacement age was found to be substantial, while the influence of different tax depreciation methods is minimal.

Key words: income tax policies; optimal replacement; farm machinery.

Tax policy has been widely used by governments as a means of influencing firms' investment decisions. The focus of this paper is on one particular aspect of taxation and investment decisions, namely the influence of tax policy on optimal replacement decisions for farm machinery.

In an important contribution to the theory of capital replacement, Preinreich [14] argues that the optimal service life of a machine cannot be determined in isolation from the economic life of each machine in the chain of future replacements extending as far into the future as the firm's planning horizon. Preinreich proposes that the firm should maximize the net present value of all future replacements, where the net present value is defined as the present value of the aggregate costs of all future machine replacements.

While it was perhaps natural to develop the theory of capital replacement in terms of profit maximization, this objective commonly poses severe problems of measurement owing to the difficulty of identifying the returns attributable to the use of a particular machine. The conventional method of overcoming this problem is to reformulate the profit maximization problem as one of cost minimization. Smith [16, Ch. 5] argues that in the absence of technological change in equipment, the replacement decision cannot affect either price or output. When a firm's price-output decisions are independent of its replacement decisions, cost minimization and profit maximization are completely separable.

The replacement model used in the present study assumes that firms aim to minimize the present cost of obtaining a constant flow of machine services over an infinite planning horizon. A stationary technology is assumed in which machines are replaced by machines of identical type, under conditions of certainty.

The paper is divided broadly into two main parts. In the first section a discrete-time replacement model incorporating income tax policy is developed, and the implications that the model holds for tax policy and optimal replacement decisions are discussed. In the following section the model is applied to a case study of the effects of recent changes in Australian income tax legislation on optimal replacement ages for farm tractors. Additionally, some comparisons are drawn between Australian and United States income tax legislation pertaining to investment in farm machinery.

A Discrete-Time Replacement Model With Tax

Replacement studies have variously used both continuous and discrete-time period models. The replacement model is represented here in terms of discrete-time variables, since this model is well adapted to real world problems involving short-lived assets of the type analyzed here. With a discrete-time model it is necessary to make some arbitrary definitions with respect to the point, within a discrete period, when costs (including tax payments) are incurred and replacement may occur. Both costs and replacement are defined here to occur at the end of each annual period.

Since the replacement problem, in the absence of taxation effects, is well covered in the economic literature, attention is now given to developing a

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The first term on the right-hand side of (1) specifies the present capital cost of a machine which is replaced at age \( n \) years. The second term defines the after-tax present value of cumulative operating costs. The following two terms define, respectively, the present value of the tax savings from an investment allowance and the depreciation allowance. The final term is a balancing charge adjustment. Conventionally, a balancing charge adjustment is made when a divergence occurs between resale value and depreciated book value at the time of asset disposal. If the resale value exceeds the depreciated book value, the "excess depreciation" is added to taxable income. Conversely, if the resale value is less than the depreciated book value, the loss may be deducted from that year's taxable income.

Assuming now an infinite planning horizon, the after-tax present value of the stream of costs for a perpetual chain of machines, each replaced at age \( n \) years, may be defined as:

\[
V_n = Q_n + V_{n+1}(1 + r)^{-n}.
\]

Solving relation (2) for \( V_n \) gives

\[
V_n = \frac{Q_n}{1 - (1 + r)^{-n}}.
\]

The optimal replacement interval could be determined by calculating the values of \( V_n \) for the complete set of feasible replacement ages and selecting the minimum value. However, to analyze the effects of tax policy on optimal replacement decisions, it is necessary to derive a more complete replacement criterion which incorporates the marginal conditions required for an optimum.

A replacement model with marginal criteria

Marginal conditions for optimal replacement can be derived from the following two inequalities:

\[
V_n \leq V_{n+1},
\]

\[
V_n \leq V_{n-1},
\]

which must hold for \( n \) an optimum. 5

Substituting (3) in the right-hand side of (4), one obtains

\[
V_n \leq V_{n+1},
\]

\[
V_n \leq V_{n-1},
\]

The general procedure for deriving marginal conditions for optimal replacement in the form of two inequalities was developed by Burt [2].
or the following equivalent inequality,

\[ V_n \leq Q_{n+1} + V_{n+1}(1 + r)^{-\left(n+1\right)} \]

Finally, substituting (2) into the above inequality and rearranging terms gives

\[ Q_{n+1} - Q_n \geq V_n(1 + r)^{-n} - V_n(1 + r)^{-\left(n+1\right)} \]

Substituting (1) in the left-hand side of (6) gives

\[ \left[ M_n - M_{n+1}(1 + r)^{-\left(n+1\right)} \right] + 1 - T(\sum_{k=1}^{n} R_k(1 + r)^{-k}) + 1 - T(\sum_{k=1}^{n} D_k(1 + r)^{-\left(n+1\right)}) - T(I(1 + r)^{-1}) - T(\sum_{k=1}^{n} D_k(1 + r)^{-\left(n+1\right)}) - T(\sum_{k=1}^{n} B_k(1 + r)^{-\left(n+1\right)}) - M_n + M_{n+1}(1 + r)^{-n} + 1 - T(\sum_{k=1}^{n} R_k(1 + r)^{-k}) - T(I(1 + r)^{-1}) - T(\sum_{k=1}^{n} D_k(1 + r)^{-\left(n+1\right)}) \geq V_n(1 + r)^{-n} - V_n(1 + r)^{-\left(n+1\right)} \]

where \( B_k = \sum_{k=1}^{n} D_k - M_n + M_{n+1} \), which is the undiscounted balancing charge adjustment. Canceling like terms of opposite sign and dividing both sides of the inequality of (7) by \((1 + r)^{-\left(n+1\right)}\) gives

\[ M_n(1 + r) - M_{n+1} + 1 - T(R_{n+1}) - T(D_{n+1}) + T(B_{n+1}) - T(B_n(1 + r)) \geq V_n(1 + r) - V_n \]

Rearranging terms on both sides of the inequality of (8) yields

\[ 1 - T(R_{n+1}) + (M_n - M_{n+1}) + rM_n - T(D_{n+1}) + T(B_{n+1}) - B_n(1 + r) \geq rV_n \]

Applying similar algebraic operations to (5), one can derive.

\[ 1 - T(R_{n+1}) + (M_n - M_{n+1}) + rM_n - T(D_{n+1}) + T(B_{n+1}) - B_n(1 + r) \leq rV_n \]

The optimal policy for replacement is therefore defined by the double inequality

\[ 1 - T(R_{n+1}) + (M_n - M_{n+1}) + rM_n - T(D_{n+1}) + T(B_{n+1}) - B_n(1 + r) \geq rV_n \]

\[ 1 - T(R_{n+1}) + (M_n - M_{n+1}) + rM_n - T(D_{n+1}) + T(B_{n+1}) - B_n(1 + r) \leq rV_n \]

The optimal policy is to continue to hold the current machine until the marginal cost of holding the machine for a further year exceeds the amortized cost, \( rV_n \), which in turn exceeds the marginal cost incurred in the preceding year.\(^6\) At this point, the marginal cost with respect to time (machine age) most closely approximates the average cost per unit of time, i.e., the amortized cost.

In empirical applications, probably the best method of determining the optimal replacement age is to evaluate the middle expression of (11), for \( n = 1, 2, 3, \ldots \), and select the integer value of \( n \) for which the amortized cost is a minimum. Substituting from (1) and (3) into the middle expression of (11), the complete relationship for the amortized cost is

\[ rV_n = \frac{r}{1 - (1 + r)^{-n}} \left[ (M_n - M_{n+1}) + rM_n - T(\sum_{k=1}^{n} D_k(1 + r)^{-k}) - T(\sum_{k=1}^{n} R_k(1 + r)^{-k}) - T(\sum_{k=1}^{n} B_k(1 + r)^{-k}) \right] \]

\[^6\) The main differences between (11) and the corresponding before-tax replacement criterion are additional terms for depreciation and the balancing charge adjustment on both the right-and left-hand sides of (11) and the incorporation of these effects plus the influence of the investment allowance in the middle expression. A sufficient condition for there to be only one value of \( n \) which satisfies (11) is that starting from \( n = 1 \), \( V_n \) is monotone decreasing to some point \( n = k \) and thereafter monotone increasing. This condition will not always be met, and in empirical work it will usually be necessary to evaluate \( V_n \) for the complete set of feasible replacement ages.\]
It follows from relations (11) and (12) that the influence of the separate components of tax policy on optimal replacement decisions can be assessed by determining the functional relationship between the annuity value of an investment allowance (and a depreciation allowance) and replacement age.

Consider first an investment allowance of amount \( I \), which is written off against taxable income at the end of the first year of a machine's life. From equation (12) the after-tax annuity value of an investment allowance (denoted \( P^* \)), is

\[
P^* = \frac{r}{1 - (1 + r)^{-n}} \cdot \left(\frac{1}{1 + r}\right)^n T.
\]

The value of the annuity factor in relation (13) is inversely related to the value of \( n \), and it is thus clear that the value of \( P^* \) will also vary inversely with \( n \). It follows that if the annuity value of the tax saving from an investment allowance is a decreasing function of replacement age, an investment allowance will induce a bias towards shorter optimal replacement intervals.

Determination of the effect of the time pattern of tax-deductible depreciation on optimal replacement age is a more difficult task, because it is necessary first to define a "neutral" depreciation allowance which can be used as a basis for comparison. For this purpose the author drew upon a fundamental theorem of tax-rate invariance established by Samuelson [15, p. 604]:

If, and only if, true loss of economic value is permitted as a tax-deductible depreciation expense will the present discounted value of a cash-receipt stream be independent of the rate of tax.

Based upon this theorem, a depreciation schedule (henceforth termed a neutral depreciation allowance) which allows the actual annual decline in asset value to be deducted from taxable income in the year it is incurred is used as a basis for comparison.\(^8\)

In the latter part of the application of the model which follows, the effect of alternative depreciation allowances on the replacement decision is assessed by evaluating the absolute difference between the annuity value of a neutral depreciation allowance and the annuity value of the particular depreciation schedule under consideration, for \( n = 1, 2, 3, \ldots \).

An Application

In 1973 two important changes were made to the income tax legislation pertaining to investment in farm machinery in Australia.\(^9\) First, an investment allowance of 20 percent of machine cost, deductible from taxable income in the year of purchase of a new machine, was removed. Second, an accelerated depreciation schedule, which allowed the cost of farm machinery to be written off over five years at the rate of 20 percent per annum, was replaced with a "standard" depreciation schedule allowing a 15 percent per annum write-off over the first six years and a 10 percent write-off in the seventh year.

To illustrate the effects of these changes in income tax policy on optimal replacement decisions, the replacement model is applied to survey cost data for a farm tractor. The estimated annual operating costs and resale values for a farm tractor with an acquisition cost of \$3,100 are given in Table 1.\(^1\) Applying the replacement model derived earlier to this data, the optimal replacement ages are evaluated for various comparison.\(=\) ...

\(^8\) It can be seen both from inspection and from tabled values of the annuity factor, \( \frac{r}{1 - (1 + r)^{-n}} \), that its value (and therefore \( P^* \)) is monotone decreasing for \( n = 1, 2, 3, \ldots \).

\(^9\) Some economists, for instance Smith [17], have proposed that neutral tax depreciation write-off rules would permit all capital outlays to be fully expensed—that is, a policy of 100 percent immediate depreciation regardless of the economic life of an asset. The conflict between Samuelson's [15] and Smith's conclusions may be explained by the fact that Smith's analysis implicitly assumes that a firm's before- and after-tax discount rate are identical. Samuelson, on the other hand, explicitly assumes that under a neutral income tax the after-tax discount rate will always equal \((1-T)\) times the before-tax discount rate. I consider Samuelson's interpretation to be the correct one.

\(8\) From equation (12) I define the annuity value of a depreciation allowance—net of the balancing charge adjustment—as

\[
\frac{r}{1 - (1 + r)^{-n}} = \frac{(\Sigma D_k (1 + r)^{-k})}{(\Sigma D_k - M_n + M_{n+1})}.
\]

Multiplying this expression by \( T \), I obtain the net value of the annuity to a particular firm.

\(9\) These tax changes were first announced by the Australian Federal Treasurer in the 1973-74 Budget Speech.

\(10\) Table 1 is based on farm survey data of tractor costs obtained from a study made by Harrison [10]. Both Harrison's study and a separate study by Glau [9] examine the problem of the optimal timing of replacement of farm equipment under an income tax. In neither study, however, was a satisfactory methodology given for rigorously analyzing the effects of different tax policies on optimal replacement.
A detailed description of U. S. tax policy relating to investment in farm equipment is contained in [20]. In my analysis, I assume that U. S. farmers accurately predict the future resale (salvage) value of their equipment when calculating tax-deductible depreciation, so that there is no balancing charge (recapture) at the time of its disposal.

Further insight into the influence of the tax change on optimal replacement strategies can be gained by separating the effect of the removal of the investment allowance from the effect of the removal of the accelerated depreciation allowance. This separation is achieved by calculating optimal replacement ages for a tax policy which allows accelerated depreciation, but which has no investment allowance. The optimal replacement ages for this situation are identical to those given in parentheses in Table 2. Thus the changes in optimal replacement ages shown in Table 2 derive solely from the removal of the investment allowance.

To draw some comparisons between the Australian and United States income tax legislation and to allow further testing of the sensitivity of optimal equipment replacement decisions to tax policy, the replacement model was also used to examine the current United States tax situation. The main features of the current United States income tax legislation, as it relates to investment in farm machinery, are an investment credit; a choice between several forms of depreciation write-off including some accelerated forms of depreciation; and an additional first-year depreciation allowance. In addition, and in contrast to the former tax situation in Australia, there are strict rules governing the minimum number of years (useful life) that an asset must be held by a firm to qualify for the above forms of favorable tax treatment. The above analysis is in the nature of partial equilibrium theory, since the structure of secondhand tractor prices is assumed to remain constant. An extension of the analysis would be to construct a model of the market for new and secondhand tractors and examine simultaneously the effects of changes of tax policy on the structure of equilibrium tractor prices and optimal replacement.

For a study on the secondhand market for farm machinery, see Candler [13].

Table 1. Operating costs and resale values for a farm tractor

<table>
<thead>
<tr>
<th>Replace Year</th>
<th>Tax Deductible End Operating Costs</th>
<th>Resale Price</th>
<th>Actual Depreciation</th>
<th>Cumulative Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>472</td>
<td>2508</td>
<td>592</td>
<td>592</td>
</tr>
<tr>
<td>2</td>
<td>557</td>
<td>2235</td>
<td>273</td>
<td>865</td>
</tr>
<tr>
<td>3</td>
<td>529</td>
<td>1992</td>
<td>243</td>
<td>1108</td>
</tr>
<tr>
<td>4</td>
<td>636</td>
<td>1775</td>
<td>217</td>
<td>1325</td>
</tr>
<tr>
<td>5</td>
<td>674</td>
<td>1582</td>
<td>193</td>
<td>1518</td>
</tr>
<tr>
<td>6</td>
<td>826</td>
<td>1410</td>
<td>177</td>
<td>1690</td>
</tr>
<tr>
<td>7</td>
<td>546</td>
<td>1257</td>
<td>153</td>
<td>1843</td>
</tr>
<tr>
<td>8</td>
<td>612</td>
<td>1110</td>
<td>137</td>
<td>1980</td>
</tr>
<tr>
<td>9</td>
<td>808</td>
<td>998</td>
<td>122</td>
<td>2102</td>
</tr>
<tr>
<td>10</td>
<td>796</td>
<td>889</td>
<td>109</td>
<td>2211</td>
</tr>
<tr>
<td>11</td>
<td>805</td>
<td>793</td>
<td>96</td>
<td>2307</td>
</tr>
</tbody>
</table>

Further insight into the influence of the tax change on optimal replacement strategies can be gained by separating the effect of the removal of the investment allowance from the effect of the removal of the accelerated depreciation allowance. This separation is achieved by calculating optimal replacement ages for a tax policy which allows accelerated depreciation, but which has no investment allowance. The optimal replacement ages for this situation are identical to those given in parentheses in Table 2. Thus the changes in optimal replacement ages shown in Table 2 derive solely from the removal of the investment allowance.

To draw some comparisons between the Australian and United States income tax legislation and to allow further testing of the sensitivity of optimal equipment replacement decisions to tax policy, the replacement model was also used to examine the current United States tax situation. The main features of the current United States income tax legislation, as it relates to investment in farm machinery, are an investment credit; a choice between several forms of depreciation write-off including some accelerated forms of depreciation; and an additional first-year depreciation allowance. In addition, and in contrast to the former tax situation in Australia, there are strict rules governing the minimum number of years (useful life) that an asset must be held by a firm to qualify for the above forms of favorable tax treatment. The above analysis is in the nature of partial equilibrium theory, since the structure of secondhand tractor prices is assumed to remain constant. An extension of the analysis would be to construct a model of the market for new and secondhand tractors and examine simultaneously the effects of changes of tax policy on the structure of equilibrium tractor prices and optimal replacement. For a study on the secondhand market for farm machinery, see Candler [13].

12 The above analysis is in the nature of partial equilibrium theory, since the structure of secondhand tractor prices is assumed to remain constant. An extension of the analysis would be to construct a model of the market for new and secondhand tractors and examine simultaneously the effects of changes of tax policy on the structure of equilibrium tractor prices and optimal replacement. For a study on the secondhand market for farm machinery, see Candler [13].

Table 2. Optimum replacement intervals (years)*

<table>
<thead>
<tr>
<th>Discount Rate (percent)</th>
<th>Marginal Income Tax Rate (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12.5</td>
</tr>
<tr>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

* The figures without and within parentheses in the body of the table show the optimal replacement intervals before and after the tax change, respectively.

Further insight into the influence of the tax change on optimal replacement strategies can be gained by separating the effect of the removal of the investment allowance from the effect of the removal of the accelerated depreciation allowance. This separation is achieved by calculating optimal replacement ages for a tax policy which allows accelerated depreciation, but which has no investment allowance. The optimal replacement ages for this situation are identical to those given in parentheses in Table 2. Thus the changes in optimal replacement ages shown in Table 2 derive solely from the removal of the investment allowance.

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13 A detailed description of U. S. tax policy relating to investment in farm equipment is contained in [20]. In my analysis, I assume that U. S. farmers accurately predict the future resale (salvage) value of their equipment when calculating tax-deductible depreciation, so that there is no balancing charge (recapture) at the time of its disposal.
ages were determined under the United States straight line and the sum of the years-digits methods of depreciation respectively, both with and without the investment credit and the additional first-year depreciation allowance. For all of the above combinations, the optimal replacement ages were identical with those given in brackets in the right-hand side column of Table 2, i.e., under the current "standard" Australian depreciation allowance. In effect, the strict eligibility rules which allow assets to qualify for favorable tax treatment only if they are held by a firm for certain minimum time periods nullify any incentives that may otherwise be given towards more rapid replacement.

Finally, as was discussed earlier in the paper, a more precise measure of the influence on replacement of the time pattern of tax-deductibility of depreciation can be obtained by evaluating absolute differences between the annuity value of a neutral depreciation allowance and the annuity value of the particular depreciation schedule under consideration, for each feasible replacement age. Using the data in Table 1, the above calculations have been made for a number of alternative forms of depreciation. The results are presented in Table 3.

The procedure for assessing the direction of the effect of a particular method of depreciation on replacement age may be illustrated by considering the most extreme form of accelerated depreciation, namely an immediate 100 percent depreciation allowance. From Table 3 it can be seen that the annuity value of this depreciation allowance exceeds that of a neutral depreciation allowance for all values of $n$. The absolute difference between the annuity values of the two depreciation schedules is, however, a decreasing function of $n$.

Hence, an immediate 100 percent write-off policy induces a bias towards shorter replacement intervals. This situation does not apply, however, with all forms of accelerated depreciation, as can be seen from the results for the former Australian accelerated depreciation allowance, where the bias is in the opposite direction.

It is apparent from the results given in Table 3 that there is no simple general rule for predicting the direction of bias on replacement age of a particular method of depreciation. Perhaps more important is the fact that in no instance was the magnitude of the bias stemming from a particular method of depreciation of sufficient size to change the optimal replacement age.14

14 It is apparent, though, from some of the large dif-

Conclusions

A replacement model has been developed to analyze the effects of the time pattern of the tax depreciation policy and special investment incentives, on optimal farm equipment replacement decisions. A case study application of the model to analyze the effects of recent changes in Australian income tax legislation showed that the combined removal of a 20 percent investment allowance and an accelerated depreciation allowance substantially increases the optimal tractor replacement age for high tax bracket farms. Separation of the influence of the investment allowance from that of the accelerated depreciation allowance indicated that the impact of the tax change on optimal replacement age was solely attributable to the removal of the investment allowance.

The main indications emerging from a rather more restricted application of the model to United States tax policy were that due largely to the rules preventing assets receiving favorable tax treatment from being turned over too rapidly, the current tax policy would not appear to influence significantly the optimal farm machinery replacement decisions.

Evaluation of the relationship between the annuity value and replacement age for each of a number of alternative feasible depreciation methods—with the same annuity relationship for a neutral depreciation allowance—indicated that changes in the time pattern of the tax-deductibility of depreciation will in general have only minimal influence on optimal replacement decisions.

Finally, it may be observed that the original policy goal of the Australian investment allowance was to stimulate the use of new and up-to-date equipment in primary production [5, p. 23]. While this policy goal was probably to some extent achieved, it is not desirable from either an equity or efficiency viewpoint to provide an incentive the size of which is directly linked to a firm's marginal tax bracket. In this respect an investment credit which is independent of a firm's marginal tax bracket would appear to be a superior form of investment incentive.

[Received April 1974 and revised July 1974.]
Table 3. Annuity values for various depreciation methods relative to a neutral depreciation allowance

<table>
<thead>
<tr>
<th>Replace at End of Year</th>
<th>Former Australian Accelerated Depreciation Plus Investment Allowance</th>
<th>Former Australian Accelerated Depreciation Only</th>
<th>Current Australian Standard Depreciation</th>
<th>U. S. Straight Line Depreciation</th>
<th>U. S. ( ^a ) Sum of the Years-Digits Method Plus Additional First-Year Depreciation</th>
<th>U. S. ( ^b ) Investment Credit</th>
<th>Immediate 100 Percent Depreciation</th>
<th>Total Depreciation at Time of Asset Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>620</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>288</td>
<td>1</td>
<td>-6</td>
<td>-7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>310</td>
</tr>
<tr>
<td>3</td>
<td>204</td>
<td>12</td>
<td>-3</td>
<td>-12</td>
<td>-</td>
<td>-</td>
<td>26</td>
<td>282</td>
</tr>
<tr>
<td>4</td>
<td>170</td>
<td>26</td>
<td>5</td>
<td>-14</td>
<td>-</td>
<td>21</td>
<td>215</td>
<td>-26</td>
</tr>
<tr>
<td>5</td>
<td>156</td>
<td>40</td>
<td>12</td>
<td>-17</td>
<td>-</td>
<td>35</td>
<td>238</td>
<td>-46</td>
</tr>
<tr>
<td>6</td>
<td>153</td>
<td>56</td>
<td>21</td>
<td>-19</td>
<td>20</td>
<td>30</td>
<td>228</td>
<td>-72</td>
</tr>
<tr>
<td>7</td>
<td>148</td>
<td>64</td>
<td>30</td>
<td>-23</td>
<td>21</td>
<td>40</td>
<td>218</td>
<td>-92</td>
</tr>
<tr>
<td>8</td>
<td>144</td>
<td>70</td>
<td>38</td>
<td>-25</td>
<td>21</td>
<td>37</td>
<td>210</td>
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<td>73</td>
<td>44</td>
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<tr>
<td>10</td>
<td>135</td>
<td>75</td>
<td>46</td>
<td>-31</td>
<td>21</td>
<td>32</td>
<td>197</td>
<td>-113</td>
</tr>
<tr>
<td>11</td>
<td>129</td>
<td>75</td>
<td>50</td>
<td>-34</td>
<td>20</td>
<td>30</td>
<td>191</td>
<td>-119</td>
</tr>
</tbody>
</table>

\(^a\) An asset must be held by a firm for at least three years to qualify for the sum of the years-digits method of depreciation and a period of at least six years to qualify for a 20 percent additional first-year depreciation allowance. For \( n \geq 3 \) the differences between the sum of the years-digits method only and neutral depreciation was negligible.

\(^b\) An asset must be held for at least three years for a firm to receive any investment credit and at least seven years to receive the full investment credit.
November 1974

TAX POLICY AND OPTIMAL REPLACEMENT

References


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CHAPTER 4

INCOME TAXES AND INVESTMENT DECISIONS: THE LONG-LIFE APPRECIATING ASSET CASE

Anthony E. Cline
Australian National University
University of California

In this paper a mathematical tax planning model is used to analyse the effects of alternative methods of taxing income derived from productive assets whose productive potential is temporarily suspended. The model is applied to a long-life, appreciating asset, which is assumed to be located in Australia and the United States, respectively. The productivity growth potential increases land (real) values and depletes stockholder wealth.

The general concern of this paper is with the taxation of long-lived appreciating assets, such as growing trees, tax shelters and the assets of firms. The timing of income that accrues from growing timber is of importance in itself and also because growing trees have traditionally been used as a natural hedge.

A notable input-output output example is the literature on capital theory.

The research described in this paper was carried on by the author while a Visiting Associate Research Associate in the Advance Research Center for Agricultural Economics, University of California, Davis and Berkeley.

The author acknowledges the assistance of the many people who helped with the research. The author is grateful to Robert Wiseman and Bruce Odell for helpful comments on the earlier version.

The author's affiliation with agricultural economics in the absence of tax law effects is given in a companion paper.

The term "tree" as used in this paper, is synonymous with wood fiber, in all the cases.
INCOME TAXES AND INVESTMENT DECISIONS: THE LONG-LIFE APPRECIATING ASSET CASE

Anthony H. Chisholm*
Australian National University
University of California

In this paper a neoclassical tax incidence model is used to analyze the effects of alternative methods of taxing income derived from products whose production process is long-lived. Forestry is selected as a classic case. Compared with a "neutral" income tax, two other types of income tax, which approximate those currently applying to the forestry sectors in Australia and the United States, respectively, bias production toward longer growth periods, increase land (site) values, and depress timber prices.

The general concern of this paper is with the taxation of long-lived appreciating assets, such as growing trees for timber and the aging of wine. The taxation of income that accrues from growing timber is of importance in itself and also because growing trees have traditionally been used as a classic point input-point output example in the literature on capital theory.¹

* The research described in this paper was carried on by the author while a Visiting Associate and Research Associate on the Giannini Foundation of Agricultural Economics, University of California, Davis and Berkeley, respectively. An earlier version of the paper was presented at the 1974 annual meeting of the American Agricultural Economics Association. The author is grateful to Daniel Bromley and Mason Caffney for helpful comments on the earlier version.

The author's (Chisholm 1966) analysis of the optimal rotation problem in the absence of taxation effects is given in a supplementary Appendix.

¹ The term "timber", as used in this paper, is synonymous with wood fiber in all its uses.
Particular attention has been given to the problem of the optimal rotation or growth period. This problem has, for instance, been analyzed in the absence of taxation influences by Gaffney (1960), Chisholm (1966), and Hirshleifer (1970). The first detailed study analyzing the effects of various forms of taxation on the optimal maturity period was made by Gaffney (1967).² Gaffney's framework for analysis and conclusions was later vigorously attacked in a paper published in this Journal by Thomson and Goldstein (1971).

It is not the purpose here to provide a detailed critique of these papers. Rather, using a differential tax incidence model, a fresh approach to the problem is taken. This is done in the belief that a large part of the conflict between the above writers may be attributed partly to their attempting to analyze the impact of various forms of taxation on optimal growth periods, without considering simultaneous effects on factor and product prices within the forestry sector, and partly because they do not adequately specify the alternative situations in which they are making comparisons.

The plan of this paper is as follows: First, I define a neutral income tax which, if applied uniformly over all sectors of the economy, has the characteristics that the before-tax and net-of-tax present discounted valuations of all investments, and hence optimization decisions, are independent of the tax rate to which each firm is subject. Second, I define two additional types of income tax which approximate the current federal income taxes in Australia and the United States, respectively, as they apply to the forestry sector. The equation defining the net present value of an infinite

² Gaffney's first paper (1967) was followed by an extended treatment of the topic published during 1970-71. Gaffney considered the influence of taxation of income derived from both appreciating and depreciating assets. The present paper considers the case of long-lived appreciating assets only. For a recent analysis of tax policy and the depreciating asset case, see Chisholm (1974).
sequence of timber harvests and the optimal rotation cycle is given for the before-tax and the net-of-tax situation for each type of income tax. Third, using a differential tax incidence procedure, I analyze the economic effects of substituting alternative forms of the income tax in the forestry sector. Fourth, a numerical example is given to illustrate the conclusions that emerge from the preceding qualitative analysis. The paper ends with some concluding remarks and an Appendix in which the relationship between my approach to the problem and the papers by Gaffney and by Thomson and Goldstein are discussed.

I. A NEUTRAL INCOME TAX

The definition of a neutral income tax (henceforth termed an accrued income tax) used in this study follows directly from a fundamental theorem of tax-rate invariance established by Samuelson (1964, p.604). The essential characteristics of the income tax base may be stated as follows: 3

1. Current receipts and current outlays (i.e. outlays which make their full contribution to production within a single year) should be subject to tax and deductible from taxable income, respectively, at the time they are incurred.
2. The true loss of economic value of an asset should be allowed as a tax-deductible depreciation expense as it accrues.
3. The increase in the real value of an appreciating asset should be subject to tax as it accrues.

Applied to a point input-point output forest growth model, the accrued income tax would allow planting and establishment costs to be deducted from taxable income at the beginning of each rotation and tax the

3 This definition of a neutral income tax is also the one proposed by Gaffney (1967 and 1970-71). Other economists who have proposed this concept of the income tax base include Haig (1921), Simons (1938), Vickrey (1947), and Musgrave (1967).
value of the annual growth increments as they accrue. A uniformly applied accrued income tax has the crucial property that the net-of-tax rate of return on all investments equals \( i (1 - t) \), where \( i \) and \( t \) denote the before-tax rate of return and the rate of tax, respectively. In other words the proportion of the gross rate of return, siphoned off to the government as taxation, is constant for all investments; and the opportunity cost of capital to firms is thus reduced in precise proportion to their tax rate.

Of course, any form of income tax which taxes the interest income earned on capital has an inherent bias against aggregate savings and associated capital formation, as compared with a consumption, or wealth tax, since it lowers the effective interest rate on which rational individuals base their saving-consuming decisions. The important point is that, for any given level of aggregate capital formation, a uniformly applied accrued income tax will, in a perfect capital market, have no distorting influence on the allocation of capital between alternative avenues of investment.

It may be argued that it is administratively too costly to apply an accrued income tax to forestry because it would require an annual valuation of growing timber. Also, it may be claimed that, due to imperfect lending markets, the payment of taxes before the income is actually realized, would cause severe liquidity problems for some timber growers. However, under an accrued income tax, it is not essential that the tax be collected before the income is realized. If for administrative or any other reasons the tax can be collected only upon realization of the income, an interest adjustment charge could be added at this time. The present value of the cumulative tax payments would then be equal regardless of whether the tax was paid on an annual accrual basis or in a lump sum at the time the trees were felled.

Given perfect markets and full tax deductibility of interest charges on all investment financed by borrowing, the gross rate of return on investments will be equated with the market rate of interest.

It is beyond the scope of this paper to attempt to analyze, within a macroeconomic framework, the effects that a general income tax (and the associated government expenditure that it finances) may have on an economy's time path of aggregate private capital formation and the market rate of interest.
II. PRESENT VALUES

The equations for determining the net present value of an infinite sequence of forest harvests for the before-tax situation and for each of the alternative income tax regimes are given in this section of the paper. An annual discrete time period model is used since this model would seem to best accord with the annual income tax accounting period of the real world. The following notation will be used in the models:

\[ S: \text{ before-tax present value (site value)}, \]
\[ S^*: \text{ net-of-tax present value (site value)}, \]
\[ V_n: \text{ undiscounted value of each harvest (stumpage value)}, \]
\[ C_o: \text{ establishment cost incurred at the beginning of each rotation}, \]
\[ G_k: \text{ value of the annual growth increment for the } k \text{th year}, \]
\[ i: \text{ before-tax rate of discount}, \]
\[ r: \text{ net-of-tax rate of discount}, \]
\[ t: \text{ rate of tax}, \]
\[ n: \text{ rotation period measured in years}. \]

The equation defining the before-tax net present value for an infinite sequence of harvests is

\[ S = \left[ V_n (1 + i)^{-n} - C_o \right] + \left[ V_n (1 + i)^{-2n} - C_o (1 + i)^{-n} \right] \]
\[ + \left[ V_n (1 + i)^{-3n} - C_o (1 + i)^{-2n} \right] + \ldots . \]  

Assuming constant values for both \( V_n \) and \( C_o \), equation (1) simplifies to

\[ S = \frac{V_n - C_o (1 + i)^n}{(1 + i)^n - 1} . \]

The net present value \( S \), of the trees, determines the site value of
the land on which they grow.\textsuperscript{7} And the excess of $S$ over the opportunity cost of the land in its next best alternative use, e.g., grazing livestock, represents pure rent attributable to the forestry enterprise. The length of the rotation cycle, $n$, which maximizes $S$, may be viewed as a tradeoff between size and frequency of harvests.\textsuperscript{8} In practice, probably the simplest way of solving for the optimal value of $n$ is to calculate the values of $S$ for the complete set of feasible growth cycles and select the maximum value.\textsuperscript{9} 

Equation (2) may now be modified to incorporate an accrued income tax as given below:

$$S^* = \frac{V_n - t \left[ \sum_{k=1}^{n-1} \frac{C_k}{(1 + r)^{n-k}} + \frac{C_n}{(1 + r)^n} \right] - C_o (1 + r)^n}{(1 + r)^n - 1}.$$  

(3)

The first bracketed term and the following term in equation (3) specify the values of the cumulative tax payments on the annual growth increments and the net-of-tax establishment costs, respectively, both compounded forward to the year of timber harvest.\textsuperscript{10}

\textsuperscript{7} For simplicity, it is assumed here that the only product of forest land is wood fiber. In practice, forest lands will also commonly provide recreational amenities as a joint product.

\textsuperscript{8} The economic choice of an optimal growth period assumes particular importance for forestry as the production of wood fiber is unique among crops in its flexibility with regard to the timing of harvest.

\textsuperscript{9} Though additional insight into the problem is obtained when a marginal replacement criterion is formulated: See, for instance, the marginal replacement criterion as defined by equation (7), in Chisholm (1966). The modified form of equation (7) which incorporates the effects of an accrued income tax is: $(V_{n+1} - V_n)(1 - t) \approx i(1 - t)V_n + c_n(1 - t) + \Lambda^*(1 - t)$. Compared with the before-tax marginal replacement criterion, under an accrued income tax all terms are reduced in exact proportion to the rate of tax and the choice of the optimal rotation period is thus not influenced by the tax.

\textsuperscript{10} The taxable income assessed at the end of the first year of a forest’s life, $G_1$, is equal to the value of the one-year-old forest less the cost of planting. While for simplicity of exposition, a point input-point output forest model is used here, the treatment of intermediate outlays, e.g. prunings, under an accrued income tax is in principle quite straightforward. Intermediate outlays should be tax deductible in the year in which they are incurred, since it is at this point in time that such expenditures will increase the value of the forest and thus taxable accrued income.
If equations (2) and (3) are applied to a set of forest growth data, the value of $S$ will equal $S^*$ for all values of $n$, providing that a net-of-tax discount rate, $r$, equal to $i(1-t)$, is used in equation (3). That is to say, under a general accrued income tax, the discounted present valuation of all investments in timber production (and elsewhere) will be independent of the tax to which each firm is subject, and the tax will not therefore affect the choice of the optimal growth period for a particular tree species nor will it influence the planting choice between short- and long-maturing tree species.\textsuperscript{11}

The second type of income tax to be considered - currently applying to the forestry sector in Australia - allows planting costs to be "immediately expensed" but delays taxing forest income until it is realized at harvest. The equation defining $S^*$ under an income tax that permits immediate expensing (henceforth termed a \textit{full-expensing} income tax) is

\begin{equation}
S^* = \frac{V_n (1-t) - (1-t)[C_o (1+r)^n]}{(1+r)^n - 1}.
\end{equation}

The final type of income tax considered (henceforth termed a \textit{realized} income tax) differs from the above income tax in that planting costs must be capitalized and deducted from realized income at the time of harvest.\textsuperscript{12} The equation for $S^*$ under a realized income tax is

\begin{equation}
S^* = \frac{V_n (1-t) + tC_o - C_o (1+r)^n}{(1+r)^n - 1}.
\end{equation}

Comparing equations (3), (4), and (5), it is now clear that the only differences between the three types of income tax arise from differences in

\textsuperscript{11} It is assumed that the tax rate to which a firm is subject is constant over time. Under a progressive income tax, this implies the existence of comprehensive income-averaging provisions.

\textsuperscript{12} This, essentially, is the form of federal income tax applying to the forestry sector in the United States which is commonly referred to as a net severance tax. However, the preferential capital gains tax rates, which apply to most timber production in the United States, are not considered in the present paper. For a discussion of this topic, see Meade (1965). Property taxes also have important implications for forestry in the United States; see, for example, Trestrail (1969).
the timing of the tax deductibility of costs and/or the taxing of income. Compared with an accrued income tax, both a full-expensing income tax and, to a lesser extent, a realized income tax confer an effective tax subsidy which stems from their more generous timing provisions.

III. ECONOMIC EFFECTS OF ALTERNATIVE TYPES OF INCOME TAX ON FORESTRY

The analysis in this section of the paper is based on the following assumptions: the initial (benchmark) situation is one in which a proportional accrued income tax is applied uniformly over all sectors of a closed economy; all markets are perfectly competitive, and market relationships, under any given tax regime, are expected to hold constant over time; and, with the exception of land, adjustments in the size of the forestry sector induced by a tax change do not appreciably affect factor or product prices in other sectors.

Consider now the substitution in the forestry sector of a full-expensing income tax for the accrued income tax while maintaining the accrued income tax elsewhere. It follows from the above assumptions that prior to the tax change, in the absence of differential risk, both the before-tax and net-of-tax rates of return on capital will be equated at the margin in all sectors. Immediately following the tax change, the net-of-tax rate of return in the forestry sector will exceed that elsewhere. This, in turn, will give rise to market forces which will lower the before-tax rate of return in forestry to a point where the net-of-tax rate of return is once more equal between sectors. The market adjustment will occur through tax-induced changes in the prices of factors used in forest

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13 The general approach taken here and, in particular, the assumption that market forces will operate to equate the net-of-tax rate of return between uses of capital is similar in spirit to that which is now especially associated with the names of Harberger and Mieszkowski; see, for instance, Harberger (1962) and Mieszkowski (1972).
production and/or changes in the price of timber. Given that the supply of both labor and capital (net-of-tax) to the forestry sector is assumed to be perfectly elastic with respect to price, land is the only factor whose market price can be affected by the tax change.

Two polar cases regarding the supply of land to the forestry sector may be distinguished. First, the supply of land to forestry is perfectly inelastic, and, second, it is perfectly elastic. In the first case, the full incidence of the tax change will be reflected in higher site values for forest land. The site values for forest land will be bid up to the point at which the net-of-tax return for forestry is equal to that elsewhere. A windfall capital gain is thus conferred upon owners of forestry land at the time the tax change is announced.14

Assuming that the tax change applies only to trees planted after its announcement, there will be an incentive to bring forward the harvest-time of growing trees which were planted prior to the tax change since the opportunity cost of the site (land) is now higher. For trees planted after the tax change, however, a full-expensing income tax will induce a bias toward longer rotation cycles. The distortion is most easily explained by considering equations (2) and (4) and assuming initially that a firm uses a net-of-tax discount rate equal to the before-tax discount rate, r, to calculate values of \( S^* \) for alternative values of \( n \). Using equation (2) it is then possible to rearrange equation (4) in the following form:

\[
S^* = S (1 - t) \tag{6}
\]

It is clear from equation (6) that imputed site values, for all values of \( n \), would be reduced by an amount exactly proportionate to the

14 It is assumed that, when a tax change is announced, investment plans are made on the expectation that the new tax will be permanent.
tax rate if a constant discount rate, equal to the before-tax rate of return, was used for both the before and net-of-tax evaluations. The appropriate net-of-tax discount rate, r, to use in equation (6) is, however, lower than the before-tax rate, i, since in equilibrium it must equal the net-of-tax return elsewhere. And when the correct (lower) rate of discount is used, the impact on $S^*$ will be more favorable for longer rather than for shorter maturity periods.

Consider now the opposite polar case in which the supply price of land to the forestry sector is perfectly elastic. The higher net-of-tax return for forestry resulting from the tax change will provide an incentive to increase the land area planted to trees. The area of new land planted to trees will depend on the expected price elasticity of demand for timber. In the new long-run equilibrium, the price of timber will have decreased to a level just sufficient to yield a net-of-tax return equal to that in other sectors. The full incidence of the tax change is thus reflected in lower timber prices in the long run.

It was shown in the preceding discussion that a change to a full-expensing income tax in the forestry sector with an inelastic land supply caused the imputed site values, $S^*$, to increase proportionately more for longer rather than for shorter maturity periods. It then follows that, when the supply of land to forestry is perfectly elastic, the lowest prices for timber which are just compatible with earning a net-of-tax return to forestry equal to that obtainable elsewhere will also be biased toward longer maturity periods.

In reality, of course, we would expect the supply of land to the forestry sector to be neither perfectly elastic nor inelastic. In these circumstances the incidence of the tax change will be partially reflected in an increase in the site values of forest land and longer rotation cycles and partially in an expansion of the land area planted to forests and lower
long-run timber prices.

The economic effects of substituting a realized income tax for the accrued income tax in the forestry sector are, in all essential aspects, similar to those analyzed above for the full-expensing income tax. From equations (2) and (5), the equivalent constant discount relation for the realized income tax, i.e., the analogue of equation (6), may be expressed as

\[ S^* = S (1 - t) - tC \]

The additional term that appears on the right-hand side of the above relation is also independent of \( n \). Thus, by analogous reasoning to the full-expensing income tax case, it can be seen that when the correct (lower) net-of-tax discount rate is used, the impact of a realized income tax on \( S^* \) will also be more favorable for longer maturity periods. In the following section of the paper, a hypothetical numerical example is constructed which illustrates the conclusions reached in this section.

IV. A NUMERICAL ILLUSTRATION

Consider a plot of forest land which under an accrued income tax, has a site value, \( S^* \), of $50 and a planting cost of $25 for establishing each rotation. To highlight the impact of a tax change on site values and the choice of an optimal rotation cycle, the example is structured so that under the accrued income tax, all maturity periods (to a maximum rotation period of 50 years) are equally profitable. The forest grows at a constant annual compound rate just sufficient to provide a gross rate of return of 10 percent on both the initial planting outlay and the site value. A tax rate of 50 percent is assumed, and the corresponding net-of-tax discount rate used by private timber growers is therefore 5 percent.

Following the earlier procedure, it is initially assumed that the supply of land to forestry is perfectly inelastic. Using equations (4)
and (5), the incidence on site values of substituting a full-expensing income tax and a realized income tax, respectively, for the accrued income tax has been evaluated for various maturity periods. Probably the most striking point to emerge from the results, which are given in Table 1, is the magnitude of both the tax-induced bias toward longer maturity periods and the associated increase in site values. For a 50-year rotation cycle, a change in the timing only of taxing income and the tax deductibility of production costs results in an approximately eightfold increase in site values. The comparatively small differences between imputed site values for the full-expensing income tax and the realized income tax indicate that the major influence stems from the postponement of the taxation of income until realization at harvest. The differences in the timing of the tax deductibility of planting costs have a comparatively small effect on site values.

Table 1

<table>
<thead>
<tr>
<th>Maturity period</th>
<th>Stumpage value</th>
<th>Site values</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Full-expensing income tax</td>
<td>Realized income tax</td>
</tr>
<tr>
<td>years</td>
<td>dollars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>32.50</td>
<td>63</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>70.79</td>
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<td>58</td>
</tr>
<tr>
<td>10</td>
<td>144.53</td>
<td>83</td>
<td>70</td>
</tr>
<tr>
<td>15</td>
<td>263.29</td>
<td>98</td>
<td>85</td>
</tr>
<tr>
<td>20</td>
<td>454.56</td>
<td>117</td>
<td>105</td>
</tr>
<tr>
<td>25</td>
<td>762.60</td>
<td>142</td>
<td>130</td>
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<tr>
<td>35</td>
<td>2,057.68</td>
<td>213</td>
<td>200</td>
</tr>
<tr>
<td>50</td>
<td>8,754.31</td>
<td>404</td>
<td>392</td>
</tr>
</tbody>
</table>

a Under the initial accrued income tax, the imputed site value is $50 for all maturity periods.

Source: Calculations based on hypothetical example.
To determine the incidence of tax changes on long-run timber prices when the supply of land to forestry is perfectly elastic, it is first necessary to derive modified forms of equations (4) and (5). These modified equations in which stumpage value appears on the left-hand side of the respective relations are given below:

\[ V_n = \frac{S^*[(1 + r)^n - 1]}{(1 - t)} + \frac{C_0}{1 + r^n} \]

and

\[ V_n = \frac{S^*[(1 + r)^n - 1]}{(1 - t)} + \frac{C_0}{1 + tC} \]

Equations (8) and (9) are then solved for \( n = 50 \) since it is known that after the tax changes, this will be the most profitable maturity period and that the corresponding site value will be $50. Having derived the stumpage values for a 50-year maturity period, the stumpage values for shorter maturity periods can be determined quite simply. The derived stumpage values for both the full-expensing and realized income taxes are given in Table 2. The imputed site values for \( n < 50 \), which are also shown in Table 2, were calculated by substituting the derived stumpage values back into equations (4) and (5) and solving for \( S^* \). It is apparent from the results given in Table 2 that the reduction in stumpage values, which exceeds 80 percent when the full incidence of a tax change is on timber prices, is comparable with the increase in site values when the full incidence of the tax change is on site values.

Stumpage values for values of \( n < 50 \) were derived by multiplying the original stumpage values, shown in Table 1, by the ratio (for \( n = 50 \)) of the new over the original stumpage values. For example, for the full-expensing income tax, the ratio is 1,333.43/8,754.31.
### Table 2

Imputed Site Values for Different Rotation Periods With Full Incidence of Tax Change on Timber Prices

<table>
<thead>
<tr>
<th>Maturity period</th>
<th>Full-expensing income tax</th>
<th>Realized income tax</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stumpage value</td>
<td>Site value</td>
</tr>
<tr>
<td>years</td>
<td>dollars</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4.95</td>
<td>&lt; 0</td>
</tr>
<tr>
<td>5</td>
<td>10.78</td>
<td>&lt; 0</td>
</tr>
<tr>
<td>10</td>
<td>22.01</td>
<td>&lt; 0</td>
</tr>
<tr>
<td>15</td>
<td>40.10</td>
<td>&lt; 0</td>
</tr>
<tr>
<td>20</td>
<td>69.24</td>
<td>1</td>
</tr>
<tr>
<td>25</td>
<td>116.16</td>
<td>7</td>
</tr>
<tr>
<td>35</td>
<td>313.42</td>
<td>19</td>
</tr>
<tr>
<td>50</td>
<td>1,333.43</td>
<td>50</td>
</tr>
</tbody>
</table>

Source: Calculations based on hypothetical example.

### V. CONCLUDING REMARKS

The main thrust of this paper has been expository, and there are clearly a number of directions in which the perfectly competitive comparative-statics model used here could be extended. Some care, therefore, should be exercised in drawing policy recommendations. In the real world we would expect, ceteris paribus, the before-tax rates of return to be lowest in those sectors most favorably treated under existing income tax legislation since it is the net-of-tax rate of return between sectors that competitive market forces will equate. In the absence of nontax market distortions, which are being corrected by a discriminatory tax policy, tax-induced divergences...
between before-tax rates of return represent an inefficient allocation of society's capital since overall returns could be increased by transferring capital from uses with low before-tax yields to those with high yields. Under current income tax legislation in both Australia and the United States, long-lived investments in land-intensive enterprises tend, in general, to be more lightly taxed than short-lived investments. And in forestry where the production cycle is typically extremely long, the effective income tax burden and also, we would expect, the before-tax rate of return are particularly low. Assuming there are no nontax market distortions, the efficiency goal of equal before-tax rates of return between sectors and uses of capital could be attained by simultaneously removing all tax subsidies, that is to say, by applying the accrued income tax uniformly over all sectors.

Actual policy decisions on tax reform tend, however, to be made in a piecemeal fashion, and we know from Lipsey and Lancaster's theory (1956) of the second best that a change toward the conceptual ideal in one sector may worsen rather than improve efficiency if a "first best" situation does not exist elsewhere. It is important, therefore, that when tax reform is being considered for forestry, due cognizance be given to the prevailing tax treatment of other agricultural activities which will commonly provide the best alternative use for resources currently employed in forestry. Incentives to shift resources to Pareto-inferior uses to minimize the tax will be completely removed only when the tax on each use of resources is equal to the tax on their best alternative use.

16 Baumol (1968 and 1970) uses this line of reasoning within the context of selecting an appropriate social discount rate for evaluating public investments. This question is particularly pertinent to forestry because governments tend to be large producers and compete with private enterprise in the production of wood fiber. The return from public investments is, of course, not taxed. Therefore, to achieve the "correct" balance between public and private investment in forestry, the appropriate discount rate for making public investment decisions is that which equals the before-tax rate of return on the resources in their best alternative use.
APPENDIX 1

I consider here the relationship and crucial differences between my approach to the problem and the approaches taken by Gaffney and by Thomson and Goldstein.\(^{17}\)

The whole focus of Gaffney's analysis is on the impact of various taxes on the rate of turnover of capital, that is to say, in the appreciating asset case, the impact of taxes on optimal maturity periods. His model assumes an initial situation in which the pretax internal rate of return is constant for the full continuum of feasible maturity periods. The bias on the optimal maturity period, induced by a particular tax, if any, is measured by the variation of the after-tax internal rate of return associated with differences in the length of the maturity period. Given the constant pre-tax internal rate of return, an increase in the after-tax internal rate of return, as the maturity period is lengthened, denotes a tax-induced bias toward longer maturity periods and vice versa.

If I interpret the assumptions underlying Gaffney's approach to the problem correctly, his standard for comparing each of the after-tax situations is a tax-free economy. Each of the taxes is then, in turn, assumed to be imposed on all sectors of the economy. Moreover, it is implicitly assumed that forests grow on marginal land which has a zero site value and that product and factor prices within the forestry sector remain constant and are not influenced by the imposition of a tax. Ideally, of course, to compare a tax-free economy to an economy "with tax" would require the use

\(^{17}\) The author is grateful to Mason Gaffney for allowing him to read some unpublished research work which has been helpful to the author in preparing the final version of the Appendix. After the present paper was completed Mason Gaffney also brought to the author's notice a good study by Sunley (1972) on Federal tax subsidies to the United States timber industry. While the present paper is concerned solely with alternative types of income taxes, it should be noted here that Gaffney and Thomson and Goldstein also analyze the case of a gross tax imposed on the value of the timber harvest. They conclude, and I consider correctly so, that a gross tax with no tax deductibility of planting costs causes a bias toward longer maturity periods.
of a complete macroeconomic model of budgetary incidence.

Despite substantial differences in our approach to the problem, a comparison of the results given in Table 3 indicates that there is a broad area of agreement between Gaffney and myself with respect to the impact of various taxes on the optimal maturity period. Most importantly, we are in agreement that a uniformly applied accrued income tax will not distort investment decisions. We are also in agreement that a realized income tax induces a bias toward longer maturity periods.

Table 3

Effect of Taxes on Maturity Period

<table>
<thead>
<tr>
<th>Type of Income Tax</th>
<th>Chisholm</th>
<th>Gaffney</th>
<th>Thomson and Goldstein(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accrued</td>
<td>Neutral</td>
<td>Neutral</td>
<td>Not Neutral</td>
</tr>
<tr>
<td>Full expensing</td>
<td>Increase</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Realized</td>
<td>Increase</td>
<td>Increase</td>
<td>Neutral</td>
</tr>
</tbody>
</table>

\(^a\) The full-expensing income tax is equivalent to Thomson and Goldstein's income tax which permits the\(\text{compounded}\) value of planting costs to be deducted from the income realized at harvest. The realized income tax corresponds to their net tax.

Sources: Gaffney (1967 and 1970-71); Thomson and Goldstein (1971).
Our differing conclusions for a full-expensing income tax stem from Gaffney's use of an internal rate-of-return criterion and the fact that, when the impact of this tax on the forestry sector is being analyzed, it is assumed, at least implicitly, that the tax is imposed on all sectors of the economy. Given this assumption, together with the implicit assumption that forests grow on marginal land with a zero site value, it then follows that, regardless of the nominal tax rate, the "effective" tax rate is zero in the sense that the pre-tax and after-tax internal rates of return are identical.

I, on the other hand, explicitly assume that an accrued income tax is applied to other sectors when I analyze the impact of a full-expensing income tax on the forestry sector. In these circumstances, competitive market forces will equate the net-of-tax rate of return in forestry with that in other sectors which have an accrued income tax. And the bias I obtain toward longer rotation periods stems from the use of this lower net-of-tax discount rate.

The results given in Table 3 show that the conclusions reached by Thomson and Goldstein conflict sharply with my conclusions. These differences, I believe, can be traced to a crucial assumption contained in Thomson and Goldstein's analysis (1971, p.27) which they make no attempt to defend, namely, the before-tax and net-of-tax discount rates are identical. If it is accepted that the appropriate before-tax and net-of-tax discount rates to evaluate investments in forestry are those which measure the before-tax and net-of-tax rates of return on the best alternative use of the resources, there would appear to be two situations in which it could be argued that the use of a constant discount rate is justified.

The first is one in which the particular tax under consideration is assumed to be imposed on the forestry sector only and is not imposed on other
sectors which compete with forestry for resources. The second situation is one in which a tax is imposed uniformly on all sectors but is confined to a small tax jurisdiction (e.g., a regional or state tax) so that the net-of-tax supply price of capital is independent of any tax changes within the particular jurisdiction.

The first case is simply not relevant since a federal income tax which taxes the interest earned on capital is, in fact, imposed on other sectors. The second situation is probably relevant for some state taxes in the United States, although, if this is the situation Thomson and Goldstein had in mind, they did not say so in their paper. If a state that is unable to influence the net-of-tax supply price of capital were to impose a full-expensing income tax, it can be seen from equation (6) that all site values will be reduced proportionately by an amount equal to the rate of tax. All land in forestry before the tax will remain in production after the tax and, furthermore, the tax will not influence the choice of the optimal maturity period. A similar conclusion also holds for the imposition of a realized income tax except that it is now apparent from equation (7) that some imputed site values may become negative, and any such land will be taken out of production. The tax though does not affect the choice of the optimal maturity period. The results obtained by Thomson and Goldstein are thus quite valid for the above set of circumstances. As I interpret Gaffney, however, he is concerned with taxes imposed uniformly over a whole economy and not just a small tax jurisdiction within an economy. A substantial part of Thomson and Goldstein's criticism of Gaffney's work is, therefore, in my view, unjustified; and I believe they have considerably underestimated Gaffney's contribution to this area of research.
REFERENCES


APPENDIX
Criteria for Determining the Optimum Replacement Pattern

ANTHONY H. CHISHOLM

This article is an attempt to clarify some confusion that has been apparent in the literature of agricultural economics in recent years with respect to providing a criterion for determining the optimum replacement pattern for long-lived assets. In particular, for appreciating assets of the type represented by growing timber, the previous criteria have generally overlooked an important item of marginal cost: namely, the interest on the total revenue obtainable from the sale of the asset. These criteria have hence provided a replacement pattern which is longer than the optimum.

In an article which appeared in this journal, Faris [2] presented a criterion for determining the optimum duration of the production period for enterprises that are of a sequential nature. The Faris criterion was subsequently criticized by Winder and Trant [5], who put forward two alternative criteria. However, in his reply [3] Faris maintained that Winder and Trant's criticism did not invalidate the general principle of optimum replacement as set forth in his initial paper. In my opinion this controversy was not satisfactorily resolved; it is my belief that both Faris in his original paper and Winder and Trant in their critical note overlooked an important component of the marginal cost of an increment of time. The aim of this note is to use the forestry example given by Faris [2, pp. 761-764] for the purpose of illustrating this point and helping to clarify the issue. The pertinent portion of the original data given by Faris and also some additional information based on this data are summarized in Table 1.

I make no claim to originality for the conclusions reached in this note, since they can be fairly simply derived from the classic Faustmann formula of forest economics. Gaffney [4] has published a very comprehensive study, based largely on Faustmann's approach, in which he critically reviews most of the techniques that have been proposed from time to time for determining the financial maturity of an asset. It is apparent from this controversy, however, that some confusion still exists with respect to defining marginal cost within the context of the forest-rotation type of replacement problem. The following definitions by Winder and Trant will be used in this note:

- $n$ is the duration of a production period;
- $v$ is the gross revenue per period;
- $c$ is the variable cost per period;\(^1\)

\(^1\) Both $c$ and $f$ embody appropriately compounded interest charges that permit costs to be compared with revenues at the same point in time.

ANTHONY H. CHISHOLM is a research fellow in the Faculty of Agricultural Economics of the University of New England, Australia.
Table 1. Production costs and revenues per acre for timber production

<table>
<thead>
<tr>
<th>Age of trees (years)</th>
<th>Total revenue</th>
<th>Establishment and running costs</th>
<th>Net revenue</th>
<th>Marginal net revenue</th>
<th>Average net revenue</th>
<th>Present value of net revenue</th>
<th>Amortized present value of net revenue</th>
<th>Present value of total net revenue</th>
<th>Average annual increment in total revenue</th>
<th>Annual increment in total revenue as a percent of capital value</th>
<th>Interest cost with respect to time</th>
<th>Marginal cost with respect to time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td>9.82%</td>
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* The methods used for deriving columns 1-7 are given by Faris [2].

** The figures given in column 8 are derived from the formula $PNV^* = PNV + \frac{PNV}{(1+i)^n - 1}$. 

PNV = $\frac{V_n + C_n}{(1+i)^n - 1}$
The Optimum Replacement Pattern

\[ f \] is the fixed cost per period, and may be regarded as the cost of initiating a production period;  
\[ P \] is the net payoff of each period, i.e., \( v - e - f \);  
\[ i \] is the ruling market interest rate for outside borrowing and investment;  
\[ r \] is the time-preference discount rate;  
\[ A \] is the amortized present value of net revenue;  
\[ A^* \] is the maximum amortized present value of net revenue;  
\[ PNV \] is the present value of net revenue from a single production period;  
\[ PNV^* \] is the present value of net revenue from a perpetual sequence of production periods.

In terms of these definitions, the Faris criterion is

\[
\frac{dP}{dn} = A^* \max,
\]

where \( d_n = 1 \). That is, according to Faris, “The optimum time to replace is when the marginal net revenue from the present enterprise is equal to the highest amortized present value of anticipated net revenues from the enterprise immediately following” [2, pp. 761-762]. Applying this criterion to the data given in Table 1, Faris concludes that the optimum time to cut the present stand of timber is at the end of the fifty-third year.

Winder and Trant [5], in formulating their criteria, make a careful distinction between opportunity costs and time preference. They state that opportunity costs refer to alternative income-earning possibilities, and that these costs are considered in both their criteria, whereas time-preference proper is preference for income in one time-period rather than another, and is considered only in the second criterion.

Their no-time-preference-proper criterion is

\[
\frac{dv}{dn} - \frac{de}{dn} = \frac{P}{n}.
\]

That is, the aim should be to maximize profit per unit of time, which requires equating the marginal net rate of profit per unit of time to the average net rate of profit per unit of time. According to this criterion the optimum time to cut the present stand of timber is at the end of the forty-eighth year.

*The amortized present value \( A = P [1/(1+i)^n - 1] \)
*For long-lived assets, such as forest rotations, continuous discounting is in many ways preferable to annual discounting; however, in order to conform with the notation used in the articles under discussion, an annual discounting procedure is adopted.
*It should be noted that Faris used the term time preference to denote opportunity costs or alternative income-earning possibilities. It appears that Winder and Trant's definition of time preference corresponds to what Faris referred to as “discounting for risk and uncertainty.”
Winder and Trant’s time-preference-proper criterion is

\[ A^* = P \frac{r}{(1 + r)^n - 1} \]

According to this criterion the optimum time to cut the present stand of timber is at the end of the forty-third year.

Winder and Trant conclude that, of the two criteria, the one maximizing net profit per unit of time in the absence of time-preference proper appears to be more important than the one embodying time-preference proper [5, p. 950]. They reach this conclusion because according to their definition time preference is simply preference for income in one time-period rather than another and as such is not related to opportunity costs (or alternative income-earning possibilities).

We may begin with a general premise which appears to be fairly universally accepted, namely that the aim in replacement problems is to select the particular production period which over a specified planning horizon will yield the maximum net present value of future profits. From this deceptively simple criterion arises the real problem of correctly specifying all the cost elements, both actual and opportunity. There appears to be complete agreement that the fixed and variable costs which are actually incurred should be compounded at an appropriate interest rate to permit comparison of costs and returns occurring at different points in time. The point that appears to have been overlooked by the previous authors is that not only does the money sunk in fixed and variable costs have an opportunity cost, but so also does the money tied up in the appreciating asset (i.e., the growing trees). This is perhaps best illustrated if we look at the total-revenue column in Table 1. It is apparent that if the 46-year-old stand were harvested immediately, $651.00 would be released for consumption or for some other investment. Hence, if we assume a return of 3 percent on outside investment, the stand should be left unharvested only so long as the value of its annual increment in growth is at least as high as that which could be obtained if the stand were cut and the money released. If the $651.00 were released, the annual interest at 3 percent would amount to $19.53. On the other hand, if the stand were left uncut, the average annual value of the growth increment between the forty-sixth and forty-eighth year would be $18.50. Hence, on the grounds of the annual interest on the total revenue obtainable from the sale of the trees alone, it is uneconomic to leave the stand unharvested beyond the forty-sixth year. The Faris determination and the first criterion proposed by Winder and Trant would therefore appear to be invalid.

An indication of the rate of return on the money tied up in the trees is given in column 10, where the annual increment in total revenue is expressed as a percentage of the capital value of the trees.

\[^{a}\text{An indication of the rate of return on the money tied up in the trees is given in column 10, where the annual increment in total revenue is expressed as a percentage of the capital value of the trees.}\]
It is suggested that the following criteria, or any modified form thereof, provide the optimum duration of a production period. First, it should be stressed that these criteria incorporate the following elements of marginal cost with respect to time: (a) the annual running cost ($1.30 in Fari's example), (b) the interest on the total revenue obtainable from sale of the asset, and (c) the amortized value of net returns from the following rotation.

The net-present-value criterion provides the solution to the problem if the aim is to select the production period which maximizes the net present value for a perpetual sequence of production periods, and not, as has sometimes been advocated, to choose the single production period having the maximum net present value. Assuming a time horizon of $t$ production periods, we may express this criterion as

\[ \text{PNV}^* = \frac{P_1}{(1+i)^n} + \frac{P_2}{(1+i)^{2n}} + \ldots + \frac{P_t}{(1+i)^{tn}} \quad a\ max. \]

For a perpetual sequence of production periods, this equation may be expressed as

\[ \text{PNV}^* = \text{PNV} + \frac{\text{PNV}}{[(1+i)^n - 1]} \quad a\ max. \]

From Table 1, column 8, it can be seen that a perpetual sequence of rotations, each 43 years long, provides a maximum net present value\(^6\) of $165.32. The maximum net present value for a single production period ($120.93) occurs at the end of the forty-sixth year.

Where $P_1$, $P_2$, \ldots, $P_t$ are equal, as assumed in this example, the preceding criterion can be redefined as follows:

\[ A^* = P \frac{i}{(1+i)^n - 1} \quad a\ max. \]

This is equivalent to the time-preference-proper criterion given by Winder and Trant. However, I consider that this formula embodies, not time-preference proper, as defined by Winder and Trant, but rather all the relevant opportunity costs of the resources tied up in the production process.

There are a number of closely related criteria which illustrate the relevant opportunity costs of continuing the present production period. For example, if we adopt a marginal-revenue-equals-marginal-cost (with respect to time) criterion, the equation is

\[ V_{n+1} - V_n = IV_n + c_n + A^*. \]

\(^6\) Clearly, maximizing the net present value will provide the same optimum-length production period as maximizing the cumulative profit at some terminal point, providing that the interest earned on the "throw-off" at the end of each production period is taken into account.
where \( V_n \) is total revenue from sale of the timber at age \( n \) (column 1, Table 1) and \( c_n \) is the annual running cost at age \( n \) ($1.30 in the example). A comparison of columns 9 and 12 in Table 1 on the basis of this criterion indicates that the optimum length of the rotation is 43 years. Equation (7) is only approximate and is more precisely given as a double inequality:7

\[
V_{n+1} - V_n - c_n - iV_n \leq A^* \leq V_n - V_{n-1} - c_n - 1 - iV_{n-1}.
\]

Faris's contribution in providing a statement of a dynamic criterion for replacement should not be overlooked. Apparently his error stemmed from his definition of marginal net revenue. His verbal statement is, however, valid when marginal net revenue is defined correctly as \( \Delta Y - iV_n - c_n \).

I gratefully acknowledge the referees' comments on this note and in particular their bringing to my attention a paper written subsequently to this note, giving the form of the double inequality of equation (8). See Burt [1, esp. p. 332].

References


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CHAPTER 5

COMPARISON OF INCOME AVERAGING PROCEDURES
FOR INCOME TAX PURPOSES
EXTRACT FROM
THE AUSTRALIAN JOURNAL
OF AGRICULTURAL ECONOMICS

The Journal of
The Australian Agricultural Economics Society
A COMPARISON OF INCOME AVERAGING PROCEDURES FOR INCOME TAX PURPOSES

A. H. CHISHOLM*

Australian National University

A comparison is made of a number of income averaging procedures on the basis of selected performance criteria. The main conclusion which emerges is that the Australian income averaging procedure, currently applied to primary producers, has a number of defects. Several of the alternative income averaging procedures reviewed are judged to be superior to the current Australian system.

It is well known that the interaction of an annual tax accounting period and a fixed progressive rate scale causes taxpayers with unstable annual incomes to pay more taxes over a span of years than those receiving the same total income in equal annual amounts. This fact has significant implications with respect to both equity and resource allocation, and has led to a number of proposals for supplementing the automatic averaging period of one year by some procedure for inter-period averaging [12, 14]. In Australia, due to the particular instability of income derived from primary production, primary producers may use a five-year moving average income to determine the rate of tax applicable to their current year’s income [3]. This paper aims to compare this averaging system with a number of alternative procedures.

The main focus of the paper is on income averaging for primary producers. It is clearly inequitable, however, to discriminate between unstable incomes according to their source. Primary producers do not have a monopoly on earning unstable incomes, viz. authors, entertainers, Miss Worlds, etc. Some consideration is therefore given to certain aggregative effects of particular income averaging procedures, which would arise if they were applied to all taxpayers with unstable incomes.

The need for some system of averaging for unstable incomes can be argued both on the grounds of equity and resource allocation. Whilst the most widely accepted notions of equity, as embodied in the ability-to-pay concept, do not point unambiguously to an ideal time period for measuring income, most writers agree that mere irregularity of the income flow is unlikely to increase an individual’s ability to pay tax. A related equity problem arises if the rates of income tax are changed from time to time, as part of a government’s stabilization policy. Compared with a taxpayer with a stable annual income, a taxpayer whose income fluctuates directly with tax rate changes pays more tax, while one whose income fluctuates inversely with rate changes pays less tax.

A somewhat distinct group of problems arises from the fact that, in practice, the partitioning of a flow of income into separate annual periods is achieved by the use of a number of essentially arbitrary rules.

* This paper reports on an aspect of a research project which has been partly financed by the Rural Credits Development Fund of the Reserve Bank. The author would like to thank his colleagues for their comments and suggestions.
for determining when income from appreciating and depreciating assets is realized. This creates opportunities for taxpayers to influence the timing of their tax payments, by adjusting the date at which income is realized. For instance, a taxpayer may seek to reduce his tax burden by adopting a system of do-it-yourself averaging. Alternatively, if the scale of tax rates is changed in accordance with economic conditions, a taxpayer may speculate on these changes by realizing a higher taxable income in years when rates have been reduced, and conversely. Finally, the assessment of income tax on realized income, rather than accrued income, provides an incentive for taxpayers to postpone the realization of income from appreciating assets, and thus their tax liability, thereby effectively obtaining the use of an interest free loan.1

The opportunities that taxpayers will have for influencing the timing of their tax burden are greatest when the income tax base includes realized income from all appreciating and depreciating assets. However, the present Australian income tax, which is commonly thought of as excluding most capital gains, still provides opportunities for shifting the realization of income.2 The reduction in the tax burden achieved by shifting income over time is inequitable, as it favours taxpayers who are in a position to manipulate the timing of their taxable income. The equity arguments in favour of some system of income averaging are reinforced by the potential distortion in the allocation of resources. Without some averaging procedure, investments yielding an unstable income flow are discriminated against. The optimum pre-tax farm enterprise combination, or farm development plan, will thus not necessarily be the post-tax optimum. Quite apart from the direct distortion of resource allocation, there is likely to be a misallocation of effort, as attempts are made to incorporate this aspect of taxation into decision making.

**Criteria for Comparing Income Averaging Procedures**

A necessary prerequisite for a comparison of alternative income averaging procedures is the specification of the desirable characteristics.

1 From a theoretical viewpoint, the most interesting proposal for income averaging has been made by Vickrey [13]. The proposal is for a cumulative income averaging scheme, and is based on the presumption that the correct base for an income tax is accrued income, including all capital gains and losses, and that the relevant period for averaging is the lifetime of the taxpayer. The primary objective of the scheme is to eliminate the incentive to reallocate income among years, and in particular, the postponement of the realization of capital gains. The scheme involves a fairly complicated procedure of interest rate adjustments aimed at causing taxpayers with equal earning resources to report the same total income, and pay the same discounted value of tax payments, regardless of the time that income is realized for tax purposes. From an administrative viewpoint the procedure has several major defects. Partly for this reason, and also because there is no indication that a complete capital gains tax will be introduced in Australia in the foreseeable future, Vickrey’s proposal is rejected as a practical alternative to the more rudimentary ‘short-period’ averaging procedures discussed in this paper. None of these procedures reduce the incentive to postpone the realization of capital gains.

2 For instance, a farmer has some degree of flexibility in timing the realization of income from appreciating assets in the form of livestock, or a farm forest. Even for products with a production cycle of less than one year, income may be shifted between accounting periods when the normal sale date coincides with the end of a financial year. Similarly, farmers may alter their timing of tax payments by adjusting maintenance expenditure on depreciating assets such as fences and farm buildings.
of an averaging system. The following criteria have been adopted as a basis for comparing the relative performance of alternative income averaging procedures.

(i) The total tax payment for an unstable annual income should be approximately equal to that for a stable income of the same average magnitude.

(ii) Annual tax payments should be responsive to current income without lag. In particular, any given annual tax payment should not exceed the tax that would have been due under a simple annual progressive tax.

(iii) Tax revenue should be responsive to modification of the rates without lag.

(iv) There should be no benefit to be gained from shifting income between years in response to actual, or expected, modification of the rates.

(v) The averaging procedure should not impose an unreasonable administrative burden, or lead to difficulty of taxpayer compliance.

The above requirements need some elaboration. First, most writers on the topic agree that, from an equity viewpoint, some kind of averaging is required for unstable incomes because the annual accounting period is too short a period on which to base tax progression. There is also reasonable consensus that period equity should be the primary objective of income averaging, and that the period for measuring income should be related to the economic horizon of the taxpayer. Results from empirical work aimed at determining the economic horizon of individuals vary. Some work seems to indicate that the economic horizon of the consumer with respect to adjusting their actual consumption and savings patterns to changes in income are of the order of three to seven years. On the other hand, other work suggests that savings and consumption patterns are related to the sum of current and expected discounted earnings over a lifetime. It is not surprising, therefore, to find that proposals for income averaging fall into one of two distinct groups; lifetime averaging, and averaging over a period of three to seven years.

In the present paper the comparison has been confined to 'short-period' averaging procedures. Even if averaging should ideally be over a taxpayer's lifetime, it seems to the writer that administrative considerations, particularly the problem of inflation, would make it difficult to adopt a period of greater than, say, seven years.

Second, compared with an annual progressive tax, some averaging procedures have the undesirable characteristic of substantially reducing the tax burden in high income years whilst increasing it in low income years.

3 It is interesting to note that under a regressive income tax scale smaller tax payments would be made for a varying annual income than for a stable income of the same total size. Only under a proportional income tax does the way in which income is distributed over time, and thus the period over which it is measured, become unimportant. It should also be pointed out that most writers do not distinguish between different forms of unstable income. Goode [6], however, asserts that the case for averaging is strongest with respect to income received in one year for effort extending over several years, and for cyclical fluctuations. He argues that on equity grounds the case is weak with respect to movements from one normal income level to another, and for sustained upward or downward trends in income. No attempt has been made in this paper to distinguish between different forms of unstable income.
years. This reduces the counter-cyclical flexibility of an annual pro­
gressive tax, and imposes hardship on the taxpayer in years of low
income. The fact that added taxes may be paid in some years, and
substantially lowered taxes in other years, also creates problems when
taxpayers are leaving or entering the tax jurisdiction. Ideally the pro­
portional reduction in tax payments in low income years, resulting from
averaging, should be at least as great as those in high income years.
Third, in recent years modification of the tax rates has, in a number
of countries, become an important counter-cyclical device. In Australia
the schedule of rates of income tax was unchanged over the period
1954-70. However, over the past decade a system of rebates and levies,
expressed as a percentage of income tax, has been developed. Applying
or removing this levy, or rebate, has generally been regarded as one
of the most successful recent innovations in the development of counter­
cyclical taxation policy in Australia. The ability of an averaging system
equitably to allow a rapid and predictable response to tax rate adjust­
ments is thus important, particularly if income averaging were to be
extended to all taxpayers.
Fourth, speculative shifting of income in response to modification of
the rates is clearly inequitable. Moreover, it makes it more difficult for
a government to predict the impact of rate changes.
Fifth, apart from computational simplicity, the administrative burden
will be reduced if averaging is optional, and there is some simple
eligibility rule in terms of some minimum tax saving and/or income
fluctuation. A defect of optional averaging is that it can sometimes
interact with rate changes to unduly favour a taxpayer. For instance,
a taxpayer may withdraw from averaging in a year of low income which
coincides with the imposition of a tax levy, and re-enter the following
year. Any inequities that this introduces would need to be balanced
against the lighter administrative burden of optional averaging, as com­
pared with compulsory averaging.

Alternative Income Averaging Procedures
Income averaging procedures may be based on the historic income
of the taxpayer, his expected future income, or both. The former are
more numerous and may be grouped into three broad classes; the block
average, the moving average, and the cumulative average. Income ad­
justment accounts (IAA) provide the main system of forward averaging.
In addition to these averaging procedures there is a partial averaging
device in the form of carry-over of negative net taxable incomes. This
is aimed at reducing the penalties imposed on income fluctuations
immediately above and below zero net taxable income. It is these fluctua­
tions that face the steepest rise in progressive rates and thus incur the

4 The benefit to be gained by a taxpayer on a high marginal tax rate from
successfully speculating on tax rate changes is greater than may be anticipated.
For instance, the postponement of realization of income for one year in order
to obtain a 5 per cent tax rebate, provides a taxpayer having a 60 per cent
marginal tax rate, with a post-tax yield of 7.5 per cent. To achieve a post-tax
yield of 7.5 per cent on an ordinary taxed investment, this taxpayer would require
an investment with a pre-tax yield of approximately 19 per cent.
5 The block average is sometimes called a simple average and the cumulative
average a progressive average.
It is considered that all averaging procedures should allow the carryover of negative taxable incomes. The performance of each averaging procedure has been tested by applying it to a range of hypothetical, and actual, income series data. For purposes of illustration, the application of the various averaging procedures to the estimated average taxable income of sheep farms in the High Rainfall Zone of New South Wales, over the fifteen year period 1952-53 to 1966-67, are given in Table 1. The averaging procedures are now considered with respect to each of the proposed desirable attributes of an averaging system given earlier. An attempt has been made to summarize the main results in Table 2. For each criterion, the performance of each averaging procedure has simply been classified as good, fair, or poor. There is, of course, an inevitable subjective element in making such a simple and explicit classification, and Table 2 should be interpreted in conjunction with the discussion on the various averaging procedures.

The Block Average

The block average is conceptually the simplest form of averaging. Taxes are paid annually upon each year's income in the usual way. At the end of the averaging period, the total income for the averaging period is determined and pro-rated equally over the period. The tax of each year is then recomputed, at the rates applicable in each year, and these taxes are totalled. This total is then subtracted from the total tax actually paid in respect of the averaging period and the difference assessed against, or refunded to, the taxpayer. Normally the taxpayers will receive a refund. With changing tax rates, however, it is possible for a taxpayer realizing a high income in low rate years, and vice versa, to pay less tax than a taxpayer with a stable income. The block of years to be averaged does not overlap, thus each year enters the averaging computation only once.

A number of writers on this topic have proposed that taxpayers should be able to block average their incomes [2, 4]. It was usually argued that, to reduce the administrative burden, qualifying restrictions based on attaining a specified minimum income fluctuation, and/or minimum tax saving, should be imposed. In the case of the proposal made by Downing, et al. [4], averaging is restricted to taxpayers whose income in a given year is 20 per cent, or more, below his average income over the past five years.

Under a block averaging procedure the condition of period equity is completely fulfilled, irrespective of whether annual income fluctuates around a stable mean, or is characterized by a sustained upward or

6 The net farm income data was obtained from The Australian Sheep Industry Survey (1962-67) published by the B.A.E. [1], and by private communication with the B.A.E. A sum of $2,000 covering all tax deductable items for a married man with two children, including life insurance and interest on farm debt, has been deducted from the net farm income figures to provide an approximation to taxable farm income. It should be stressed that these figures are presented for purposes of illustration only. The average variability of the individual farm net incomes would be greater than the variability of the average net farm income. However, this does not necessarily apply to taxable incomes because farmers tend to adopt a do-it-yourself averaging system by incurring, for instance, high repairs and maintenance expenditures in high income years and conversely.
### Five-Year Moving Averages

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<th>Seven-Year Block Average</th>
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<tr>
<td>(c)</td>
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</tbody>
</table>

**Notes:**

(a) The tax calculations are based on the schedule of rates operating for the financial year ending June, 1970.

(b) The unbracketed figure in each column is the percentage additional tax for the fifteen-year period, compared with the tax payable if annual income was constant within each of the five-year block periods. The bracketed figures are the minimum and maximum percentage amounts, respectively, by which the tax paid for a

five-year block period exceeds that payable on a constant income within the block period. For instance, with the Type I moving average, the tax paid over the third five-year period is 16 per cent less than for a constant income, whilst it is 128 per cent greater for

annually income was constant within each of the five-year block periods. The bracketed figures are the minimum and maximum percentage amounts, respectively, by which the tax paid for a

five-year block period exceeds that payable on a constant income within the block period. For instance, with the Type I moving average, the tax paid over the third five-year period is 16 per cent less than for a constant income, whilst it is 128 per cent greater for

the second five-year period.

(c) As for (b), except it is assumed that income should be measured over block periods of seven years.
TABLE 2

Relative Performance of Alternative Income Averaging Procedures

<table>
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<tr>
<th>Performance Criteria</th>
<th>Annual Progressive Tax</th>
<th>Five-Year Block Average</th>
<th>Downing’s Block Average</th>
<th>Five-Year Cumulative Average</th>
<th>Moving Averages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Type I</td>
</tr>
<tr>
<td>Fluctuating annual income</td>
<td>Poor</td>
<td>Good</td>
<td>Fair</td>
<td>Poor</td>
<td>Fair</td>
</tr>
<tr>
<td>Sustained upward income trend</td>
<td>Poor</td>
<td>Good</td>
<td>Poor</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Sustained downward income trend</td>
<td>Poor</td>
<td>Good</td>
<td>Fair</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>Response to current income</td>
<td>Good</td>
<td>Fair</td>
<td>Fair</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Response to modification of rates</td>
<td>Good</td>
<td>Fair</td>
<td>Fair</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Inequities and speculation arising from</td>
<td>Poor</td>
<td>Good</td>
<td>Fair</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>rate modifications</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
<td>Poor</td>
<td>Fair</td>
</tr>
<tr>
<td>Administrative burden</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
</tr>
</tbody>
</table>

* Type III* represents a modified version of Type III.
downward trend. The response of the payments to current income is the same as for an annual progressive tax, except that the taxpayer receives a refund every fifth year. From the taxpayer's viewpoint the lumpy nature of the tax rebates, and the relatively long waiting period before they are received, is undesirable. The latter defect could be met by adding an interest adjustment factor to the refund.

Staggered entry would probably be required if all, or a large proportion, of taxpayers were permitted to block average their incomes. If all taxpayers began block averaging at the same point in time, tax refunds would be bunched and would introduce an element of inflation in the years in which they were paid. Over time, however, as new taxpayers entered the jurisdiction and old ones left, the bunching problem would be reduced. With an established block averaging system, in which the bunching problem had been overcome, tax revenues would be responsive to modifications of the rates without lag. Moreover, there would no longer be any benefit to be gained from shifting income in response to modification of the rates. The administrative burden would be reasonable. For each taxpayer a record would need to be kept of the year in which his current block average began, the cumulative taxable income, the cumulative tax paid, and the tax rates ruling for each year of the averaging period.

The Cumulative Average

Under a cumulative averaging system the total sum of taxes paid over the averaging period equals the total taxes that would have been paid had the cumulative average income been received in equal annual amounts. The tax due in the current year is determined by multiplying the cumulative average income by the tax rate applicable in each year of the averaging period, summing these figures, and subtracting from this amount the total taxes already paid. Unlike the block average, the income of a particular year enters into the average repeatedly. Unlike the moving average, the most remote year in last year's average is not dropped from the current year's computation.

A cumulative averaging procedure is particularly appropriate for long averaging periods, and it is this procedure which is usually recommended by advocates of lifetime averaging. For equal averaging periods, a cumulative average gives similar results to a block average. The main difference being that an adjustment is made every year to the tax payable under the cumulative average, and not simply a lump sum adjustment at the end of the period. The present value of tax rebates to the taxpayer is thus greater.

The tax payment is particularly responsive to current income. The tax payment in any year will not exceed the tax that would have been due with no averaging. The change in tax revenue resulting from modification of the rates, in the form of a constant percentage rebate or levy, will be low in years of high income and high in years of low income, as compared with no averaging. This is due to the percentage rebate, or levy, being imposed on the cumulative average income rather than the current year's income. Providing this is realized by the government, the tax rate can be adjusted accordingly. Too, a cumulative average substantially reduces the incentive to speculate on rate modifications,
as these are based on the cumulative average income which will usually respond only slightly to changes in current income. The only information that would be required to be carried forward from the preceding year would be the cumulative income and the cumulative taxes paid. With rate modifications it would also be necessary to keep a record of the tax rates applying in each year.

Moving Averages
There are a number of types of moving averaging procedures. Their common feature is that they all utilize a moving income base.

Type I
The Type I moving average computes the tax payable each year on the basis of the average income for the current year and the preceding years of the averaging period. That is, tax on the income for the first year of the averaging period would be paid. The tax for the second year would be based on the average taxable income for the two years and so on. This procedure would be continued for the period of time established as the averaging period whereupon the first year would be dropped and the current year added. The procedure was introduced in the State of Wisconsin in the late 1920s, but due to a number of serious defects is now only of historic interest. The most notable defects are that it can result in very high tax payments being due in low income years, and that the tax paid over the averaging period may differ substantially from the tax paid on a stable income of the same total size.

Type II
This is the averaging procedure currently applied to primary producers in Australia. The moving average income is used to determine the effective rate at which current income is taxed. The effective tax rate is derived by dividing the average income for the five year averaging period into the tax payable on the average income. The tax due in the current year is computed by multiplying the current year's income by the effective tax rate. Under the present Australian system the full benefits of averaging apply only to primary producers whose current taxable income and average income over the five year period are both less than $16,000. Averaging is optional. However, under the present law once a primary producer has elected to average and then subsequently withdrawn from the scheme, he cannot elect to re-enter. Averaging can only commence when a taxpayer's taxable income of one year is equal to, or greater than, the taxable income of the previous year. That previous year then becomes the first year of the moving average. Primary producers are also currently permitted to carry forward negative taxable incomes for an indefinite period and then write them off against future income.

The Type II moving average fulfils the requirement of period equity reasonably well when differences between the average income of successive five year block periods are small. When there are significant differences between the average income of successive five year block periods, the total tax paid on the fluctuating income, over each period, will not be equal to the tax on a steady income of equal size. For income streams characterized by a downward trend, the total tax paid will
always exceed both the tax payable on a constant income of the same average magnitude, and the tax that would have been payable with no averaging.

For an upward trending income, the total tax payments under the Type II moving average will never exceed those which would have been paid with no averaging. The total tax payments may be less, or greater than, the total tax payable on a stable income. In contrast to the situation with a downward trending income, the effective tax rate applied to the current year’s income will always be less than the annual progressive tax rate. The tax penalty imposed on upward trending incomes will thus always be reduced. Usually the total tax payment will still be greater than that on a stable income. It is feasible, however, when income rises rapidly from a zero or low level that the tax penalty will be overcompensated for. Other weaknesses inherent in this averaging system derive from a common cause, namely the undue lag in the responsiveness of current tax payments to changes in income. This causes the tax payments in low income years to be greater than they would have been in the absence of averaging, thus impairing the built-in flexibility of the annual progressive tax, and accentuating the hardship facing individual taxpayers in these years. Conversely, in high income years the tax payments will usually be considerably lower than with no averaging.

When rate modifications are in the form of rebates or levies based on a constant percentage of annual tax payments, as is currently the situation in Australia, the lag between current tax payments and changes in income will also cause a lag in the responsiveness of tax revenue to rate changes. Moreover, the inequities arising from changing tax rates and fluctuating incomes, and the benefits attained from shifting income between years, are only slightly reduced under this averaging procedure. The administrative burden is slightly greater than for the block average.

Type III

With a Type III moving average the current tax payment is derived from two components. The first component is the simple moving average, that is, the tax payable on the moving average income at the current rate. The second component involves an adjustment factor. This is determined by multiplying the marginal tax rate on the moving average income by the difference between it and the current year’s income. If the current year’s income exceeds the moving average income the adjustment factor will be positive, and is added to the first component to derive the current tax payment. Conversely, when the current year’s income is less than the moving average income, the adjustment factor is subtracted from the first component.

The Type III moving average fulfills the requirement of period equity at least as well as the Type II moving average when differences between the average income of successive five year block periods are small. This is due to the moving average income fluctuating only slightly in response to changes in current income. The marginal tax rate will, therefore, be fairly stable. Its application to deviations from the moving average income results in positive deviations being taxed at approximately the same rate as is used for computing the tax adjustments for negative deviations. Where a five year period with a low average income follows a high average income period, the total tax paid in the low income
period will usually be equal to, or less than, that paid on a stable income. This is in contrast to the undesirable feature of the Type II moving average, whereby the total tax paid in a low income period will usually be significantly greater than what would have been paid with no averaging. With trend incomes the results are the converse of those for the Type II moving average. For downward trends in annual income the total tax payments will be substantially less than with no averaging, but usually not less than the tax on a stable income of the same total size. The total tax payable on an upward trending income, whilst always less than with no averaging, will be greater than that for a constant income of the same average magnitude.

The Type III moving average maintains the built-in flexibility of the annual progressive tax to a significantly greater extent than does the Type II moving average. Generally the Type III moving average will result in a proportionately larger decrease in tax payments in low income years than in high income years. With an unchanged rate scale the tax payment in any year will never exceed the tax that would have been payable with no averaging. With a changing rate scale the current tax payment may exceed that payable with no averaging if a low income year, following several high income years, coincides with a substantial increase in the rate scale. In general, however, when the current year's income is significantly below the moving average income, the tax payment for that year will be substantially below the tax payable with no averaging. This is in direct contrast to the Type II moving average.

The inequities, and incentive to shift income, arising from the interaction between changes in the rate scale and a fluctuating income stream, can be largely overcome by applying the fluctuating component of the tax rate to the moving average income, rather than to the current income. The incentive to shift income to years in which the tax scale was expected to be lowered would be significantly reduced, since such income shifts would have a comparatively small effect on the moving average income. To achieve the same adjustment in tax revenue from the rate modification, it would be necessary to impose a higher levy in high income years and provide a lower rebate in low income years, compared with the situation where the fluctuating component of the tax rate is applied to the current year's income. The administrative burden is comparable with the Type II moving average.

The administrative burden of the Type III moving average could be substantially reduced by using a weighted moving average income. [8, p. 352-3]. This could be based on a system of weights which gradually decreases the influence of old income. For instance, the income for each year could be given a weight which is a constant proportion of the weight assigned to the income of the succeeding year. Each weight may, for example, be four-fifths of the weight attached to the income of the succeeding year. Under this system the older incomes

1 For instance, over the low income years 6-10 given in Table 1, the total tax paid with no averaging is $966, whilst $1,239 tax is paid under a Type II moving average.
have a continuously decreasing influence on the average income until their effect is negligible. The weighting coefficient, which is the ratio between successive weights, can probably most easily be determined by deciding what percentage of the total weight should be attached to income of, say, the preceding five years. A weighting coefficient of between 0·70 and 0·80 gives results which approximate reasonably closely those obtained with the Type III moving average. In Table 3 the weights for a weighting coefficient of 0·70, 0·75 and 0·80 are given. A weighting coefficient of 0·75 has been used for the net income data for the N.S.W. High Rainfall Zone. This system of weighting simplifies the calculation of the average income and minimizes the data which need to be carried forward. Once the weighted average has been calculated it contains all the relevant past income data and is the only information which needs to be carried forward.

TABLE 3
Averaging Weights for Various Weighting Coefficients

<table>
<thead>
<tr>
<th>Weights by Years</th>
<th>Weighting Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>w = 0·70</td>
</tr>
<tr>
<td>Weight for income of present year, t</td>
<td>0·300</td>
</tr>
<tr>
<td>Weight for income of year t−1</td>
<td>0·210</td>
</tr>
<tr>
<td>Weight for income of year t−2</td>
<td>0·147</td>
</tr>
<tr>
<td>Weight for income of year t−3</td>
<td>0·103</td>
</tr>
<tr>
<td>Weight for income of year t−4</td>
<td>0·072</td>
</tr>
<tr>
<td>Total weight for the income of the most recent five years</td>
<td>0·832</td>
</tr>
</tbody>
</table>

Type IV
This averaging procedure combines a moving income base with the block averaging procedure. Annual tax payments are calculated in each year according to the block average procedure, but the income base is now a moving average. With respect to period equity, the results are identical to those obtained with block averaging and cumulative averaging. Unlike the block average, whereby tax relief is received in a lump sum at the end of each block period, the Type IV moving average provides annual tax adjustments. This procedure, however, has the undesirable characteristic of causing tax payments in some years to be significantly greater than they would be in the absence of averaging. The cumulative average appears to give results which are at least as good in some respects, and better than the Type IV procedure in all other respects.

Income Adjustment Accounts
The foregoing averaging devices have all used the income history of the taxpayer to determine his current tax liability. Income adjustment accounts (IAA) allow a taxpayer to take into account his prospective income in the determination of his current tax liability. It permits a taxpayer to allocate part of his current income to a non-interest-bearing government account. The deposit is deductible from the tax assessable income of the year for which the deposit is made, and is added to the taxable income in the tax year in which it is withdrawn. An IAA may
currently be used by primary producers in New Zealand [11, p. 293], and was also proposed by the Canadian Royal Commission as a complement to the block average [2, 9]. The Canadian Royal Commission saw an IAA as a supplement to averaging devices based on historic income. An IAA would be inadequate as the only form of relief because it does not provide any benefit to taxpayers who are experiencing steady increases in income, or to those who suffer unexpected declines in income. Use of an IAA would thus be made mainly by taxpayers who received large lump sum receipts, and by taxpayers who could foresee sharp drops in their income in future years. IAA would be particularly relevant then when the income tax base included realized capital gains and losses, and to people with very peaked earnings.

If farmers could accurately predict their future income stream, the post-tax income stream with an IAA would be more stable than with any other form of averaging. This is because an IAA is the only averaging procedure which involves the actual transfer of income from periods of high to periods of depressed income. Part of the reason for introducing IAA would appear to be to stimulate saving in high income years. This, for example, is a clear aim of the Commonwealth Drought Bond scheme introduced in Australia in 1969. This is a form of IAA which has very restrictive eligibility rules, and is confined to primary producers who derive the bulk of their income from grazing sheep and cattle.

Farmers will not usually be in a position to predict their future income stream with the accuracy required to use the IAA successfully as the only form of income averaging. Moreover, there is an opportunity cost of the interest forgone on the deposits in an IAA which is not incurred with the other averaging devices. The main argument against the payment of any interest, even at a nominal rate, is that it would provide an IAA with an unfair advantage over banks and similar institutions.

It would be possible to speculate on rate modifications with an IAA. For instance, if a taxpayer predicted a reduction in next year’s rates he could deposit a large sum at the end of the current financial year and withdraw it at the beginning of the following financial year. Such speculation could largely be overcome by stating that deposits cannot be withdrawn within twelve months of when they are made. The administrative burden would be reasonably light as neither the government, nor the taxpayer, would need to keep extensive records of the taxpayer’s previous returns.

Concluding Comments

In the judgement of most writers on the topic, the primary function of income averaging should be to attain period equity. That is, over
some specified period, equal taxes should be paid on incomes of equal total size, regardless of how the income is distributed over the period. In the absence of income averaging, the size of the additional tax payments caused by an unstable income flow is determined by the magnitude of the variance of taxable income, and its mean level \( [7, 10] \). For the Australian progressive rate scale, the additional tax payments are proportionately greater for low mean incomes than for high mean incomes. This is because the rate of change of the marginal tax rate is greater at lower than at higher income levels.

A detailed study of the variability of individual Australian farm incomes has not been undertaken in the present study. The B.A.E. data for the sheep industry \([1]\) suggests that, compared with stable incomes of equal total size measured over a period of five to seven years, it would be fairly common for sheep farmers to incur additional tax payments of 15 to 25 per cent if there were no income averaging. And in some instances additional tax payments of 30 per cent, or more, would be incurred. If the aim is to define an averaging period such that the average income for successive block periods is reasonably comparable, the period should not be less than five years. For the particular income data presented in Table 1, a seven-year period appears the most appropriate. The averaging procedures reviewed could all quite readily be applied over averaging periods ranging from two to seven years. One of the main problems arising with longer averaging periods is the changing real value of money.

Regardless of the relative weighting given to the performance criteria listed in Table 2, Downing's block average and Types I and IV of the moving average, are judged to be inferior forms of averaging. Also, due to the lower administrative cost, Type III* moving average appears superior to Type III. The present comparison is therefore restricted to one between the block average, the cumulative average, and Types II and III* moving average.

The condition of period equity is completely fulfilled by the block and cumulative average, and reasonably well met by the Type III* moving average. The main defect of the Type II moving average (current Australian procedure) arises when there is a sustained downward income trend, or when a block period with a low mean income follows a high mean income block period. In both of these situations the tax payments usually be substantially above those that would have been paid with no averaging.

The response of tax payments to current income is best maintained by the cumulative average and the Type III* moving average. It is also fairly well maintained by the block average, the main disadvantage being the lumpy nature of the tax rebate. The Type II moving average performs badly on this count. It will be fairly common for a given annual tax payment to significantly exceed that paid under the simple annual progressive tax. Moreover, in contrast to the other procedures, the Type II moving average provides only a small reduction in the incentive to speculate on rate modifications.

On the basis of the performance criteria adopted in this paper, and given any reasonable weighting of the desirable attributes of an averaging system, the block average, cumulative average, and Type III* moving average are all considered to be superior to the current Australian
averaging procedure. The overall difference in performance between the former three averaging procedures is comparatively small. The main disadvantage of the block average compared with the other two procedures is the lumpy nature of the tax rebate. The cumulative average is slightly better than the Type III* moving average with respect to period equity, but has a greater administrative burden.

With respect to forward averaging procedures, it is desirable that a taxpayer should be allowed to carry forward negative taxable incomes and balance them against future positive taxable incomes. It is unlikely that primary producers would be able to predict fluctuations in their future income stream with sufficient accuracy to make an IAA adequate as the sole form of averaging. However, it would be a useful supplement to an averaging procedure based on historic income, if a government seeks to stimulate savings in high income years and to reduce annual fluctuations in farmers' spending income; or if income averaging was extended to all taxpayers with variable incomes.

References
CHAPTER 6

A NEGATIVE INCOME TAX AND LOW INCOME FARM FAMILIES
EXTRACT FROM
THE AUSTRALIAN JOURNAL
OF AGRICULTURAL ECONOMICS

The Journal of
The Australian Agricultural Economics Society
A NEGATIVE INCOME TAX AND LOW INCOME FARM FAMILIES*

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An efficient procedure is proposed for making welfare payments to low income farm families. This is a negative income tax. It uses the income tax system for linking directly transfer payments to income needs, without unduly adverse effects on resource allocation. The negative income tax proposal is considered in relation to rural adjustment and reconstruction.

In Australia over recent years, low farm incomes have generated considerable adjustment pressures in the rural sector. Concomitant with the deterioration in economic conditions in the rural sector, total Commonwealth financial grants to the sector have increased from $160m. in 1966-67 to an estimated $380m. in 1971-72. Although traditional subsidies on farm outputs and inputs have maintained their relative importance, the introduction of a general rural reconstruction programme in 1971, marked a significant shift in Commonwealth Government rural policy. It seems likely that downward pressures on farm income will be maintained, and that rural adjustment and reconstruction will be a major feature of rural policy during the 1970s. 2

At present, Commonwealth financial grants to the rural sector are not linked directly to the income needs of farm families. Rather, their incidence is usually the reverse. The focus of this paper is on a procedure for making income transfers to farm families whose income needs are greatest from a welfare viewpoint. Negative income tax (NIT) uses the income tax system as a vehicle for making income-conditioned transfers to low income families. Already a form of NIT has been suggested by Schapper [22]. However, no attempt has been made to consider alternative forms of NIT, problems of designing a NIT suitable for farm operators, and the general place of NIT in the continuing process of rural adjustment.

The relevance of this paper to the Australian rural sector rests on the untested hypothesis that there are a significant number of low income farm families. 3 It is argued that many of these are at present ‘trapped’

* The paper has benefited from constructive suggestions made by a referee, and discussions I have had with R. L. Mathews, C. A. Tisdell, C. Walsh, and various members of the Bureau of Agricultural Economics, especially A. G. Cuthbertson. The research was partly financed by the Rural Credits Development Fund of the Reserve Bank. I am solely responsible for the views expressed.

1 Derived from [1, Table No. 12, p. 22]. Income tax concessions are excluded.

2 It is estimated [1, p. 9] that aggregate real farm income in 1970-71 was the lowest since 1944-45. Although some increase in farm income is anticipated for 1971-72, downward pressures on income are expected to continue [1, p. 26], especially for producers in the wheat, dairy, sugar and horticultural industries, who will be affected by the entry of the U.K. into the E.E.C.

3 The data necessary to test this hypothesis—the pooled income of individual farm family units, including income derived from off-farm sources—is unavailable. However, McKay [17] has estimated that, in the early 1960s, approximately one
in agriculture, in the sense that their welfare would be permanently lower if they left their farms immediately. For most of these farm families NIT would provide temporary relief until they attained adequate income in farming or in an alternative occupation. For those with no opportunities to attain adequate income, transfer payments would be permanent.4

NIT and Rural Adjustment

For the purpose of relating NIT to rural adjustment,5 three groups of low income farmers may be distinguished. Those who are without prospect of earning an adequate income either in farming or in an alternative occupation, given their physical and mental capacity, managerial and other skills, and net worth. Those who are without prospect of earning an adequate income in farming, but who consider they have occupational alternatives. And those who consider they can eventually achieve an adequate income in farming, by methods such as debt reconstruction, acquisition of more land, change of farm activities, and supplementary income acquired through part-time off-farm work. These low income groups will henceforth be referred to as groups one, two and three, respectively.

In the process of rural adjustment, farmers are continually moving into and out of these low income groups. They eventually leave their farm,6 retain an adequate income, or become 'permanent' low income farmers. At any time, many farmers will be uncertain to which low income group they belong, due to deficiencies in information. Uncertainty will be particularly high when a rapid deterioration of economic conditions occurs.7 In these circumstances, a period of several years may be required for a farm family to decide and implement its best course of action. Time is required to search for information and to evaluate it with regard to the profitability of alternative farm activities, opportunities for debt reconstruction and acquisition of more land. If these prospects are bleak, more time is required to seek information regarding occupational alternatives, job retraining opportunities, and the general con-

third (80,000) of Australian farms regularly earned less than $2,000 per annum, for their owner's labour, management and capital. Given the recent trends in aggregate net farm income and the number of farm operators, the number of farms with incomes below $2,000 would have since increased [1, pp. 9-11], unless a very marked change in the income distribution pattern has occurred. See also Davidson [6].

McKay's estimates do not account for income derived from 'off-farm' sources, and the comparison of farm with non-farm incomes is fraught with difficulties. It may be noted, however, that the age pension for a married couple with two dependants (i.e. equivalent to a family of four) effectively guarantees their annual income will not be less than $2,000; and that the minimum annual wage equivalent for a male adult in N.S.W. is approximately $2,700.

It is outside the scope of this paper to justify a Government policy providing a minimum income guarantee to a particular group in society, suffice to note that all employees have such a guarantee in the form of minimum wage legislation and unemployment benefits. For a discussion of policies to redistribute losses caused by 'economic progress' see Schultz [23].

6 Here, knowledge of the general process of rural adjustment is assumed. See, for instance, Heady [15].

7 The best indicator available, of the decline in number of farm operators, is for male owners, lessees or sharefarmers working permanently on rural holdings [3, p. 27]. These have decreased by 12-7 per cent over the period 1967 to 1971.

For example, the 1970-71 drop in wool prices.
sequences of what could be a major change in occupation and family location. Search for information on job alternatives will probably require more time when, as at present, unemployment is high. Finally, if a decision to leave farming is made, it may then take several years to negotiate a sale, or to lease the property.

Consider the introduction of a NIT with the following features. A NIT transfer would be made to farmers in group one until they were eligible for an age pension, or moved out of the group. For farmers at present in groups two and three, NIT would be temporary, and must be known to be temporary, so that adequate pressures to adjust are maintained. For instance, a possible condition is that no farmer would be entitled to more than three annual NIT transfers, unless in the opinion of the authority there were exceptional circumstances. This would ensure that NIT would not encourage low income farm families to remain in agriculture indefinitely.

NIT and Resource Allocation

NIT may affect work-leisure choices, risk-taking, the rate that farmers enter and leave the low farm income category, and the occupational choices of those leaving farming. The former effect is discussed separately, and the other influences are considered here.

NIT may influence decisions made by families not at present in the low farm income category. Both for potential entrants to farming, and for farmers at present with adequate incomes, NIT would change the after-tax probability distribution of expected future income from farming. By increasing the mean and reducing the variance of expected farm income, it may encourage potential low-income families to enter agriculture, and discourage farmers, who at present have adequate income but have some probability of becoming low income farmers, from leaving agriculture. For the first category, it could be stated that no family entering agriculture, subsequent to the introduction of NIT, would be eligible for transfers unless Government approval for entry had been obtained. For farmers in the second category, the effect would be unlikely to be very marked, because they would not anticipate receiving more than three NIT transfers.

For farmers in groups one and three, the significant resource allocative effect of NIT would be its influence on the work-leisure choice. For group two farmers, however, NIT may also influence the rate at which they would leave their farms and their choice of occupations. Consider first the situation where NIT delays the exit of farmers from farming, but does not alter the "post-adjustment" resource allocation. Assume also, that there are no divergences between private and social returns from alternative resource allocations, before NIT. The economic cost to society of the delay in adjustment caused by NIT would be equal to the present value of the difference between the actual returns on farmers' labour, land, and capital for the period of delay, and that which would have obtained in the absence of NIT.

It was suggested previously that a period of several years may be required by some farmers to make and implement a decision to leave farming. NIT may similarly affect the choice of farm activities, when the probability distribution of expected returns from alternative activity combinations intersects the NIT range.
their farm. If a farmer is not given this time due to foreclosure by his creditors, his welfare may be permanently lowered; either because the realized value of farm assets would be less under conditions of forced sale, or because his new occupation would be inferior to the one he would have chosen, given more time. 9

For both of these situations the farmer may be prepared to borrow more credit to buy time to negotiate more favourable terms of sale, or to select his 'best' future occupation. If, however, the only collateral he could offer for credit is his own human capital, embodying the expected capitalized value of his prospective earnings outside agriculture, he will usually be unable to obtain a loan. There is, here, a case of market failure similar to that for persons with negligible net worth, apart from their human capital, who seek to invest in retraining themselves for a new occupation. The market failure is that commercial lenders will not usually accept human capital as collateral for a loan, and society would probably not permit it. Yet from society's viewpoint, the risk of these prospective earnings outside agriculture being unrealized is negligible.

NIT and Rural Reconstruction

NIT could be made independent of the existing rural reconstruction programme: 10 or it could be linked to the programme. For instance, NIT transfers to farmers in groups one and two could be made conditional upon agreement to have their property purchased for amalgamation, under conditions previously agreed to by government and farmer. A farmer in group one, at the discretion of the authority, could be given the opportunity to retain his home and a few acres.

With respect to group two farmers, a government may permit a NIT to operate for a period after they leave their farm. This action may be taken to encourage persons who are not eligible for the Commonwealth retraining scheme to train for a new occupation while working part-time. Alternatively, it may be considered that some farmers view migration as being a high risk, while the risk from society's viewpoint is negligible.

Finally, the Commonwealth Government, having embarked on a programme of rural reconstruction, may begin gradually to dismantle the existing high levels of protection to some rural industries, 11 on the grounds that it induces an inefficient resource allocation and has a regressive incidence. This action, however, would increase adjustment pressures. NIT would ameliorate these pressures for marginal producers, who would have to make the most substantial adjustment.

Form of a NIT

The different forms of NIT, and their likely economic effects, have

9 See also, in this regard, the RAE statement that some farmers who may have benefited from rural reconstruction may be forced to take irrevocable action because of immediate pressures [2].

10 I do not discuss the principles of a general rural reconstruction programme. See Edwards [8], Harris [13], and Mauldon and Schapper [18].

11 Even when the most generous allowance is made for 'second-best' arguments of the type advanced by Gruen [12], it is clear that the existing level of protection to some rural industries causes an inefficient allocation of resources. For instance, the dairying industry.
been a subject of discussion in the economic literature over recent years. All NIT plans contain three basic elements: a guaranteed minimum income paid by government; a negative tax schedule relating the size of the NIT transfer to the earned income of the tax unit; and a break-even income at which NIT ceases.

Assuming a proportional negative tax rate, \( t \), specifying the rate of decline of the NIT transfer as income from other sources, \( Y' \), a guaranteed minimum income, \( Y_g \), and a break-even income, \( Y_b \), the NIT transfer is given as:

\[
NIT = Y_g - tY' 
\]

Thus a low income family would receive a direct income grant from government. This grant would be reduced as earned income increases, but usually by less than the full amount of the increase. The reduction in the tax represents a tax on earned income. A limiting case of NIT, commonly referred to as an income maintenance or poverty gap plan, sets a minimum guaranteed income to the tax unit. If earned income is below this guaranteed level, the difference would be made up by transfer. The effective marginal tax rate on additional earnings below the guaranteed level would be 100 per cent, and the income gain from the surrender of leisure would be zero. Such an expropriatory tax rate is likely to induce considerable leisure-work substitution effects.

All income transfer schemes have these adverse substitution effects to some degree; unless transfers are independent of income status, and thus correspond to lump-sum taxes. One such lump-sum transfer procedure would be to give all families—including high income families—a grant equal in size to the guaranteed minimum income. The budget cost of this scheme would, however, be prohibitive. The marginal tax rate that is set for a NIT thus reflects a trade-off between the magnitude of the adverse leisure-work substitution effects and the budget cost of the programme.

**NIT and Work Effort**

The decision-making unit's response to a tax induced change in its earned income is usually analysed in terms of substitution and income effects. The positive marginal rates of ordinary income taxation reduce the opportunity cost of a unit of leisure time, and thus produce a substitution effect adverse to income-producing effort. Positive average rates, however, reduce the aggregate net return for such efforts, causing an income effect which operates in the opposite direction. Therefore, it is impossible a priori to say whether the imposition of an income tax, or any other tax, would induce more or less effort. Positive average tax rates thus have the potential to produce a substitution effect and a negative income effect. The positive marginal tax rate on the additional income from a unit of leisure increases with the income earned from leisure.

12 A good introduction to NIT is given in Green [10]. The effects of a general and permanent NIT on farm operators have been discussed by Meyer and Saupe [19]. In a recently published paper, Bawden [4] discusses some interesting preliminary results of a rural experiment with NIT in the United States. For a discussion of various aspects of NIT see [5, 7, 9, 16, 21, 24, 26].

13 The present tapered means test for age pensions has the essential features of a NIT. For the pension transfer itself, the effective marginal tax rate is 50 per cent. However, when this is combined with the age allowance income tax schedule, the 'true' marginal tax rate can be as high as 100 per cent. Tax induced disincentives to work are much less significant for the aged.
an increase in the rates of an existing income tax, will increase or de­
crease work effort.\textsuperscript{14}

The NIT under discussion is negative only in terms of the direction of
the aggregate income transfer. Although the average rate is negative,
a positive marginal tax rate is applied to earned income. With NIT then,
both income and substitution effects would operate towards reducing
income-producing effort. Farmers have more opportunities than most to
vary their income-producing effort. It is expected, therefore, that a NIT
having a very high marginal tax rate could substantially reduce work
effort in low income families.\textsuperscript{15} NIT would influence the on-farm work
of the owner operator and other family members, and also lessen the
effort made to find part-time off-farm work.

The impact of NIT on work effort is important in two respects. First,
the substitution effect, arising from the change in the relative prices for
leisure and earned income is allocatively distorting, assuming that there
is a Pareto optimal resource allocation before NIT. It is likely that some
farm families who would be eligible for a NIT transfer are paying income
tax. However, the marginal tax rate, and hence the substitution effect,
would be much less than with NIT. A second consideration is the effect
of lowered income-producing effort on earned income, and the aggregate
NIT transfer made to low income families. The lower the earned family
incomes resulting from reduced work effort, the higher the budget cost
of maintaining a given guaranteed family income. Alternatively, if the
budget cost of NIT is held constant, the lower the minimum family
income guarantee.

\textit{Tax Unit}

In this proposal, the tax unit for NIT is the farm family which would
be eligible for a NIT transfer when its pooled income is less than the
break-even income.

Adoption of a family tax unit raises the problem of definition. Here, a
family consists of an adult nucleus, plus any other persons claimed as
members by the adult nucleus. For the purpose of qualifying for NIT,
the adult nucleus could be any married couple, or any person over the
age of 21 years.\textsuperscript{16} Persons who are not eligible to form part of the adult
nuclear may be claimed as members of the family unit, providing they
receive more than one half of their support from the adult nucleus.
These members need not necessarily reside on the farm to be included
in the family unit for NIT.

No person could be a member of more than one family unit, nor
could any adult qualify as a separate unit and receive NIT while remain-
ing economically a part of a unit with adequate income. Also, no person
for whom an exemption is claimed on an ordinary income tax return
could be included as a member of a family unit claiming a NIT transfer.

\textsuperscript{14} For an analysis of the effects of ordinary income tax on work effort see
Musgrave [20].

\textsuperscript{15} The underlying assumption is that leisure is a normal good. It is conceivable
that leisure, for some individuals, may be an inferior good. For instance, a NIT
transfer may change an individual's 'life-style' in such a way so as to increase
their 'taste' for income relative to leisure, causing less leisure to be consumed. See

\textsuperscript{16} In exceptional circumstances a person under 21 may be granted adult status
for NIT, e.g. an orphan farm operator.
The income of all members, from all sources—except intra-family unit transfers—would be aggregated to determine the size of NIT transfer.

Another problem is to specify the absolute level of the guaranteed minimum income, and its relationship to family size and composition. Although in the following section a specific NIT schedule is given, it is only illustrative. From a welfare and equity viewpoint, guaranteed minimum incomes should be neutral among families of different size. For instance, a family of four should be given just enough more than a family of three to maintain an equivalent standard of living. This would require the guaranteed minimum income to rise with family size, although not proportionately, as there are economies of scale in family consumption.

Illustrative NIT Schedule

Attempts to avoid adverse substitution effects of a NIT give rise to unavoidable trade-off conflicts. As already shown, all NIT plans contain three basic variables: a guaranteed minimum income, a NIT rate schedule, and a break-even income. The conflicts arise because any two of the three basic variables determine the third. Thus the objective of a high guaranteed minimum income, combined with a NIT rate that keeps low the disincentives to work, is not compatible with a low break-even income. The high break-even income resulting from such a plan means that NIT transfers would be made to many non-low income families, and that the budget cost of the programme would be high. In the illustrative NIT plan outlined below, an attempt is made to achieve balance between these trade-offs, and to link the NIT schedule with the ordinary income tax schedule. 17

A guaranteed minimum income of $600 for a single adult is arbitrarily chosen. For larger family units, the guaranteed minimum income is determined by adding to this amount the tax deductions for dependants allowed under the ordinary income tax. Table 1 summarizes the situation for a family of four, assuming a 50 per cent proportional NIT rate, and a minimum guaranteed income of $1,276. The NIT plan is illustrated in Figure 1. Y is the total family income before tax and DY is the total disposable income after tax. The line OED shows the relationship be-

<table>
<thead>
<tr>
<th>Before Tax Family Income (Dollars)</th>
<th>Positive Tax Liability (Dollars)</th>
<th>NIT Transfer (Dollars)</th>
<th>After Tax Family Income (Dollars)</th>
<th>Average Tax Rate (Per cent)</th>
<th>Marginal Tax Rate (Per cent)</th>
</tr>
</thead>
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<td>3,127</td>
<td>+10.7</td>
<td>25.0</td>
</tr>
</tbody>
</table>

17 This NIT system is similar to that proposed by Tobin et al. [24].
between DY and Y under the ordinary income tax, for a married couple with two dependent children, assuming a single tax return in which the wife and children are claimed as full dependents.

The line OED has a slope of 1, for incomes below $1,092, because the family would pay no tax if its income were below this level. The line then takes on successively lower slopes as income rises and higher progressive tax rates apply. The total tax on any given income is the vertical difference between OED and the 45° line.

With NIT, the relationship ACD is substituted for OED. Families without income receive a NIT transfer of $1,276. All families with incomes below the break-even income of $2,552 receive a NIT transfer. Families with incomes between $2,552 and $3,128 pay lower tax payments than they would under the ordinary schedule. Families with incomes above $3,128 are not affected by NIT. It is necessary to include families in the NIT plan with incomes somewhat above the break-even income level to avoid confiscatory marginal tax rates. If the ordinary income tax schedule is applied to all incomes above $2,552, a family with an income of $2,553 would pay a tax of $174 and have a disposable income of $2,379. The additional dollar of earned income would cost
the family $173. This is avoided by extending the NIT schedule to where an equivalent tax is paid under it, and under the ordinary income tax schedule.

**NIT Base**

Administration of a NIT would be simplified if the base used for the ordinary income tax were adopted. However, given the basic welfare aim of NIT, this concept of taxable income is unacceptable. A NIT should be based on economic ‘well-being’. This may be broadly thought of as a function of the flow of goods and services over which a family has command. The most important determinant of this flow is current annual income. But this is not a simple and unambiguous concept. Adjustments need to be made to the existing definition of taxable income to provide a more equitable measure of command over a flow of goods and services. These adjustments, and the question of the time period over which income should be measured, are outlined in Appendix I.

We now consider the question of whether positive net worth provides a command over goods and services that is not reflected in current income, and whether there should be an offsetting tax on net worth.

**Offsetting Tax on Net Worth**

Underlying the proposals for reduced NIT transfers to low income families with positive net worth is a presumption that asset holdings provide command over goods and services additional to the annual income. One method of taking this into account is to impute a return to net worth assessed at fair market value. Actual money income from asset holdings is subtracted from imputed income and the difference—if positive—is added to the income base. In effect, this procedure adds to the income base, income arising from such factors as the imputed rental to owner-occupied dwellings, psychic income, and unrealized capital gains.

Apart from difficulties of accurately estimating the market value of farm assets, there is the problem of distinguishing between returns to farm labour and to farm capital. If the return to farm assets is not fully netted out before imputed income is added, there will be double counting of returns to net worth. This difficulty does not appear to justify the use of imputed income to net worth for the purpose of NIT assessment. Also, the main argument for using imputed income, namely that money income provides an underestimate of ‘true’ income, has been considerably weakened by the proposed adjustments to taxable income.

A separate argument for including net worth in the assessment of a NIT relates to the potential to consume net worth. The implication is that low income families with positive net worth should contribute to their own support through dis-saving some of their wealth. Weisbrod and Hansen [25] have considered problems of measuring the economic ‘well-being’ of a consumer unit. Although they do not discuss a NIT, their work is relevant. They suggest that the economic ‘well-being’, $Y^t$, of a consumer unit in time period $t$, is the sum of current annual income $Y_t$ (which is net of the yield on net worth), and the annual lifetime

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18 For a good discussion of the problem of measuring the economic ‘well-being’ of farm families see Hathaway [7].

19 To avoid double counting of net worth.
annuity value of current net worth \( NW_t \cdot An \); where \( An \) is the value of an \( n \) year annuity whose present value is $1. Thus, \( Y_t^* = Y_t + NW_t \cdot An \).

Economic 'well-being' is the income obtainable in period \( t \) if net worth is converted to yield a lifetime flow. The annuity value will be a function of net worth, life expectancy, and the rate of interest used for the conversion. For any given interest rate, the greater the net worth of the unit, and the shorter its life expectancy, the greater will be the annual annuity.

For the purposes of NIT, any proposal to add the annuity equivalent of net worth to current income would need to show that conversion of net worth to an annuity is both possible and desirable. Possibilities for converting net worth in the form of farm assets into income for consumption, without selling the farm, are extremely limited. The major possibilities are to use farm assets as collateral to borrow from financial institutions, and to reduce farm maintenance expenditure. These limited opportunities, and possible difficulties of estimating market values of farm assets, probably preclude including net worth at the time NIT transfers are made. To avoid the possibility of families with substantial net worth claiming a NIT transfer an upper limit on net worth could be specified, above which NIT transfers would not be made, regardless of the family income.

If it is inappropriate to have an offsetting tax on net worth before sale of the farm, the question arises whether NIT transfers should be refunded at the time of sale. NIT transfers would then be an interest-free loan. Schapper's [22] NIT proposal is restricted to group one low income farmers, and is conditional upon the farmer giving government first refusal of the property in the event of intended sale. The total NIT transfers would be repaid at this time, or eventually from the estate.

There is probably a stronger argument for these farmers to contribute to their own support through dis-saving of net worth, than for other low income farmers. Their life expectancy will tend to be shorter and the lifetime annuity equivalent of their current net worth, for any given net worth, therefore higher. The aggregate NIT transfer they receive will also be greater.

If both group one and two farmers were required to repay NIT transfers, the latter would be discriminated against in relation to groups one and three. Group one is favoured because the present value of repayments, per dollar of NIT transfer, will usually be much lower, due to a longer time lag before repayment, and the third group because they do not sell their farms.

The most equitable alternatives are probably to make NIT a permanent grant for all groups; an interest-free loan for group one, and a grant for groups two and three; or a loan for all groups, with repayment of NIT transfers from farmers' estates.

Concluding Comments

As a welfare programme, NIT has a number of features. It is directed specifically at low income farm families. It provides help in its most useful form, cash. It makes the cost to society explicit. NIT would not
discriminate between the various sectors within the rural sector. Although NIT will have some adverse effects on resource allocation, these are unlikely to be minimal. The NIT would fit into the present income tax system, and it could be administered by the Commonwealth Department of Taxation.

APPENDIX I

Income Base for NIT

Personal Deductions

Ordinary income tax allows deductions for dependants and certain personal expenditures. Deductions for dependants would be incorporated into NIT; via the guaranteed minimum incomes for families of varying sizes. The deduction of non-discretionary personal expenditures (e.g. hospital and medical) should continue under NIT because it would allow maximum response to the welfare position of individual families.

Gross Income

Ideally, the NIT base would include the aggregate money income, income-in-kind, and imputed income, of the family unit. Money income would include earned income, gifts and inheritances received from persons outside the family unit, payments from government, and realized capital gains. Income-in-kind, i.e. farm products grown for home consumption, is recorded in the ordinary tax return. Probably the greatest source of untaxed imputed income is the imputed rental from owner-occupied homes. Exclusion of this item under NIT is unlikely to discriminate significantly between farm families, given the predominance of owner-occupied homes on farms.

Business Expenditures

Under the ordinary income tax, primary producers may claim a 20 per cent investment allowance on most new plant and equipment, write-off depreciable assets at an accelerated rate, and deduct the full amount of many capital outlays in one year. To prevent farmers with adequate 'real' income from claiming a transfer, the 20 per cent investment allowance would be excluded, and normal depreciation only allowed under NIT. Also, with NIT, a distinction would be made between expenditure required to maintain production, and capital expenditures incurred for improving future earning prospects. The former would be deductible, the latter would not. Thus all developmental expenditures leading to assets, which given moderate maintenance expenditure do not depreciate, would be completely excluded under NIT. With ordinary income tax, these expenditures—for instance most land improvements—can be immediately expensed. Finally to prevent some farmers claiming NIT while accumulating unrealized capital gains through build-up of livestock numbers, these increases would be valued at market prices, and not at a nominal cost price valuation.

Income Averaging

In direct contrast to an ordinary progressive income tax, families who have annual income that fluctuates in and out of the NIT range would benefit in relation to those with a stable income of the same total size.
Apart from the instability of farm incomes caused by such factors as drought and fluctuating prices, farmers may influence the size of their annual income by adjusting the timing of their sales and expenditures. To prevent families with high average annual incomes claiming NIT, a cumulative averaging system is proposed. The present averaging procedure for primary producers is unsuitable for NIT, because it responds too slowly to current income. Under the cumulative procedure, the size of the initial NIT transfer would be based on the preceding year's income. At the end of the following year, the average of the two years' income is calculated. The NIT transfer, or tax payment, that would have been received over the two-year period on this average income is then measured. The NIT transfer or tax payment at the end of the second year is the difference between the previously calculated amount and the size of the first NIT transfer. This procedure would then be repeated for an averaging period of not more than five years. Averaging would be compulsory. Negative annual income would be treated as zero in the year incurred, and the losses carried forward and written off against future income. Thus, NIT would not provide a guaranteed minimum annual income when net farm income was negative.

References

CHAPTER 7

POLLUTION AND RESOURCE ALLOCATION
EXTRACT FROM
THE AUSTRALIAN JOURNAL
OF AGRICULTURAL ECONOMICS

The Journal of
The Australian Agricultural Economics Society
'Everything I like is either illegal or immoral, pollutes the environment, or increases the population'.

[R. A. Lewin, Bioscience, 19, 1969, p. 584].

Our economic perspective of the pollution problem characterizes that problem as involving a conflict between the consumption of two broad classes of goods—physical (or produced) commodities and the direct consumption of 'clean environment'. After considering the relative merits of market and political decision-making processes used to achieve appropriate social choices between the consumption of physical goods and 'clean environment', we focus on the alternative policy options for pollution control. The main conclusion we reach is that, in general, fiscal instruments (taxes and subsidies) are a more efficient means of controlling pollution than the widespread use of regulations or other legal instruments.

Introduction

An ever-increasing popular and technical literature has been concerned with persuading us that mankind is on the brink of ecological disaster. However seriously one ultimately takes this threat, it seems difficult to contemplate the pressures of population growth, the rapid exploitation of known reserves of exhaustible resources, and the apparently perceptible deterioration in the quality of the natural environment without some disquiet. And judging by the attention devoted to these matters in the economics literature, the economics profession at large regards them as enormously important.

The purpose of this paper is to submit to examination just one of these problems—that of environmental quality disruption. From the start, however, it has been obvious that the task of providing a comprehensive coverage of all aspects of even this one problem would be quite impossible except in terms of largely meaningless generalizations. The environmental quality problem as a whole is just so complex that policy discussion requires some way, initially, of breaking it down into manageable components, which can ultimately be brought together again to form a consistent total perspective. In this spirit, we have chosen to focus on only one (albeit a particularly important) aspect of environmental quality disruption—the so-called problem of pollution.

* This paper has evolved from a more wide-ranging paper which was presented to the Annual Conference of the Australian Society of Agricultural Economists held at the Australian National University in February 1973. Order of authorship for the present paper was decided by tossing several coins.

A
In doing so, it is probably desirable to indicate, at the very outset, just where we see the pollution problem as such fitting into the wider context. Basically, we regard the general problem of environmental quality disruption in a growing economy as a compound of three related, but distinguishable, phenomena—increasing pollution, increasing congestion, and an increasing demand for recreational and other services provided directly by a clean environment. It is clear that these can be viewed as quite distinct matters—at least at the conceptual level. Congestion may worsen without any change in pollution levels or the demand for clean environment per se. Likewise, technological changes may influence pollution levels without affecting congestion or preferences for environmental services. And tastes for environmental services may alter while congestion and pollution levels stay constant.

In practice, though, the distinction may be extraordinarily difficult to maintain. An increase in population size, or income per head, will generally involve a simultaneous increase in pollution levels and demand for environmental services; an increase in pollution levels may increase the observed demand for environmental services (e.g. trips to national parks), even when the underlying preferences for environmental services remain unchanged. (In the latter case, we observe a move along the demand curve rather than a shift in it). Needless to say, it may be difficult (and, incidentally, quite wrong in some cases) to deal with these effects separately. Nevertheless, some such distinction seems necessary if the topic is to become manageable, and we shall endeavour to emphasize, wherever it seems relevant in the discussion, the essential interdependence of the various dimensions of the total problem, without actually concerning ourselves with questions of congestion or conservation as such.

Our primary objective has been to provide a broad conceptual economic framework, within which the pollution problem might be analysed and appropriate means of reducing the impact of pollution on society's well-being discussed. The need for such a framework seems to us to be extreme. Although much has been written on the pollution question—particularly, recently—most proceeds on a relatively ad hoc basis, and many of the more fundamental questions are skated over or completely ignored. We have, by way of contrast, attempted to start at first base with the question 'what is the economic dimension of the pollution issue?' and to proceed logically from there to identify that aspect of the issue which makes it a social problem, and through this to the ultimate question of what we should do about pollution.

In no sense is this paper to be considered as a review of the literature. It is both less than, and (we hope) more than, that. It is less, because there are many issues aired in the literature which we have ignored (and possibly even a number that we have overlooked). It is more, because it involves an attempt to re-think the fundamental questions and to present the answers (in so far as we have found any) in a novel and hopefully stimulating form. In this way, our aim is that the framework set out here should prove useful to those who are familiar with

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Footnote:

3 We must, nonetheless, admit that our thinking has been influenced by the contributions of Dales [7], Ayres and Karase [1], Parish [10] and Coase [6]. This is by no means a complete list, and we indicate other important sources as we make use of their ideas.
much of the relevant literature, as well as to those who are not; and
to those who are economists as well as to those who are not.

Regrettably perhaps, this paper has no explicitly agricultural orienta-
tion. The reason for this is simply that we considered that the conceptual
exercise we have undertaken here needed to be conducted first. The
extremely interesting question of how the pollution problem bears on the
rural sector—and indeed the more general question of the optimal
location of polluting industries, which we hardly do justice to here—
must remain for a logically and temporally subsequent discussion.

The plan of the paper is as follows. In section I we attempt to derive
an economic perspective of the pollution problem. In section II, we are
concerned to discuss the extent to which the economic problem of pollu-
tion requires political intervention because the market fails to solve
it—and further, the extent to which the political mechanism can be
expected to achieve what the market cannot. Section III presents a
discussion of alternative pollution control procedures available to govern-
ments and attempts to outline appropriate criteria for policy choice.
Section IV presents the conclusions.

I

Pollution as an Economic Problem

The fundamental economic problem, or at least the problem with
which economists have traditionally concerned themselves most, is that
of maximizing society's welfare in the face of various constraints—
constraints imposed both by the natural world, and by man's limited
knowledge of the ways in which the natural world can be manipulated
to achieve society's ends.

One of the most basic constraints prevailing (although one which,
until recently, has received little explicit attention from economists)
is that implied by the law of Conservation of Mass. This law insists
that processes of production and consumption can, via chemical
and physical change, modify but never destroy the matter used in those
processes. In other words, except to the extent that re-use is feasible
(and economical), production-consumption activities inevitably in-
volve the conversion of productive inputs (including oxygen from the
atmosphere) into an equivalent mass of non-productive residuals that
must somehow be disposed of.

It perhaps needs to be emphasized in this connection that it is
consumption, and not production, which is the ultimate objective of
economic activity: production processes exist, not as ends in themselves,
but merely to satisfy individuals' demands for physical consumption
goods. Thus, while production activities no doubt typically generate a
larger volume of more objectionable waste products than consumption
activities do, nevertheless all disposals can ultimately be seen as arising
from a multi-stage process in which naturally occurring matter is trans-
formed, firstly into a form in which it is amenable to consumption, and
then via the consumption process itself into some other form in which it
is generally not consumable. It is consumption therefore which provides
the rationale for all economic activity—and hence society's demand for
physical consumption goods which is ultimately responsible for the need
for residuals disposal.
Once this point is admitted, it is clear that that view of the pollution problem, quite common in popular discussion, which seeks to categorize individuals into two mutually exclusive classes—the wicked polluters on the one hand, and the deserving polluted on the other—and sees the pollution problem as arising out of the moral degeneracy of the former group, is in fact hopelessly misguided. It is, more seriously, dangerously confusing. The truth of the matter is that all consumers contribute to pollution by the very act of consumption: firms pollute, not because they derive fiendish delight from doing so, but because the individual consumers of their products pay them to.2 In this sense, it is not a case of ‘them’ against ‘us’, but us against ourselves—and it saves a lot of misplaced indignation to realize that this is so.

Until quite recently, residuals disposal did not seem to have been widely regarded as posing a serious problem—in economic, or any other, terms. That this is so is presumably attributable to the fact that such disposals had not interfered at all significantly with other production and consumption activities which individuals wished to pursue. Disposal is, of course, effected simply by the discharge (either deliberately or as the result of natural processes) of the unwanted residuals into the atmosphere (as gases or waste energy), into the waterways (as sewage, or as industrial residuals suspended or dissolved in water), or onto the land (as rubbish, scrap, junk, garbage and so on). And over some range, the basic assimilative capacity of these media can handle such discharge. That is to say, the environment at large is capable of transporting, dissipating, diluting, degrading or storing to some extent all types of residual generated by man’s production/consumption activities, though its capacity to do so may be affected by natural phenomena (temperature, wind-speed and stream flow variations, for example) or by deliberate human intervention (such as augmenting stream flows, treating residuals before discharge, or such relatively simple things as building higher chimney-stacks).3 Up to a point, the natural qualities of the environment thus provide us with a means of disposing of residuals in an essentially costless fashion. Beyond that point, however, there begins to emerge a conflict between man’s use of the environment as a sink for residuals disposal, and such other uses for it as he may have.

Once recognized, the precise nature and extent of this conflict needs to be specified. And this is not necessarily a trivial exercise, in part because the nature of the ‘other uses’ of the environment are not clearly or completely specified, but also because hard facts, and even convincing theories, are in short supply. However, it is clear that an almost endless list of potential or actual damage caused by residuals could now be compiled, ranging from potential threats to man’s existence, through scarcely less potentially devastating (though less specific) threats of ecological instability, right down to relatively minor damage to buildings and the like. In other words, apart from providing a sink for residuals, the natural environment provides a variety of other services which con-
Pollution as a Problem of Social Choice

To recognize a social problem as a question of choice does not necessarily identify it as one requiring an explicitly social choice—i.e., one demanding the explicit application of public policy.

Many—indeed perhaps most—social choices are not made explicitly as such. Rather, they emerge as the summation of the outcomes of a large number of decentralized market decisions. And we know that there is nothing inherently inefficient about such decentralization of decision-making; indeed, quite standard and widely applied theorems of welfare economics state that in many cases the resulting choices are the best conceivable ones. In such cases, co-ordination of decisions is achieved nearly, and at least cost, by the market mechanism.

On the other hand, it is equally clear that some choices are not appropriately left to the co-ordinating forces of the market or, at least,
it is not obvious that market solutions represent the best or least-cost solutions. In these circumstances the social choices may be made, or may require to be made, explicitly as social choices through a political mechanism of some sort.

But it is not immediately apparent that choices made in a political context will better represent 'the aggregate desires of society'; the question of whether the political mechanism makes better choices than the market mechanism depends on a number of things, including the precise form of the political decision-making process, and the nature of the commodity over which the choice is being exercised. For example, the very characteristics which disrupt the smooth working of the market mechanism may also preclude efficient choices being exercised through the political mechanism.

Thus, in focussing on the pollution 'problem' from a policy viewpoint, we might ask two sorts of questions—firstly, what are the characteristics of pollution that are likely to make it difficult for the market to make a satisfactory allocation of resources to the output of 'clean environment'; and secondly what are the characteristics of the political mechanism as an allocator of resources to alternative uses, and to what extent is its performance in this context likely to be superior to (or different from) the market's?

**Market Failure**

In the case of pollution problems, what appears likely to result in failure of decentralized market processes to ensure an ideal choice between the competing uses of the environment is the fact that such problems are characterized by externality. Externalities are often said to arise whenever the well-being of one economic unit is affected by the activities of other units—that is, whenever utility and/or production functions exhibit interdependencies. However, from the viewpoint of identifying the existence of externality with the failure of the market mechanism to make appropriate (allocative) choices rather more is required than mere interdependence. Clearly many activities involve interdependencies, but not all of them involve market failure problems. Indeed the very existence of markets depends upon the existence of interdependencies, for it is the function of markets to internalize the interdependencies. In simple terms an example of what we have in mind is the observation that our welfare is increased by the productive activities of others, but at the margin we pay for their products what they are worth to us, so that the marginal social contribution of their activities is matched by the payments they receive. It is only when appropriate compensation is not forthcoming—when interdependencies are not internalized—that externalities exist. More precisely externalities exist whenever decision-makers do not take into account relevant costs or benefits of their actions, which benefits and costs, if they were taken into account would result in different, and socially preferable, choices being made.

The application of these notions to the economic problem of residuals disposal is, however, perhaps not so obvious as it might at first seem. Certainly to the extent that externalities do exist they can be associated
with interdependencies between the production/consumption of physical goods (which involves residuals disposal) and the consumption of 'clean environment'. By the same token, what exists is not a single interdependence, but a compound of inter-related interdependencies which we could classify according to environmental media involved (atmosphere, lithosphere or hydrosphere) and/or according to ultimately affected 'parties' (humans, animals, plants or inanimate objects). However, we cannot immediately conclude that we are faced with problems of externality, for up to a point the market permits, and indeed positively encourages, adjustments by individual economic units which resolve or mitigate the conflict of demands. For example, individuals may make their demands for a clean environment effective by changing their residential location, or by installing air cleaning or conditioning devices in their homes, and will do so if this constitutes their least-cost response to the interdependencies. Moreover, to take another related example, those individuals who demand pollution-free food or water provide a stimulus through the profit motive to others to produce commodities which will satisfy these demands, as witnessed by the availability of bottled 'pure' water and of 'uncontaminated' foods.5

What is characteristic of these adjustments is that they involve attempts to internalize the interdependencies at the point where residuals appear as an unwanted input into other production/consumption activities, rather than at the point where the residuals arise as an inevitable output (by-product) of the production or consumption of physical goods. The extent of such adjustments is of course limited in the first place by technical feasibility considerations, and ultimately by their economic viability, and if adjustments above and beyond these seem to be economically desirable the emphasis must be shifted to tackling residuals disposals at source, where they occur simultaneously with the production and consumption of physical goods. However it is at this point that market inefficiencies—genuine externality problems—are most likely to emerge since adjustments of this sort inevitably involve cooperative agreements among the relevant individuals in circumstances where such cooperation seems likely to break down.

In the market context, and given the common-property nature of most dimensions of the natural environment, any changes in residuals outputs which are desirable will be achieved only by the 'polluted' parties offering compensation to the 'polluter' for any adjustments he makes.6 Any such adjustments can be regarded as socially desirable if the marginal damage suffered by the polluted individuals exceeds the marginal cost to the polluter of changing his output, and indeed such adjustments could only occur through voluntary action in so far as these implied net benefits exist. However, it is unlikely that the cooperative agreements—the bribes—will be appropriately arranged because the benefits of such agreements are non-excludable—that is, the benefits of

5 We should perhaps emphasize two points relating to cases where the market does provide apparently efficient solutions. First, market processes may be slow in responding to the emergence of previously unrecognized conflicts; and, secondly, the market solutions may sometimes be grossly inequitable. Either of these observations might be sufficient to justify public intervention.

6 The compensation or 'bribes' referred to here is in an economic sense no different from prices paid for goods and services in the market.
reduced pollution arising from a bribe offered to the polluter by one individual accrue to all affected individuals even though they have made no contribution to the cost of reducing the pollution level. Each individual thus obtains a 'free-ride' (cost-free benefits) at the expense of all others and, of course, has an incentive to obtain as substantial a free-ride as is possible. If the numbers of individuals involved is large, as will typically be the case in pollution problems, then each individual will be aware that any attempt on his part to obtain a free-ride will have a negligible impact on the final negotiated outcome. He is thereby given a very definite incentive to understate his true preferences. Thus, the market is doomed in these circumstances to produce an inefficient allocation of resources between physical commodities and clean environment—and this despite the presumed existence of benefits to everyone from a successful internalization of the relevant interdependencies.

If the government is to succeed where the market fails, it must be able to overcome the difficulties inherent in the non-excludability problem associated with tackling residuals disposal at source. To this end, of course, governments have available to them a wide variety of policy instruments ranging from their ability to manipulate the legal system within which the market operates, through to their ability to manipulate the market process via the imposition of taxes and subsidies. However, before turning to a discussion of the instruments available, and their relative success in achieving an efficient allocation of resources between physical goods and clean environment, we shall consider the second of our two general questions—is there any reason for believing that explicit social choices, made through the political mechanism, will result in better choices than those achieved by the market?

Political Failure

It is typically presumed in economic policy discussions that where the market proves to be an inefficient coordinator of decisions, the government should step in to remedy the market's failings. As a value-judgement, such a view would presumably meet with widespread approval, but it is an altogether different matter to establish the positive proposition that where the government does intervene, its decisions will be superior to those made in the market; political mechanisms themselves may be imperfect in coordinating decisions. Certainly the real-world political framework appears to bear little relationship to the omniscient, infinitely benevolent government implied in much of the policy literature, and in this sense the answer to the question 'can the government do better than the market?' is not at all obvious.

In fact, the performance of the government in economic policy matters has been subjected to a certain amount of analysis in the recent past. Unfortunately most of the theoretical issues are nowhere near to being resolved so that any attempt on our part to deduce conclusions about the likely performance of the government with respect to pollution control must necessarily be tentative. Nonetheless, given the importance of the pollution problem (as well as the importance of the issues to be raised for policy discussion of all sorts) an attempt to indicate

1 The major contributions are the work of Downs [8], Tullock [13], and Buchanan and Tullock [5].
some of the more important features of the political mechanism's operation seems worthwhile.

There is one sense in which the usual presumption that government intervention will be oriented towards improving the allocation of resources is understandable. When we say that the market fails to allocate resources efficiently, what we generally mean is that there is a possible change in allocation which would make some individuals better off and none worse off: if this is so then there would appear to be benefits to elected governments (in terms of improvements in their popularity, or probability of being re-elected) from improving the allocation of resources where the market decisions are inefficient. Indeed, if it were true that all government decisions required unanimous support from the electorate then this observation would have substantial relevance. At least one assumes that no-one would give their support to policies which made them worse off, so that overall those changes in policy which occur would involve improvements in resource allocation in the normal Paretoian sense.

However, once we recognize that governments need only strive for majority, and not unanimous support, then we must also recognize that both the motivation and ability of governments to seek improvements in resource allocation are likely to be weak for at least two important reasons:

(a) Given that the politicians who compose political parties are motivated, roughly speaking, by much the same aims as most 'ordinary' individuals, and hence that they are not likely to be more than usually altruistic, it would seem likely that political parties would aim to improve the efficiency of the allocation of resources only in so far as political processes (and especially interparty competition) constrains them to do so. In fact, however, a party can be elected or ensure continuing support by redistributing income in favour of electorally important or dominant coalitions of individuals in society. For this reason we would expect that political competition is at least as likely to take the form of 'bribing' such groups of individuals (floating voters, farmers, the unions, businessmen and so on) by offers of specific tax concessions or subsidies, as it is to involve pressures to improve the allocation of resources. Ultimately, under majority rule, even a policy platform offering a perfectly efficient allocation of resources can be defeated by another platform offering redistribution of income from a minority to a majority of voters.8

(b) To the extent that incentives do exist for governments to attempt to improve on the allocation of resources determined by the market mechanism, they are constrained by the information that is made available to them about individuals' preferences. The information made available to the government through voting behaviour is likely to be deficient for a number of reasons. In the first place, since an individual voter recognizes that his vote is unlikely to be decisive, he will (quite rationally) tend to seek little information

8 Strictly speaking, of course, redistributions need only be aimed at potential floating voters, or groups which carry enough influence to affect the outcome of elections.
about the benefits of publicly provided services, or at least will not obtain as much information about them as he would about equivalent goods or services available in the private market. In the second place, voters have only one vote with which to express their preferences over competing packages of policies (policy platforms): they are not in a position to reveal their preferences over specific projects, nor the intensity with which those preferences are held. For these sorts of reasons the ballot-box is likely to be a poor source of information for government, and they will be obliged to rely fairly heavily on less direct sources of information provided by lobbies, formal surveys and enquiries, letters to members, and so on. However, while these sources may provide some information, the quality of that information is unknown. It may, for example, reflect peculiarities in the cost-sharing (tax) arrangements: anyone will demand more of a publicly provided service if it will cost them little or nothing.

Considerations of this sort certainly confirm what was perhaps intuitively obvious anyway: that the government is not at all likely to make the most efficient choice between physical goods and clean environment. It also gives us reason for treating with considerably more caution than is usually done the presumption that the government will nonetheless improve on the market's results. The government has, of course, a number of advantages over the market: through its coercive powers (through taxation) the government can force everyone to contribute to the cost of pollution control, and in this sense has a means of coping with the 'free-rider' (non-excludability) problem that is the prime cause of the market's failure. Moreover, by responding to the desires of a coalition of individuals the government obtains a degree of co-operation which (as explained earlier) would be missing in the market where each individual attempts to free-ride at others' expense. Clearly, the more homogeneous the preferences of the individuals in society the more likely it is that preferences of the dominant coalition will be fairly representative of those of society as a whole, and hence that the government's response will be substantially better than the market's. Unfortunately, we have little reason for supposing that the pollution issue is one on which there is a great deal of agreement. At least, that is, we regard the pollution question as involving more intense divisions of opinion than many other current issues, and hence we suspect that the performance of the political mechanism is likely to be correspondingly poorer: we cannot be certain, though, whether this is likely to involve too much, or too little pollution control.

This catalogue of difficulties inherent in the political mechanism convinces us that we should not expect too much of the government as a decision-maker in relation to pollution control. This is not to say that the government cannot be expected to improve at all on the market, and clearly the better informed it is, the greater are its chances of achieving a significant improvement. The economist's role would, then, appear to be to attempt to inform the government about its main policy options in controlling pollution, and the considerations which are likely to be crucial in choosing between them. It is to an outline of this task that we now turn our attention.
In so far as the market fails to establish an efficient allocation of resources between the output of physical commodities and the output of clean environment, the government is faced with the problem of choosing between a large number of instruments for modifying the behaviour of economic units. Since our major concern is with general conceptual issues, it seems useful to begin by attempting to classify the instruments available into broad categories. One such classification which immediately suggests itself is that which distinguishes those instruments which involve the use of the government's legal powers from those which involve the use of its fiscal powers.

This particular classification is one that has been quite widely used in economic analysis, apparently in the belief that it provides a clear distinction between the use of direct controls and the use of fiscal instruments. However, in an important sense this particular distinction is misleading, for the legal powers available to the government are of two quite distinct sorts, only one of which corresponds to the 'direct controls' mentioned above.

One form of legal power available to the government is that which allows it to establish liability rules. That is, the government may establish whether or not those whose activities impose damage on others are 'liable' for the damages caused. Once such liability rules are established, and the means of enforcing them (i.e. the legal system) provided, it may be left to voluntary activity to determine the extent to which individuals are prepared to allow their rights to be abridged in exchange for some form of compensation.

The second form of legal action involves the government establishing structural rules, such as regulations and prohibitions, which directly limit permissible behaviour of individuals and/or firms. In one sense, these structural rules are not unlike the liability rules since both establish particular patterns of property rights. However, while the liability rules form a base from which negotiations may freely proceed between damaged and damaging parties, the structural rules provide a non-negotiable upper limit to the extent that one party may inflict damage upon another.

It is clear, then, that there are three distinguishable policy types available to government—the establishment of liability rules, the establishment of structural rules, or the use of fiscal instruments—and at the most general level the issue to be tackled is the question whether there are reasons for favouring one policy type over the others in attempting to achieve an efficient level of pollution control. For purposes of analysis, the subsequent discussion is broken into two sections. The first considers briefly the way that changing liability rules might help to relieve the pollution problem, while the second contains a more extensive discussion of regulations (i.e. structural rules) and fiscal instruments in controlling pollution.

Liability Rules, Property Rights and Pollution Control

There is a clear connection between the establishment of liability rules (i.e. the definition of property rights) and the successful operation of
the market system. The process of exchange which characterizes market transactions essentially involves the exchange of property rights over the services of assets owned by the transacting parties. This of course is most obvious in the case of a barter process, but the only substantive difference in modern market systems is that money is interposed as the medium through which the exchange of property rights is effected. These ‘property rights’ embody the relevant liability rules, if the exchange system (the market mechanism) is to function efficiently it must be possible to define and enforce all such rights. If we cannot enforce a property right over the benefits of our activities others will benefit without having to exchange some of their property to obtain the services of ours. This is, of course, precisely the problem generally referred to as the ‘free-rider’ problem arising from non-excludability, and in a fundamental sense this problem arises directly from an inability to enforce property rights.

The relationship between these observations and the possibility of using changes in liability rules as a solution for the pollution problem lies predominantly in the fact that much of the natural environment is not subject to private property rights. In most respects the air mantle, waterways and open access lands are common property resources, equally available for use by all; and even in those cases where there are liability rules relating to damages caused through use of ‘the environment’, the large numbers of economic units involved, and the diffuse nature of the damage each imposes on other users of the environment often makes the enforcement of property rights technically and economically infeasible. These facts have inspired the belief that changing liability rules—defining or re-defining property rights—would provide one way of improving the allocation of resources to pollution control.

The proposals for an ‘Environmental Bill of Rights’, awarding a property right to a clean environment to individuals in society, are a case in point. Already modest beginnings with such Bills have been made in some states of the U.S.A. and their major purpose seems to be to make the burden of proof in environmental suits (under nuisance and property laws) less demanding. If these Bills of Right achieve their purpose, they will provide some incentive to polluters to control the damage they cause, or to offer compensation to affected individuals, although the extent to which this is so depends crucially upon the success of prosecutions under the Bills, the cost of prosecutions, and the size of damages awarded.

The qualifications introduced in the last sentence are obviously of critical importance, for the point of relying on this (or any other) sort of re-allocation of property rights to solve the choice problem is not merely to provide a legal and institutional framework within which retribution can be exacted ex post for damages suffered: the essential purpose of defining (or re-defining) property rights is to establish a basis from which negotiations between polluter and polluted could emerge to internalize relevant interdependencies through voluntary action. What is required, then, is not simply the clear definition of rights, but also the means of policing and enforcing such rights. So long as it is difficult to perceive infringements of rights or to prove damages, and while large numbers of economic units are involved, the negotiation and policing of agreements between damaging and damaged parties will remain economi-
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cally infeasible. But even if Environmental Bills of Rights are successful in reducing the problems of enforcement, there is yet another problem to be faced—that is, they may give rise to a level of pollution which is inefficiently low. This is so because precisely the reasoning which induces individuals to understate their preferences for pollution control when the firm has a de facto right to pollute, will induce individuals to overstate their requirements for compensation when the firm is liable for damages caused. In this case, the choice between physical goods and clean environment will be distorted in favour of the latter, and it is by no means obvious that a distortion in that direction is to be preferred.

It certainly seems to us that whatever purpose manipulation of property rights may serve, it is unlikely that it will provide a simple solution to the pollution problem. The crucial points may, perhaps, be summarized as follows. If the market fails to achieve an efficient allocation of resources, then it may fail whatever the allocation of property rights, because market failure can often be taken to imply that enforcement of private property rights is infeasible or uneconomic; and, moreover, if the enforcement problems can be mitigated (by, for example, reducing the burden of proof in environment suits) we may find ourselves faced with a choice between inefficiently high and inefficiently low levels of pollution.

Perhaps, after all, Environmental Bills of Rights and similar legal instruments should be seen as embodying a statement of society's views on the most equitable liability rules. Effective enforcement of property rights, and hence the establishment of major improvements in the allocation of resources between clean environment and physical consumption, will, in most cases, require the government to intervene more directly in market processes, through the use of its regulatory and fiscal powers.

Fiscal Instruments and Regulations in Pollution Control

Accepting that the establishment of efficient pollution control measures will require the government to intervene more or less directly in the market, using its fiscal or its regulatory powers, what issues are likely to be decisive in choosing the appropriate policy-mix?

This question, which constitutes the subject matter of this section, is not easily answered. In part, the difficulties arise from the fact that the criteria needed to judge the relative merits of the available options are difficult to specify with precision, but, in addition, the policy options which have been grouped into the categories ‘fiscal instruments’ and ‘regulatory powers’ may themselves be employed in many different ways. For example, in a purely technical sense it is possible to distinguish three basic methods of controlling pollution: reduction in the volume and/or improvement in the quality, location, or time pattern of residuals generation; treatment of residuals after generation and/or improvement of the assimilative capacity of the environment; or application of protective measures at the point where damage is inflicted upon the ultimate receptors. To each of these technical methods of control there corres-

*The term ‘fiscal instruments’ refers to both taxes and subsidies, while ‘regulatory powers’ includes the power to prohibit or ban an activity. In the analysis which follows we generally use taxes as representative of all fiscal instruments, and regulations as a term covering all direct controls.
ponds an array of taxes, subsidies, or regulations which may be employed to achieve some given degree of control. For example, if we are concerned primarily with controlling the volume and/or quality of residuals generated in productive activities, we may choose to relate taxes, subsidies or regulations to one or more of the following dimensions of the production-consumption process:

(i) pollution 'nuisance' or damage, defined in terms of the relevant argument(s) which enter individuals' utility functions, or firms' production functions;
(ii) the emissions which are produced as a by-product in the production of goods;
(iii) the goods with which emissions are jointly produced;
(iv) the inputs used in production processes generating pollution.

Rather than attempting (and necessarily failing) to do justice to the infinite variety of alternative policies and policy-mixes available, we have concentrated on the general issue of whether there are reasons systematically favouring the use of fiscal instruments over 'equivalent' regulations, or vice-versa. By way of justification we might offer two observations. Firstly, much of the detailed investigation of the various parameters to which taxes and regulations may be applied is available elsewhere;\(^\text{10}\) and secondly discussion at this more general level may substantially reduce the difficulties which need to be resolved at the more specific level of choice. However, whichever level of choice we are concerned to examine, an essential first-step is the specification of the criteria in terms of which choice should be made, and it is to this task that we initially turn.

The Criteria

In the most general sense, the basic objective is to choose, from the available set of policy options, a policy (or policy mix) which will achieve global efficiency in the allocation of resources to alternative uses—which 'uses' explicitly include the output 'clean environment'. However, in order to make some progress towards evaluating the relative merits of alternative policy options it seems appropriate to break up the general efficiency goal into several specific aspects, which we can indicate by raising the following set of questions:

(i) does the policy achieve an efficient 'quantity' of pollution (clean environment), both in the period in which it is initially imposed, and over time?
(ii) does the policy achieve the established level of pollution control at least social cost in terms of other goods and services foregone?
(iii) how does the policy distribute cost between the various parties in the pollution conflict?
(iv) what, for any given level of policy success, are the informational requirements of the policy?
(v) what are the measurement and monitoring costs associated with the chosen policy?

\(^\text{10}\) See, for instance, Brennan, Walsh and Chisholm [3], Parish [10] and Zerbe [14].
These questions involve, to a certain extent, distinct dimensions of pollution control techniques. The first two relate to aspects of the standard Paretian efficiency goal. The third, in contrast, is basically concerned with the incidence of the various policy options. While incidence questions might typically be thought of as being concerned with the distribtional impact of the adopted policy, it is important to recognize that distributional effects may not be allocatively neutral: the incidence of the policy may directly influence the quantity of pollution control applied.

The last two of the questions raised relate to administrative matters: they merit explicit attention here precisely because they are of such importance. To achieve Pareto optimality "regardless of cost" is clearly a contradiction in terms—and as has been emphasized in the externality literature (at least from Coase [6] onwards) questions of administrative cost, in the widest sense, may be crucial in determining the appropriate choice between policy tools. Because of their importance, particular attention is given to information and measurement costs in the comparison of fiscal instruments and regulatory controls which follows.

Fiscal Instruments versus Regulations

The primary difference between the use of regulations and the use of fiscal instruments to achieve a given end is that the former seeks to achieve the objective by directly manipulating relative quantities, while the latter operates on relative prices. While we shall have reason to suggest that this difference is of crucial importance in determining whether one or the other policy-type is generally to be preferred as the instrument for establishing an efficient level of pollution control, it may be as well to indicate at this point that at the conceptual level the difference between fiscal instruments and regulations is not as great as is commonly suggested.

In an analytical sense, the difference between, say, a tax on the production of a commodity, and a law regulating its output level might be looked on as follows: a regulation involves an implicit tax, with a rate structure that is subject to a large, discrete change at some point—usually zero up to that point, and some other, positive and finite, rate thereafter. A tax, on the other hand, usually applies at a non-zero rate over the whole range of output, although it too could have discrete changes in the rate structure. The non-zero tax rate implicit in the regulation is, of course, associated with the cost of violating the regulation, and is determined by the probability of being detected and convicted, and the penalty imposed on conviction.

In fact, if the practice of courts or legislatures in framing penalties is to attempt to estimate the true cost to the rest of society involved in the contravention of the law, and then shore up this 'cost' to allow
for inadequacies in enforcement procedures, the expected cost to each firm of contravening the law would seem to be exactly the same as that faced by the firm under a tax calculated according to marginal social damage caused (i.e. the 'ideal' Pigovian tax). Of course, one could argue, possibly quite forcibly, that generally held notions of retributive justice ('making the punishment fit the crime') may tend to militate against offenders being fined more than the estimated value of damages caused, so that due allowance for the probability of being detected is not made. However, there are often other costs associated with the act of law-breaking arising from the disapproval of society (psychic costs, or loss of goodwill, for example). Such costs (if applying) raise the effective tax rate implicit in the regulation, and may offset the failure of the courts to take full account of the deficiencies in enforcement procedures.

Clearly, taxes and regulations can, in principle, be made to operate in precisely the same way, and the differences between them at the conceptual level are much smaller than is often suggested. Nonetheless, important differences do exist associated with information requirements, measurement costs, and allocative effects generally.

**Information Requirements.**

One of the crucial differences between the use of taxes and regulations for achieving a relatively efficient level of pollution abatement is associated with their information requirements. Surprisingly, this is a fact which has received less attention than it warrants, and such observations as have been made are often dangerously misleading.

To achieve a relatively efficient degree of pollution control through a policy of 'pure' regulation, the government would need to know:

(a) what is the optimum aggregate level of pollution abatement for each of the various types of waste emissions;
(b) how these aggregates should be allocated among individual polluting units; and
(c) the level of penalties necessary to ensure compliance with the regulations.

The information needed to make correct decisions is clearly enormous: ideally what we need to know to establish the regulations is the marginal social damage function (the demand curve for pollution abatement) and the marginal social cost of abatement function (the supply curve of pollution abatement) not merely for each type of waste emission, but also for each individual polluting unit. Estimation of the demand curves requires obtaining individuals' evaluations of different levels of environmental quality, while estimation of the supply curves involves estimating the cost of goods and services foregone to achieve different levels of pollution abatement. And we need to know both because we wish to know the optimum quantity of pollution abatement.

Pollution taxes, on the other hand, would appear to be inherently less demanding informationally than regulations designed to achieve the same efficient level of pollution abatement. The point is that if we could estimate the demand curves for pollution abatement, we could face firms with a tax schedule corresponding to the marginal social
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Damage at each level of their activity, and firms themselves would adjust their activities to the efficient level. In short, in order to impose the appropriate tax, we need only know the demand curve, whereas for regulations we need both the demand and supply curves. Of course, with the tax scheme we would not know what the optimum pollution level is: the optimum will emerge from firms' adjustments.

The difficulties associated with obtaining the necessary information to set appropriate rates of tax should not, of course, be underestimated, and the costs of failing to obtain all the required information may be extreme. Nonetheless, it does seem clear that whatever the difficulties involved in meeting the informational demands of establishing efficient pollution taxes may be, they are substantially less than those involved in establishing equally efficient regulations. Since, in practice, we will have to contend with very incomplete information, expendable uncertainties should not be introduced: the expected error in 'guessing' an optimal tax structure is likely to be less than that involved in 'guessing' an optimal quantity.

Measurement Requirements

An important aspect of the administration of pollution control policies lies in the business of measuring and monitoring individuals' use of the various recipient media for the discharge of wastes. It is tempting for policy-administrators to focus only on that dimension of measurement cost which accrues to the government; but individual firms might also be obliged to incur measurement costs under certain policy options. Thus two aspects of the measurement problem are relevant:

(a) what is the total amount of measurement required?
(b) how is the responsibility for measurement apportioned between government and individual firms?

In the absence of empirical detail it is not possible to know precisely how measurement costs vary between industries, between regulations and taxes, and according to which parameters within the production-consumption process are measured. Some general observations can, however, be made.

With a pollution tax it would appear to be necessary for each firm's activities to be continuously monitored in order to establish total tax liability. A regulation, on the other hand, is normally enforced by monitoring the activities of some (randomly selected) firms at occasional (randomly selected) time intervals. Thus under a regulation, it seems, at first glance, that measurement costs will be smaller. We do not believe

**Footnotes:**

1. For example, a tax on emissions into the atmosphere may induce firms to substitute water for air as the recipient medium for waste products—and the resulting state of the world may well be worse than formerly.

2. It seems fairly clear, however, that measurement costs will generally be lower when the target of the tax or regulation is physical inputs or outputs of goods, rather than waste emissions or actual pollution damage. Against these lower measurement costs must be set the fact that it is relatively inefficient to control pollution by imposing taxes on physical inputs or outputs. We simply do not have the formidable amount of information that would be required to specify the particular mix and level of taxes on physical inputs and/or outputs that would result in precisely the same allocation of resources as would efficient taxes on pollution damage itself.
this to be true. Although the *government* is not required to do as much measuring as in the tax case, firms themselves will be required to measure their own emissions in order to ensure obedience to the law. If the effective tax rate implied under the regulation is the same as that under a tax, the incentive to measure will be the same. Total measurement costs are therefore likely to be at least as large for a regulation as for an equivalent tax, but the government has the prime responsibility for measurement in the tax case—and the firm in the regulation case.

*Allocative Effects*

We have argued that, conceptually at least, it is possible to frame penalties such that the expected cost to a firm of contravening a regulation is the same as that which would be faced by the firm under an ideal pollution tax designed to achieve the same resultant output of residuals. The implications for resource allocation are, however, likely to differ in some respects.

In the first place, the outcome under a regulation—which is enforced by a system of occasional random checks—will depend partly upon the attitudes to risk of individual firms. If firms are risk averse, there will be less pollution under a regulation than under an ‘equivalent’ continuously monitored tax.

In the second place, the tax normally involves payment over intra-marginal as well as marginal units—the regulation applies only to marginal units. Thus, if a firm produces one hundred units of pollution on the basis of a pollution tax applying at an average rate of *t* dollars, it pays a total tax of 100.\(t\) dollars. If the same firm faces a pollution quota of one hundred units, and adheres to it (which it will if the expected cost of exceeding the quota is equal to, or more than, \(t\) dollars per unit excess) then it pays nothing at all.\(^{15}\) Although this phenomenon is customarily referred to as an ‘income effect’, this may be misleading because it is also sometimes suggested that, since firms will prefer regulations to allocatively equivalent taxes, one might get more pollution control (via more general political acceptability for pollution control) if regulations are used.\(^{16}\) Moreover, it is also frequently noted that firms have a greater incentive to invest in pollution-reducing technology under taxes than under equivalent regulations because any given reduction in pollution is worth more to them in the tax case. In this sense, taxes and regulations are *not* allocatively equivalent, even when they result in the initial period in the same level of pollution output. Thus, it is clear that the so-called ‘income effects’ mentioned here are not really income effects at all.

*Summary*

Taken together, the information, measurement and allocative aspects of the tax versus regulation comparison suggest that a fairly clear case exists for generally favouring the use of fiscal instruments over the use of regulatory powers as a means of achieving a relatively efficient level of pollution control. Of course, even at this very general level

\(^{15}\) Except, of course, the foregone profits which applies equally to the tax.

\(^{16}\) Firms would have an even higher preference for subsidies on pollution abatement, but given that subsidies would probably be financed via general taxes it seems likely they would be less politically acceptable to the general public.
of analysis the arguments are not entirely conclusive. For example, we
have already noted that the 'income effects' associated with regulations
make their use more attractive to polluting units than equivalent taxes,
and hence may make the use of regulations more politically acceptable.
Moreover, if we consider particular cases of pollution we may find
circumstances in which uncertainty is so pervasive, and the potential
social costs of failing to take appropriate action so large, that the
immediate imposition of stringent regulations appears to be essential.
It is interesting to note, too, that this general preference for taxes
over regulations also suggests that a somewhat distinct group of policies
which have been the focus of increasing attention in recent years are
not as attractive as they initially appear. These policies, which might
collectively be referred to as 'environmental standards' approaches,
involve a mixture of policy-types—partly imposing regulations (i.e. the
imposition of aggregate standards of residuals disposal), and partly
using the pricing mechanism (i.e. emissions taxes in the Baumol and
Baumol and Oates in particular have argued that these 'standards'
approaches are informationally less demanding than pure tax approaches.
Our earlier arguments, however, clearly suggest that this proposition
is subject to serious doubt.
The essential point is that in order to establish relatively efficient
aggregate standards we must obtain estimates of both the aggregate
demand and supply schedules for pollution control, whereas a pure
tax scheme would involve estimation of only the demand schedule.
However, we must also accept that the 'transferable quota' approach
does have some countervailing advantages. Using a pure tax scheme,
we would need to know not merely the aggregate marginal social damage
function, but rather the social damage function for each individual
polluting unit: but using transferable quotas, once the aggregate standard
is determined, the allocation of quotas among individual units
is achieved efficiently by the market mechanism. In contrast, the
iterative procedure involved in the Baumol and Oates schemes (i.e.
adjusting uniform emissions taxes until the desired aggregate standard
is established) appears positively clumsy.
Certainly, it seems to us, the appropriate choice between taxes and
standards is much less obvious than Baumol and Oates would have us
believe, and their particular proposal appears to be less attractive than
the transferable quota approach suggested by Dales. But it would be
misleading to leave the overall debate with an implicit suggestion that
the adoption of either taxes or standards for the attainment of efficient
levels of pollution abatement would be a fairly simple matter. It should
be clear from our previous remarks that the information and measure­
ment requirements for both policy types are very large; and policies in
this area are likely to be determined in circumstances of substantial
ignorance and uncertainty. In this case, it may be best to persuade

"The operation of a transferable quota scheme requires that waste emissions
be measured in terms of some standardized 'pollution index'. With respect to
water pollution, Biological Oxygen Demand (BOD) could be adopted as the
unit of measurement for pollution quotas, for example. It should be noted, too,
that the measurement costs required to ensure that firms do not exceed their
quota levels may be high, as we have previously suggested."
governments to adopt only modest policies, and to treat broad classes of goods or inputs in uniform fashion even though we may suspect that different inputs or production processes have different 'pollution productivities'. Exceptions to this uniformity rule could then be allowed in cases where it can be clearly shown that particular inputs or processes have much higher (or lower) than average 'pollution productivity', or in particular geographical areas where pollution is more serious, and/or the demand for abatement higher than average. To adopt a series of 'finely-tuned' policies in circumstances where information is incomplete, or prohibitively expensive is to ignore the very high social costs involved in making a wrong decision.18

Conclusions

To attempt to provide a concise summary of the contents of this paper, given its size, and the wide-ranging nature of its contents, would be an impossible task. Instead, in conclusion, we might simply emphasize some of the major issues that we have raised.

We have argued that, as an economic problem, 'pollution' must be seen as involving a conflict between various possible uses of the environment, forcing us to choose between, on the one hand, consumption of physical (or produced) commodities, and on the other, consumption of a 'clean environment'. However, to argue that a choice needs to be made is not to argue that the choice need necessarily be made through the political mechanism. Making choices is, after all, what organized markets are all about, and even accepting that substantial 'market failure' is likely, we cannot state with certainty that where political decision-making processes are utilized to resolve the conflicts the results will be substantially better than those generated by voluntary action. Nonetheless, whatever we may think about the relative virtues of market and political decision-making processes, substantial political intervention is inevitable.

All of the alternative policy options for pollution control require that the demand curve for 'clean environment' be estimated. In addition, some policy options also require estimation of the supply curve of 'clean environment'. It is essentially this observation which leads us to argue that, in general, the use of taxes and subsidies is likely to be preferable to widespread use of regulations or other legal instruments. On the other hand, there does appear to be some virtue in the proposal for using transferable quotas in the context of an 'environmental standards' approach, and a mixture of 'pure' taxation policies, and the use of this quota scheme may prove to be the most useful form of pollution control.

Finally, we believe that the information and measurement requirements involved in the implementation of appropriate pollution control policies will often be extremely costly. This suggests that attempts to implement finely tuned policies for pollution control are unwarranted. In other words, it is our view that the use of the political decision-making

18 Some of the issues relevant to this assertion are considered in an unpublished manuscript by H. G. Brennan and T. McGuire, 'Optimal Policy Choice under Uncertainty'.
process to impose discriminatory control on pollution sources can, in general, only be justified in circumstances of clear market failure and where a fairly high demand for pollution abatement exists. A general policy of reducing pollution levels might be better achieved by general and reasonably uniform taxes on all pollution sources.

References

APPENDIX

THE PARAMETER SUBJECT TO TAX

This appendix contains the major parameters to which taxes, like pollution taxes, aimed at controlling pollution, can be applied.

Section Tax

The conceptually ideal parameter to which taxes should be applied is the pollution damage itself, defined in terms of the aggregated social costs as seen negatively into individuals' utility functions, or firms' production functions. The tax, which is commonly called a "pollution tax", should be levied at a rate equal to the marginal social damage caused at each level of pollution.

In so far as the amount of pollution damage is influenced by such factors as the receipt and cost of controls and the availability of substitutes, the location of the source, the nature of the activity, the quality of the air, the chemical composition of the emissions, and the time pattern of emission generation and discharge, these factors must all enter into the calculation of the tax levied on a pollution-generating activity. Otherwise, the latter gives rise to the relevant dimensions of the resource, which continue to exist in the most efficient way, will not apply.

While the properties of the Pigovian tax are extremely appealing, there are unfortunately considerable difficulties in applying the tax. The case of the tax is not much affected variables as a firm's output level of physical amenities, or tax of particular resources, not in it would accrue in the union of discharge of particular resources. Rather, the tax levied in


See also, Parish (197) q. 664. and Coker (1982) q. 380.
APPENDIX

THE PARAMETER SUBJECT TO TAX

This Appendix examines the major parameters to which taxes (or regulations), aimed at controlling pollution, may be applied.¹

Pigovian Tax

The conceptually ideal parameter to which taxes should be applied is the pollution damage itself, defined in terms of the argument(s) which enter negatively into individuals' utility functions, or firms' production functions. The tax, which is commonly called a "Pigovian tax", should be levied at a rate equal to the marginal social damage caused at each level of pollution.

In so far as the amount of pollution damage is influenced by such factors as the receptive medium into which pollutants are discharged, the location of the discharge point (e.g. height of chimney, or location of firm), the chemical composition of the emissions, and the time pattern of emission generation and discharge, these factors must all enter into the calculation of the tax levied on a pollution-generating activity. Otherwise, the incentives to use the relevant dimensions of the scarce resource, clean environment, in the most efficient way, will not apply.

While the properties of the Pigovian tax are extremely impressive, there are unfortunately considerable difficulties in applying the tax. The base of the tax is not such tangible variables as a firm's output level of physical commodities, or its input of particular resources, nor is it based merely on the volume of discharge of particular residuals. Rather, the tax is to be

¹ The Appendix is largely based on previous discussions, on the various parameters to which pollution taxes may be applied, in Tony Chisholm and Cliff Walsh; "Environmental Quality and Resource Allocation: A Proposed Framework for Analysis", paper presented to 17th Australian Agricultural Economics Society Annual Conference, February 1973; and Brennan, H.G., Walsh, C. and Chisholm, A.H. [3], op. cit. See also, Parish [10] op. cit. and Zerbe [14] op. cit.
assessed at a rate equal to the marginal social damage caused by each firm's activity. Since a firm can vary the form of its activity to reduce the damage caused, any attempt to relate the tax to volume of emissions, output of physical commodities, or inputs used, represents a substantial departure from the principal advantages claimed for the Pigovian tax. Moreover, to calculate the optimal tax, we require to know not so much the current marginal damage caused by a firm's activity, but rather what marginal damage the activity will cause when the level and organization of the activity have been adjusted in optimal fashion.

Apart from the severe informational demands of applying taxes to pollution damage levels, per se, there will generally be very substantial measurement costs involved. For example, to monitor such highly dispersed discharges as run-off water carrying agricultural fertilizers or pesticides, may be technically quite infeasible, even when one knows precisely which fertilizers (pesticides), or compounds used in them are most objectionable and which least, and what relative negative values individuals place on them.

Such considerations have generally encouraged a less ambitious approach to policy - at least among policy-makers. The prime task is, of course, to find a parameter which is amenable to easy measurement. The major alternative tax bases are now considered.

Emissions Taxes

Taxes imposed on emissions of particular residuals seem to retain many of the desirable features of taxes based on damage caused by those residuals. In particular, they provide firms with direct incentives to adjust their production techniques, or install pollution control devices, since these adjustments will reduce the level of the emission tax paid. At the same time, unless emissions of all damaging residuals are taxed at the appropriate rates, and all points of emission subjected to monitoring, firms will have an incentive to change their techniques of production to those which generate relatively more of untaxed residuals, or to change their points of discharge
to those which are unmonitored. Since the appropriate rates of the taxes required to achieve optimal adjustments by firms must be determined by the damages caused by the emissions, the calculation of emissions taxes is ultimately plagued with broadly the same information problems as the Pigovian tax. If the rates of tax are not appropriately calculated, then more polluting emissions may be substituted for less polluting ones, discharge locations involving greater damage substituted for locations involving less, and so on. In this sense, it is not clear that the gains from departing from the attempt to determine the appropriate Pigovian tax are so very substantial, at least in informational terms. The basic point is that certain information is required and there are costs in not having it.

Production (Output) Taxes

It is commonly suggested that a tax should be imposed on the output of commodities when their production generates harmful residuals. From the standpoint of economic efficiency and incentive to innovate, a production tax is clearly a fairly crude control procedure. The primary weakness of this tax is that it provides no incentive to substitute production techniques which generate lower damage per unit of output for those creating higher per unit damage. Furthermore, output taxes provide no incentive for pollution reducing technical innovation, or for the use of pollution control processes that do not directly reduce a firm's costs of production.

At the same time, measurement (and hence enforcement) costs are relatively low with output taxes, and such taxes are sometimes defended on these grounds. However, input taxes have the same virtue, and in addition have the advantage of encouraging firms to use less polluting technologies.

Input Taxes

The prime virtue of input taxes is their administrative feasibility. In particular, input taxes may be the best control procedure for situations where the direct monitoring of pollution emissions is technically impossible, or would involve very high administrative costs. For example, for highly
dispersed discharges such as run-off water carrying agricultural fertilizers or pesticides.

With an input tax a firm would be given an incentive to reduce its pollution emissions, not simply by reducing production as with an output tax, but also by changing the input mix. Providing the appropriate rate(s) of input tax(es) is selected, the post-tax resource allocation will be more efficient than that which would prevail with an output tax. A government is extremely unlikely though to ever have sufficient information to levy 'optimal' input taxes. This would require detailed knowledge of the relative pollution productivity of the various resources, the elasticity of output supply, and the elasticity of substitution between resources. Even with such information, input taxes will not generally ensure a Pareto efficient resource allocation, since they provide no incentive to use emission-control equipment to improve the quality of emissions and/or reduce their volume. In some circumstances, the least-cost way of reducing pollution may be to continue to use the same input-mix, but install emission-control equipment.

Basically, there appear to be two main considerations in that dimension of policy choice concerned with the point in the production-consumption process at which policy is operative. The first relates to differential measurement and enforcement costs. It is almost certainly cheaper for a government to administer an inputs or outputs tax than an emissions or pollution tax. The second relates to the appropriate policy response to inadequate information. It is perhaps obvious, for instance, that any superiority of

2 With regard to the installation of pollution-control equipment, the Report of the Australian Select Committee on Water Pollution, Water Pollution in Australia, Commonwealth Printing Office, 1970, pp.111-120, is relevant. Income tax concessions and other forms of subsidy on pollution control equipment were the most commonly proposed policies for pollution control made by firms giving evidence before the Senate Committee. Perhaps the most important point to make on this matter is that any form of subsidy on pollution control equipment is, on its own, of little value as a control measure. Unless firms are penalised in some way for waste emissions, they have little incentive to install equipment which neither adds to revenues nor reduces production costs, no matter how small the post-subsidy equipment cost may be.
input taxes over output taxes, depends crucially on the presumed knowledge on the part of the policy-maker that some inputs generate more pollution than others. If the policy-maker does not have this information it is more efficient to impose a simple output tax rather than to tax all inputs at the same rate. Similarly, in circumstances where there is predominant ignorance concerning the precise pollution-generating characteristics of different outputs, it may be desirable to tax broad classes of commodities at identical rates, even though the pollution generated within those classes may differ.
APPENDIX 7.2

POLLUTION AND RESOURCE ALLOCATION: A REPLY

Richardson's comments (2) in our analysis of the pollution problem appear to contain three distinct errors. Firstly, Richardson argues in his reply to allow for the possibility of controlling pollution at any prior to the production-consumption phase, i.e. to stop pollution at the stage that we normally describe as substantiating our failure to deal systematically with potential causes of pollution problems. Finally, he questions whether conclusions about appropriate pollution control may be generated from a discussion of general principles. Each of these seems to demand some response on our part, and we consider each in turn.

It seems clear that Richardson does not focus on the question of controlling pollution at source, i.e. in the production/consumption process. He ignores the possibility of control at a stage which usually directly affects the consumption activity. "(2, p.141)

But, in even a comparatively casual reading of our article, this criticism is based on a gross misunderstanding and misrepresentation of what we say. Certainly, there is nothing in the structure of our model that places any severe restrictions on control of pollution at any prior to the point of consumption. Throughout our discussion, we emphasized the importance of viewing the production-consumption system for physical consumption goods as a whole, and in its perfectly closed form pollution control policies, designed to change the balance between physical goods and "clean environment", can be applied at any prior to the...
Richardson's comments [2] on our analysis of the pollution problem [1] appear to contain three distinct strands. Firstly, Richardson accuses us of failing to allow for the possibility of controlling pollution at any point in the production-consumption process other than that at which physical commodities are actually produced. Secondly, he is critical of our failure to deal specifically with recycling as a possible solution to the pollution problem. Finally, he questions whether conclusions about appropriate policy responses to pollution can be generated from a discussion of general principles. Each strand seems to demand some response on our part, and we consider each in turn.

It seems clear that Richardson sees our focus on the question of controlling pollution "at source" as a crucial departure from generality.

"...This model places emphasis on controlling pollution at source, i.e. in the production process, thus ignoring the possibility of control at a subsequent point, namely after the consumption activity." [2, p.1].

But, as even a moderately casual reading of our article would reveal, this criticism is based on a gross misunderstanding and misrepresentation of what we say. Certainly, there is nothing in the structure of our model that rules out control of pollution at or beyond the point of consumption. Throughout our discussion, we emphasize the importance of viewing the production-consumption process for physical consumption goods as a whole; and it is perfectly clear that pollution control policies, designed to change the balance between physical goods and "clean environment" can be applied at any point in the
chain. It is true that we draw a distinction between adjustments to pollution by the 'victims' of the negative externality "...at the point of damage" and adjustments by the externality-generating agents "...at source". This distinction is essentially that between responses to pollution at the point in the consumption or production process where residuals cause a perceived nuisance (the point of damage), and those which occur at the point where residuals are produced "...simultaneously with the production and consumption of physical goods" ([1,p.7] emphasis added). Yet Richardson seems to believe that our model equates the "source" of pollution with the production process alone. This definition of "source" is his, not ours - it is in no way a definition that is suggested by our discussion, and its relevance to our analysis lies entirely in Richardson's imagination.

Since there seems to be some confusion about this point, however, it may be useful to re-emphasize the reasons for our distinction between adjustment at 'source' and elsewhere. Typically, adjustments to pollution by receptors at the point where damage occurs - adjustments such as moving away from the pollution source, installing air cleaning or conditioning devices and so forth - are private in nature. These responses will occur naturally in the freely operating market whenever the private marginal gains exceed the private marginal costs of adjustment. By contrast, adjustments by the externality-generating agents, whether by producers or consumers, (i.e. adjustments "...at source" in our terminology) are typically public in nature, in the sense that the benefits of such adjustments are equally and totally consumed by all the affected parties. These are not responses which one would, in general, expect to emerge naturally in a freely operating market. To the extent that responses at source are least social cost (most efficient), there will be a case for government intervention via regulation or fiscal instruments - although, as we are at pains to point out in the latter part of our article, this case is only a weakly presumptive one.

Thus, the distinction between pollution adjustments at source and those
at the point of damage is of considerable policy significance, for it is only in so far as adjustments at source are the more efficient that a case for public intervention can be made. The distinction between pollution from production activities and pollution from consumption activities (i.e. between production and consumption wastes) by contrast seems to us to be of no policy significance whatsoever. And the fact that we did not provide a separate analysis of each in our paper is, we believe, a reflection of the generality of our approach, rather than the opposite as Richardson implies.

Turning to the second issue raised by Richardson, it is true that we did not explicitly consider the possibility of recycling. Such neglect was deliberate. The focus of our paper related to the question of market failure and the associated question of appropriate pollution policies. To the extent that recycling, of both consumption and production wastes, is economically viable in the freely operating market it will occur naturally and hence lies outside the concern of our discussion. The recycling issue only becomes relevant for policy purposes if one or other of two possibilities occur. The first is that the freely operating market sets prices for so-called "exhaustible" resources improperly so that their rate of exploitation over time is non-optimal: in this case, recycling decisions based on market prices will also be inefficient. But we made it quite clear in our original discussion that the problems of optimal pricing and rate of exploitation of exhaustible resources lay outside the scope of our paper.

The second possibility is that, although recycling is not economically viable at current market prices, it may become efficient when appropriate taxes or regulations on wastes disposal are imposed. In this case, however, it is the absence of these policy instruments to internalize the externality that gives rise to inefficient recycling decisions. In other words, the recycling possibility (like a whole range of other feasible methods of adjustment that serve to minimize residuals generated per unit of physical product) only emerges in response to government policies, if it emerges at
all. Whether recycling or some other change in technique is most efficient depends of course on the particular case. The important point is that if the correct policy choice is made (e.g. the appropriate Pigovian damage tax), the polluting agents themselves will make the correct adjustments.\footnote{The implementation of a 'correct policy' will commonly induce a polluting agent to simultaneously use a number of methods of pollution control, including perhaps recycling. In these circumstances, when optimal adjustments have been made, the marginal social benefit from pollution abatement will equal the marginal composite cost of pollution abatement, and the marginal cost of pollution abatement by each method in use also will be equal to the marginal social benefit.} If one accepts this, then the isolation of the 'correct policy' - and not the best response to it by firms and consumers - becomes the crucial policy issue.\footnote{Our decision not to examine recycling in detail is therefore no more surprising than our failure to discuss at some length the theory of induced technical change.} We adhere to our belief that recycling is not in itself relevant to the central policy question.

Finally, we come to the matter of whether a discussion of general principles is capable of indicating a preference for fiscal over regulatory instruments in the pollution context. To be sure, there will be cases where regulations may be more appropriate and nothing in our paper denies that possibility.\footnote{For instance, direct regulations are likely to be the most appropriate policy in situations where the level of pollution damage is subject to sudden and extreme fluctuations as a result of stochastic disturbances arising from, say, unusual meteorological conditions.} Our conclusion was simply a response to a persistent trend in the way logic appeared to take us (particularly in our arguments about information and measurement) favouring the use of fiscal instruments. Richardson's discussion has not in any way served to indicate that such a general conclusion may be inappropriate.

Generally speaking, we believe that the presumption in favour of fiscal instruments over regulations must be allowed to stand, and that the relative neglect of these instruments by policy makers, in favour of direct regulations,
cannot be easily justified in efficiency terms. A serious question is therefore raised as to whether society is currently bearing unnecessarily large costs from pollution controls.

But whether this is so or not, we believe that a good grasp of the conceptual issues at stake in the pollution/environment debate is a crucial prerequisite for policy formulation. Nothing, either in Richardson's comments or elsewhere, has persuaded us otherwise.
REFERENCES


APPENDIX 7.3

PRESERVATION AND UTILIZATION
OF WILDLIFE

Conservation and recreation in arid Australia: an economic perspective

Introduction

The natural resources of Australia's arid zone provide a unique economic stimulus of both a production and non-production nature that contributes to the state's wellbeing. The latter category includes the services in an ameliorate environment, both human and the non-living natural deposits, the former of which is the resource given for use of any economic nature.

The arid zone is the most productive part of Australia. These resources are normally used in the domestic economy of Australia and world trade. The latter category are the non-production services, which Australia provides for both domestic and international markets.

The use of wildlife for economic purposes is an important economic activity of which Australia and many other countries are conscious. The recognition of the non-production services, the supply of environmental benefits, the production of several economic activities, and the recognition of the value of non-production resources, are factors that influence the economy of Australia. The economic activities in the non-production services are economically important and affect the economy of many countries. The non-production services are important, and their economic influence is important to many countries.
Conservation and recreation in arid Australia: an economic perspective

H. CHISHOLM

Introduction

The natural resources of Australia's arid zone provide a broad array of economic services of both a production and consumption variety that contribute to man's well-being. In the former category are the intensive (in an economic sense) wool and beef industries and the point-located mineral deposits, the mining of which is the raison d'être for most of the major towns located in arid Australia. These industries are currently the dominant economic activities in arid Australia and seem destined to continue in that role for the foreseeable future.

In the latter category are the environmental/recreational services, which arid Australia provides for both Australian and overseas visitors. The use of arid Australia for leisure-oriented environmental/recreational purposes is, after the pastoral and mining activities, its most significant use. And it is this use that is the primary concern of the present paper.

The paper is broadly divided into three parts. The first section provides a brief background perspective of the demand and supply of environmental/recreational services in arid Australia. Some figures given in this section indicate that there has been a rapid rate of increase in demand for recreation in arid Australia in recent years. This suggests that there will be greater competition for scarce natural resources in the future and that an increasing number of social choices will be required to achieve appropriate utilization of the arid zone's resources.

Many of the best attainable social choices are not made explicitly as such, rather they emerge as the summation of a large number of decentralized market decisions. Certain types of environmental/recreational services may profitably be provided in arid Australia by private enterprise (e.g. as an adjunct to pastoral activities). However, most environmental/recreational resources in arid Australia have characteristics that prevent their efficient utilization through decentralized market processes. Market failure arises primarily because for many environmental/recreational resources, the enforcement of private property rights is infeasible. For the market mechanism to operate efficiently it must be possible to precisely define and enforce property rights.

When market failure occurs it is typically presumed that social choices will need to be made explicitly by government. The primary aim of this paper is to provide a conceptual economic framework within which the pertinent issues for such social choices may be considered. Towards this end, in the second section of the paper, the economic problems relating to the preservation and utilization of wildlife are considered. In the third section, we consider the problems posed by choices relating to such matters as whether or not to preserve a landscape with rare geomorphological features threatened by demands for an alternative use of the site, such as mineral exploitation. In particular, we consider the conceptual problem of how the environmental/recreational benefits of such assets should be evaluated.
Demand and Supply of Environmental/Recreational Services

Arid Australia has distinctive geomorphological features, plant and animal life, climatic conditions, and a general atmosphere of vastness and spaciousness. The visual/aesthetic qualities of the most outstanding arid landscapes (e.g., Ayers Rock and Mt Olga) probably make them the most valuable environmental/recreational resources in arid Australia. The visual character of the landscape is enhanced by a diverse range of animal and bird life, although many of the animal species are nocturnal, a characteristic which considerably detracts from their value as resources.

In addition to the natural phenomena of arid Australia, there are interesting historical and cultural features, and a distinctive 'outback' way of life that has evolved in response to the vast distances and harsh environment. Such features as Aborigines and early European settlements, cattle and sheep stations, and mining operations are important recreational attractions.

In relation to other environmental/recreational areas, the most significant comparative disadvantage of arid Australia is the distant location of the recreational attractions in relation to the main population centres in addition to the vast expanses of monotonous landscape and poor quality roads between the major recreational attractions. Travel to and within arid Australia tends to be costly in terms of both money and time.

The demand for open-space recreation in arid Australia is being moulded by a number of influences. These influences include the growth rate of both the Australian population and of overseas visitors; changes in real per capita incomes; available leisure time and tastes for open-space recreation; changes in the cost, time and comfort of travel to and within arid Australia; the levels of congestion and pollution within the large urban population centres; and the supply of environmental/recreational services in non-arid areas.

A reasonable indicator of the general growing demand for environmental/recreational services in Australia is provided by data that shows an increase in the number of people visiting natural parks. McMichael (1972) reports that the median rate of annual increase in visitors to natural parks in Australia over the late 1960s was 11 per cent. He states that an annual increase in demand for open-space recreation of the order of 10-12 per cent may be expected.

The above figures may be compared with data enumerating visitors to Alice Springs and Ayers Rock, the main recreational attractions in arid Australia. Based on figures provided by the Ministry of Tourism, the average annual growth rate of visitors to Ayers Rock and Alice Springs over the period 1968-71 was approximately 22 per cent and 32 per cent, respectively. These figures substantially exceed the annual rate of growth of the Australian population of approximately two per cent.

Many of the environmental/recreational services in arid Australia are provided by natural parks used exclusively for recreation. There are other areas of arid Australia used primarily for recreational purposes, but which also jointly supply, or influence the supply of, environmental/recreational services. Apart from the obvious example of the pastoral properties, there are two further uses of arid Australia that are related to recreation and conservation. First, there is a desire to set aside representative areas of the various arid zone ecosystems for purposes of scientific study. The gene pools preserved in such areas have a potential economic value for future plant and animal improvement programs and as a source of biologically active compounds. Additionally, studies of the structure and function of representative ecosystems would enable us to provide benchmarks against which man-induced changes in the arid environment may be understood and monitored. Such studies would have particular relevance to problems of ecosystem instability that may arise from man's use of an arid environment.

Secondly, there is a demand to conserve areas of arid Australia for Aboriginal reserves. These reserves contain some of the most scenic and best preserved areas in the arid zone, and in addition have many cultural antiquities. This is resulting in a growing tourist demand to visit these areas. It is possible that many Aboriginal reserves and their uses by visitors. By opening up and certain areas of their reserves to visitors and acting as guides and interpreters of interesting cultural features—such as cave and rock paintings and engravings and stone arrangements—Aborigines may enhance their sense of identity and pride in their own culture. At the same time they would also generate a greater understanding and appreciation of the culture and point up the inevitable problems that confront such minority groups.

Preservation and Utilization of Wildlife

Arid Australia supports a large wildlife population for which there is a significant recreational demand. In this section, we attempt to identify: the social choices relating to the preservation and utilization of wildlife, the areas of market failure, and the policy options available to government in controlling wildlife. The following discussion, which involves the kangaroo as an illustrative example, is indicative rather than definitive.

The kangaroo is by most measures, the leading form of wildlife in arid Australia. It is to be found over most of the arid zone with heavy concentrations of its larger species on relatively well-watered pastoral properties. Indeed, it is claimed that the spread of grazing and pastoral activities, and the changes induced in the composition of vegetation by domestic livestock have led to an overall increase in the populations of the larger kangaroo species, particularly the red kangaroo. At the same time, however, pastoralism has resulted in the extinction or threatened extinction of many species of smaller marsupials.

To obtain an understanding of the nature of the economic problem our first step is to identify the main competing demands for the larger kangaroo species. These are: their use for recreational attraction, their commercial exploitation for meat and meat by itinerant hunting, hunting them for sport, hunting to destroy them as pests on pastoral properties. The proper social choices were made they would result in a kangaroo population of optimum size and simultaneously achieve a correct balance among the above competing demands. The free market mechanism will, however, fail to achieve this goal.

1A number of references are relevant to the issues outlined in this section of the paper. See, in particular, Box, 1972; Christian, 1969; Costin, 1969; Day, 1971; Harris, 1969; Heathcote, 1972; and McMichael, 1972.

2In absolute terms, the number of visitors to the main recreational attractions in arid Australia is very small compared with visitors to natural parks within close reach of a large city. For example, McMichael reports that 1,000,000 people visited Royal National Park near Sydney in 1969. In comparison, 40,000 people visited Ayers Rock in 1972.

3The discussion, however, is also relevant to other non-domesticated species in arid Australia such as the emu and rabbit.
The major obstacle to the market attainment of a socially appropriate level of preservation and utilization of kangaroo is their roaming boundaries, which the author is aware. Thus, the kangaroo tends to roam equally available for use by all.

This mobility, which is characteristic of most wildlife species, usually thwarts individuals having workable property rights in them. It is usually uneconomic for individuals to attempt to confine wildlife within the spatial boundaries of particular pieces of land. Although some research work on the boundaries of particular pieces of land. Although some research work on the boundaries of particular pieces of land. Although some research work on the boundaries of particular pieces of land. Although some research work on the boundaries of particular pieces of land. Although some research work on the boundaries of particular pieces of land. Although some research work on the boundaries of particular pieces of land. Although some research work on the boundaries of particular pieces of land. Although some research work on the boundaries of particular pieces of land. Although some research work on the boundaries of particular pieces of land. 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To elucidate the economic inefficiencies likely to result from wildlife being held under common-ownership we consider in turn each of the above uses for the kangaroo. Initially, we will assume that the particular use under consideration is the only use. We later relax this assumption and examine the additional inefficiencies that may arise as a result of the interrelationships between competing uses.

First we may consider the situation where the only demand for the kangaroo is for its use as a pest on pastoral properties. In many ways this case is the inverse of the previous one. Very little knowledge exists about the degree of competition between kangaroos and domestic livestock for forage and water. There seems little doubt, however, that beyond some density kangaroos are competitive with the sheep and cattle enterprises, and this competition is probably most marked in times of un favourable seasonal conditions. Apart from competition for forage and water, kangaroos may also be a pest on pastoral properties.

In contrast with the potential excessive exploitation of kangaroo for its skin and meat, in its role as a pure pest it will tend to be undercontrolled. Due to the mobility of the pest, control undertaken on one property will create benefits for surrounding properties. There is thus a substantial element of non-excludability. Those who do not undertake pest control may nonetheless benefit from control measures adopted by others. Because individual property owners do not receive payment for the benefits they confer upon others through their pest control operations, a less than socially (collectively) optimal amount of pest control will be undertaken.

Finally, we consider the kangaroo as a visual recreational resource. In this capacity, the kangaroo will commonly have the attributes of a public good. Consumption of the visual recreational services kangaroos provide, will not diminish the quantity of services available for consumption by others. Moreover, it will usually be infeasible to attempt to make the consumption of these services dependent upon a price payment. Consequently, the market will provide less than a socially optimal quantity of kangaroo for visual recreational purposes. In this regard, the main form of market failure may be readily identified if we consider competing uses for the natural resources that support kangaroos. Private entrepreneurs who are deciding the most profitable use of natural areas of land will place a zero value on its use as a habitat for kangaroo—as a visual recreational attraction—if they are unable to appropriate payment from those who benefit. The land may thus be developed for an alternative use that is incompatible with the continued support of kangaroo, despite the fact that the preservation alternative may yield higher benefits for society.

We have now considered each of the alternative uses for kangaroo. Our conclusion is that in each case market failure will typically occur and lead to socially inappropriate preservation and utilization decisions. Up to this point we have not considered the interrelationships between the alternative uses for kangaroo. It is helpful to begin this task by specifying the necessary economic conditions that would need to be satisfied to achieve a socially efficient equilibrium among the alternative uses.

The necessary condition is given below:

$$MSV_r = MSV_h + MSD_p$$

where,

$$MSV_r$$ = marginal social value of kangaroo in its visual/recreative use.

$$MSV_h$$ = marginal social value of kangaroo in commercial hunting activity.

$$MSD_p$$ = marginal social damage of kangaroo as a pest.

*For some discussion of competition between the kangaroo and domestic livestock on pastoral properties, see Parliament, Commonwealth of Australia, 1971, and Mann, 1969.

This term is used broadly to embrace the totality of visual-aesthetic-ethical demands for kangaroos.

As we have already seen, some forms of development on pastoral properties may increase the capacity of the land to support kangaroos. That is, in some circumstances development may be complementary rather than competitive with the kangaroo.
In a freely-operating market—with no government intervention—the above condition will not be fulfilled. In some regions the marginal social value of the kangaroo in its visual/recreational use will exceed the combined marginal social value of kangaroo in the commercial hunting activity plus the marginal social damage of kangaroo as a pest, and the size of the kangaroo population should be increased accordingly. And vice versa. It is also apparent that when the interrelationships among alternative uses of the kangaroo are considered that there are market failures, which are additional to those that have been previously discussed. The most important of these is that commercial hunters and pest controllers will take no account of the social visual/recreational value foregone as a result of the kangaroos they slaughter.

It is typically argued that the divergences between private and social costs and benefits, arising from these market failures, provide a strong case for government intervention. We may distinguish two forms of intervention. The government may use its fiscal powers to impose Pigovian-type taxes (or subsidies) on the various activities associated with the slaughter of the kangaroo or the destruction of its habitat. Secondly, the government may use its legal power to impose regulations and/or prohibitions on the above activities. Alternatively, the government may use its legal power to acquire land for the purpose of establishing natural parks for the kangaroo and other wildlife. Or it may organize the construction of pest proof fences around the periphery of pastoral areas, as has been done in attempting to exclude the emu and rabbit from some pastoral areas.

In practice we would expect the government to use some combination of these policy options, but for purposes of discussion we consider separately Pigovian-type taxes (subsidies), and regulations and prohibitions. The overall aim of the tax (subsidy) approach is to induce changes in the market behaviour of individuals by removing divergences between marginal private and social costs and benefits. We may illustrate this by reference to the commercial hunting activity, where it is assumed that each individual hunter will expand his activity to the point where he estimates that the marginal cost of capturing additional animals equals the marginal revenue from their skins and meat. Each hunter’s activity, however, generates externalities and it is these that would be target of the tax. Ideally, the amount of tax paid on the capture of each kangaroo would equal the sum of several components: the loss in social visual/recreational benefits; and the present value of future losses borne collectively by commercial hunters, due to the individual hunter taking no account of the impact of his current hunting activities on the future collective profitability of hunting. From the sum of the above two external diseconomies it is necessary to deduct any favourable impact (external economy) of the capture when it reduces marginal pest damage. It is of course conceivable, that in areas where the kangaroo is a major pest, the appropriate amount of tax paid for their capture may be negative. That is, commercial hunting would be subsidized.

Insofar as the external diseconomies (economies) generated by individual hunters vary over both space and time, the above taxes (subsidies) would need to reflect such variations. Thus such factors as locality, seasonal conditions, breeding or non-breeding period, and perhaps the sex and size of individual kangaroos, may need to be taken into account when assessing the appropriate scale of taxes (subsidies).

In addition to commercial hunting activities, taxes (subsidies) would also need to be simultaneously imposed on pest control and any activities that destroy or improve the habitat for kangaroos. The operation of a tax-subsidy scheme incorporating the above features would clearly be extremely demanding in terms of information and administration. It would be necessary to take these considerations in mind that various forms of Pigovian-type taxes (subsidies) and regulations and prohibitions may be discussed.

One such procedure would be for the government to set a target (standard) for the appropriate size and distribution of the kangaroo population, on the basis of a fairly arbitrary ‘weighting-up’ of the competing demands for kangaroos and their associated areas of market failure. This is similar to the approach taken by Oates (1971) for regulating environmental pollution. The government could introduce a quota system. Quotas, specifying the aggregate numbers of kangaroos permitted to be killed, could be set for clearly defined zones. To enable an efficient allocation of quotas among individuals, they could be sold by auction (competitive bidding), or an attempt could be made to set a quota price that would equate supply and demand.

To set aggregate quotas at a socially optimal level, government would require at least as much information as would be required to set a socially optimal scale of taxes and subsidies. Some administrative costs, however, are likely to be lower for a quota scheme than for a tax-subsidy system. Quota scheme may be policed by a system of random checks combined with the imposition of sufficiently punitive fines on individuals detected hunting without quota rights, or exceeding their quota rights, or hunting in prohibited areas, or harvesting of the prohibited times of the year. On the other hand, a government would need to incur collection costs and the costs of precision assessment with a tax (subsidy) scheme.

In practice, the appropriate mix of taxes (subsidies) and regulations will vary from one situation to another, being largely determined by information and administrative considerations.

Evaluating the Social Benefits of Environmental/Recreational Phenomena

Our aim in this part of the paper is to provide a conceptual framework for identifying and evaluating the economic benefits provided by an important class of environmental and recreational phenomena in arid Australia. The kinds of social choice problems to which our discussion is applicable perhaps best illustrated by example.

First, a decision may need to be made whether or not to preserve a landscape with unique (rare) geomorphological features that is threatened by an alternative use for the land such as mineral exploitation. Alternatively, the threat of destruction may come from natural processes such as erosion, and it may be necessary to make a decision whether or not to implement costly preservation measures. Secondly, a preservation decision may be required when the use of an area for a particular purpose (e.g. pastoral activities) threatens an environment that is essential to the survival of some species of antiquities will be damaged and eventually destroyed through weathering. In many instances, these could be preserved by not 'touching-up'.

The essential characteristics of these preservation decisions are that they involve unique, or rare, phenomena, with
provide non-priced environmental/recreational services. These phenomena, once destroyed or transformed, are virtually irreparable. One of the questions these preservation decisions is the question, how can we evaluate the economic (social) benefits from the preservation of rare natural environments?

As a point of departure for evaluating the social benefits of the services provided by such phenomena, we may value the benefits as the aggregate amount users of the environmental facility would be willing to pay rather than forego its services. This value is conventionally represented by the area under the aggregate demand curve, where the demand curve relates the quantity of the service consumed per unit of time, to the price charged for the service. For a reusable, non-depreciating natural environment, the value of its services is the sum of the values under the demand curves for each time period the facility is used. The customary unit of time is one year and the total social benefits—expressed in terms of their present value—is the sum of the discounted annual benefits. For the present, the analysis is confined to valuing the benefits for a single time period only.

The area under the aggregate demand curve for the services of a particular environmental/recreational facility may be interpreted as the total 'gate receipts' that could be theoretically appropriated by implementing a perfectly discriminating pricing policy. That is, each consumer would be required to pay a price (entry fee) equal to the maximum amount he would be willing to pay rather than forgo the recreational experience. This amount would vary from one individual to another depending upon the intensity of each individual's references for the recreational experience. Some individuals could be prepared to pay high amounts and others only low zero amounts, and this is precisely why the aggregate demand curve slopes downwards to the right.

In practice, of course, discriminatory pricing is infeasible and either free entry is given to all, or a standard entry fee is charged. In the absence of congestion and/or ecological damage to an environmental facility, free entry is commonly allowed. Natural phenomena may be viewed as free gifts of nature. Until some saturation level of recreational use is reached for a particular environmental facility, the use of the area by additional people does not diminish the recreational experience for others. There is therefore no need to ration the environmental/recreational services by restricting entry to the area. This situation is depicted in Fig. 1. Suppose $D_1D_1$ is the demand curve for, and $SS$ the supply curve of, environmental/recreational services provided by the area. The aggregate value of the recreational benefits is then measured as the whole area $OBO_qo$ under the demand curve $D_1D_1$. If we now assume a new demand curve $D_2D_2$, the demand for environmental/recreational services will exceed supply unless some form of restriction is imposed on entry. For instance, entry may be rationed through the price mechanism by charging a uniform entrance fee. The area under the aggregate demand curve $D_2D_2$ may be separated into two parts. First is the area $OCEqo$, which represents the value of appropriate benefits. That is, the actual payments made for the use of the facility. Second is the area $CAE$, which measures the difference between actual payments $OCEqo$ and the maximum amount users would have been willing to pay for the use of the facility. $CAE$ is all consumer surplus given the demand curve $D_1D_1$ and assuming free entry.

The main reason for introducing the concept of consumer surplus has been to highlight the fact that the actual prices charged for the use of public environmental/recreational areas are typically an extremely poor indicator of their 'true' economic value. On the other hand, the area under the aggregate demand curve incorporates both actual payments and consumer surplus and thus provides a much fuller measure of the social benefits derived from environmental/recreational services. Even this measure, however, will not always capture the full social benefits provided by an environmental/recreational area. Following in particular the stimulus of an important contribution by Krutilla (1967) some further considerations have been recognized by economists in recent years. We will now separately consider the influences of exter nalities, option demand, and technological change on the social benefits derived from natural environmental facilities. The latter two influences arise from the presumption that the supply of natural environments is virtually inelastic and that they are non-reproducible once destroyed. It seems to be widely accepted that much of arid Australia is ecologically brittle, in the sense that intervention by man will often fundamentally change the ecology and natural qualities of the area.

More importantly, if intervention ceases, the original natural environmental qualities may have been destroyed forever, or else the rate of their recovery will be extremely slow. Clearly, man-made decisions that may irreversibly alter the environment, entail a much greater responsibility than the supply curve for environmental/recreational services probably that optimal 'carrying capacity' for the area has been specified. Theoretically, the optimal carrying capacity is attained when the marginal disutility to existing users of the increased congestion (external discomfort) generated by an additional visitor is equal to the utility gain of additional visitor.

In situations where no benefits are appropriated through actual payments, the whole area under the aggregate demand curve represents consumer surplus. In Fig. 1, for example, the area $OBO_qo$ is all consumer surplus given the demand curve $D_1D_1$ and assuming free entry.

OAEOqo. This quantity $CAE$ is termed consumer surplus. In situations where no benefits are appropriated through actual payments, the whole area under the aggregate demand curve represents consumer surplus. In Fig. 1, for example, the area $OBO_qo$ is all consumer surplus given the demand curve $D_1D_1$ and assuming free entry.

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those decisions whose consequences can be undone if hindsight shows them to be undesirable.

Externalities and Merit Goods

It has been argued by Tisdell (1972b) and others that environmental/recreational areas commonly have favourable spillover effects (externalities) for society as a whole, which are additional to the utility gained by individual users. For instance, research by psychologists and sociologists indicates that high levels of congestion and crowding of human populations in cities tend to breed aggressiveness and violence, and that such tendencies are more marked in particular circumstances when there are a large number of people. If this is true, the value of these spillover effects should ideally be added to the value of social benefits. Moreover, spillover effects of this sort provide a sound basis for subsidizing the use of these natural areas by such means as cheap transport. The reason is that spillover effects are also most relevant for natural parks, beaches etc. within easy reach of major cities; and they are unlikely to be very significant for environmental/recreational areas in arid Australia.

Perhaps of more relevance to arid Australia is the likelihood that many individuals are unable to properly evaluate the benefits to be derived from recreation in this region because they have imperfect knowledge. In such cases, it may be argued that overt preferences do not represent an individual's true preferences or real interests. This concept is relevant to services provided by natural environments when effective consumption, and full appreciation of the benefits to be obtained from such services, is dependent upon the prior acquisition of specialized knowledge gained largely from direct experience (i.e. learning-by-doing) and communication with those who have had such experience.

Option Demand

The concept of option demand has been the subject of some controversy in the economic literature since it was first proposed by Weisbrod (1964). There is now reasonably widespread agreement, however, that option demand will commonly exist for rare irreplaceable natural assets. In situations where option demand exists, the measure of expected consumer surplus will underestimate the real social benefits provided by natural phenomena. The magnitude of the option value—and thus the extent to which expected consumer surplus understates real benefits—is closely correlated with the degree of uncertainty regarding individual's future demands for the flow of services provided by irreplaceable assets. In general, the option value will be larger the greater the uncertainty of future demand. Thus, option value will assume particular importance when there are a large number of individuals who have a low probability of demand for the future flow of services provided by a natural phenomena.

The existence of rare natural phenomena in arid Australia contributes to the well-being of many individuals who have not visited the areas. Theirs of externalities, or spillover benefits individuals may have a real, but uncertain, demand to preserve these natural environments, which reflects not so much a desire to have them immediately accessible to themselves but rather a wish to maintain the option of their continued availability in the future for oneself or future generations. Option demand may therefore exist even though there is no current intention to use a preserved area and, in fact, the option may never be exercised. Indeed, option demand may exist for persons who place a value on the mere existence of biological and geomorphological variety and its widespread distribution, even though they have no intention of any kind of visit to natural phenomena like Ayers Rock.

While the above forms of option demand apply to situations where individuals have reasonable knowledge of the type of environmental/amenity services provided by particular natural phenomena, there is another form of option demand that relates to the expectation that natural environments, if preserved, will be eventually used for purposes we cannot at present foresee. This form of option demand seems to be at least partially implicit in statements like that made by Slatyer.11 Differences of opinion as to the best means of arid land utilization are inevitable. In particular, there is a conflict of interest about whether and how much of the land should be devoted to pastoralism. If pastoralism is thought of as a preferable alternative to agriculture, it may be argued that the land should be used primarily for that purpose, and that it would be better for the national economy to use the land for that purpose immediately rather than to wait indefinitely for it to be used in some way that is yet to be determined. However, if pastoralism is thought of as unwisely exploiting the land, or if it is thought that the land should be used for some other purpose, it may be argued that the land should be used immediately for that purpose, even though it may be better in the long run to wait and see what the best use of the land is.

The opposition of some scientists to pastoralism in arid Australia seems to be largely a question of getting-the-facts-straight as to whether the induced changes to the natural ecosystems are stable or unstable. It appears however that part of the scientific concern arises from the view that irreversible changes to natural ecosystems—even if stable—are unlikely to substantially restrict the range of future option available to society in the use of these areas.

Technological Progress and Conservation

It has been suggested that the impact of technological progress on the production of physical goods that require inputs of natural resources, and environmental/recreational services supplied directly by natural resources, is likely to be asymmetrical. The argument supporting this proposition is that the supply of processed goods may be capable of continuous expansion as a result of technological progress. On the other hand, the supply of natural phenomena is virtually inelastic.12 Thus, as the supply of rare natural arid phenomena cannot be augmented, the annual value of the service provided by such phenomena will grow, reflecting supply influences as growth in population and per capita income. The area under the aggregate demand curve for the initial time period (year) will therefore need to be adjusted upwards by a growth factor. This adjustment would reflect the anticipated annual increase in the value of the environment. If recreational services as the aggregate demand curve shifts upwards over time. Given constant tastes for environments recreational services and for processed goods based on natural resource inputs, it is thus implicitly assumed that the shadow prices of the former will increase more rapidly than the price of the latter. In other words, the presumption for an Australia would be that the per unit value of products like

Notes


12 For some discussion on various aspects of this problem see Camps 1966; Duncan, 1972; and Tisdell, 1972.

13 The major exception is wildlife, whose population can be managed by man to some degree.

14 The procedure most commonly used to empirically estimate demand functions for visits to natural phenomena (parks) involves specifying distance attenuation curves around the natural amenity. An examination of the price elasticity of demand is then made from observations on the percentage of visitation from different distance zones. The basic hypothesis is that travel costs are analogous to price. An important weakness of this procedure is the implicit assumption that the purpose of the trip was to visit the particular natural facility. Moreover, the observations on participation rates of population groups by different distance zones provide a measure of consumption and non-consumption. This, in turn, is a function of the quantity of recreation facilities (which will vary from one distance zone to another) as well as the demand for the particular natural facility.
In the future it seems likely that society will be increasingly confronted with difficult problems of social choice relating to the preservation and utilization of the natural resources of Australia's arid zone. It will be necessary for most of the social choices to be made explicitly through the political mechanism, since the natural resources typically have characteristics that do not permit socially appropriate choices to be made via a freely-operating market mechanism.

The primary concern of this paper has been to provide a conceptual economic framework within which the problems associated with preservation and utilization of arid Australia's natural resources may be analysed. Following a brief discussion on the supply and demand for environmental/recreational services in arid Australia, the problem of achieving a socially optimal pattern of preservation and utilization of the kangaroo has been analysed. The focus of the final part of the paper is the problem of evaluating the economic benefits of the environmental/recreational services provided by natural phenomena.

It emerges from this latter discussion that the conventional measure of economic benefits - i.e. the area under the aggregate demand curve of current users - is likely to result in an underestimate of the 'true' social benefits derived from rare natural phenomena. Consideration should also be given to option demand, favourable externalities, and asymmetrical technological change. Ideally, the estimated influence of these factors would be incorporated in a measure of the annual social benefits derived from an environmental/recreational area.

The total present value of the natural asset would then be determined by the summation of the appropriately discounted annual benefits. The net present value may then be derived by subtracting the present value of the costs associated with the administration and management of the area. It is this net present value that may then be compared with the corresponding estimated net present value of using the area (natural resources) for another purpose that is incompatible with the preservation of the natural phenomena of the area.

Empirical measurement of the social benefits derived from the environmental/recreational services provided by natural phenomena clearly involves some formidable measurement problems. It is the writer's view, however, that a full understanding of the conceptual issues is a necessary precursor to effective empirical measurement.

References


POLLUTION AND RESOURCE ALLOCATION: COMMENT

The authors argue that "market failures" in solving pollution problems arise because of the existence of externalities. Administrative solutions through fiscal or regulatory measures are therefore considered since these may be main policy instruments for pollution control.

A principal difference with the authors concerns the generality of the approach used either to derive the demand for the clean environment, or to meet the demand for cleaner physical products and "clean environment". Some of these products are generally regarded as ineluctable; it is not possible to have some of the without loss of the other.

This model places emphasis on understanding pollution at the source, i.e. in the production process, thus ignoring the possibility of control at a subsequent point, namely after the consumption activity. Elaboration of this point may throw some light on the issue of market failure in controlling the pollution issue.

Physical products and their associated wastes may be viewed as joint products. Some wastes are associated from products during the production process, i.e. they are part of the production process. In addition, there may be separate disposal costs which are not treated as part of the production process. The authors point out that pollution results from measured output of identical products (pp. 41, 42). However, I suggest that emission standards should not be used for their own satisfying characteristics rather than simply economic physical...
In a recent article in this journal, Chisholm, Walsh and Brennan [1] discuss a conceptual framework and some policy principles for pollution control. They conclude that...

"... in general fiscal instruments (taxes and subsidies) are a more efficient means of controlling pollution than the widespread use of regulations or other legal instruments."

The authors argue that "market failure" in solving pollution problems occurs because of the existence of externalities. Administrative solutions through fiscal or regulatory measures are therefore examined since these may be main policy instruments for pollution control.

My principal difference with the authors concerns the generality of the approach used rather than the substance of the above conclusion. Briefly, the authors use a model in which there are two commodities, physical products and 'clean environment'. These two products are generally regarded as substitutes; it is not possible to have more of one without less of the other. This model places emphasis on controlling pollution at the source, i.e. in the production process, thus ignoring the possibility of control at a subsequent point, namely after the consumption activity. Elaboration of this point may cast some light on the issue of market failure in resolving the pollution issue.

Physical products and their associated wastes may be viewed as joint products. Some wastes are separated from products during the production process; these might be called production wastes. An important class of wastes is inseparable from products until after the act of consumption; these may be called consumption wastes. I have made the above distinction because the article by Chisholm, Walsh and Brennan concentrates on pollution control at the production stage thus ignoring consumption wastes.

The authors point out that pollution results from consumer demand for physical products [1, p.4]. Lancaster [3] suggests that consumers demand products for their want satisfying characteristics rather than simply demanding physical
products per se. Consumption wastes are a subset of product characteristics not normally considered in analyses of consumer demand, but which should be considered in dealing with waste disposal and the associated externalities. With rises in income consumer demand for convenience factors and services (particular characteristics of products) rises faster than the demand for other product characteristics. Consumption wastes, therefore, assume increasing importance in what has come to be known as the "effluent society".²

Chisholm, Walsh and Brennan's emphasis on pollution control at the production stage results in a failure to consider a market solution through resource recovery (or recycling). Recycling should be given explicit treatment because of its unique position in relation to the production of both physical commodities and "clean environment". Resource recovery may be complementary with production of physical commodities as wastes are a potential source of secondary inputs to production activities. In the future, with further depletion of primary resources and rises in costs of exploitation,³ resource recovery may become a more economically attractive source of raw materials for production. There may also be a complementarity between resource recovery and the production of the product clean environment. This double complementarity situation must take account of the law of Conservation of Mass [1, p.3] and, in fact, resource recovery may imply a more efficient use of residuals. The attraction of resource recovery is its potential to simultaneously conserve scarce primary resources and reduce the adverse environmental effects of the disposal of wastes.

The development of an economically viable recycling industry is necessary before resource recovery can fulfill the role suggested above. Such a development depends upon a number of market determined factors. The supply of input products in the waste stream is an important factor and results of a study in the U.S.A. [4] indicate that large quantities of potentially valuable raw materials are discarded in the household consumption waste stream. Technological developments have occurred in the mechanical separation of mixed household wastes which are making such wastes an economic source of raw materials relative to
reserves of primary resources. The demand for recycled inputs is related to the supply and price of primary resources, and the substitutability between primary and secondary inputs.

In the case of consumption wastes and many production wastes, recycling represents a market solution to the pollution problem. As suggested above, the development of recycling will only occur in profitable circumstances which are created by factors other than the level of pollution. Environmental constraints are generally determined politically (or administratively) and it is not surprising that there is a divergence between the market and the administrative solution. This distinction between a market and an administrative solution may, however, be misleading since any administrative solution (fiscal or regulatory) inevitably affects market solutions by altering the circumstances in which the market operates. The critical question for policy principles then becomes one of recognising the interaction of both fiscal and/or regulatory measures and the market place in our approach to environmental problems. The allocative effects of any combination of policies will not be clear unless this interaction is recognised, and most certainly depends on the particular mix of policies and market responses. In any case, it is questionable whether any statements about resource allocation can be distilled from a discussion of policy principles, particularly when this discussion involves pollution control solely at its source in the production stage of economic activity.

In summary, it appears that the use of a two-product model and the preoccupation of the authors with pollution control at the source, result in an unnecessarily restrictive framework for discussing the principles of pollution control policy. The role of the market system in the context of fiscal and/or regulatory measures is not adequately considered, particularly with regard to recycling. The market system already recycles wastes in profitable circumstances. Allowing for the social costs of pollution and the value of inputs recovered, recycling may represent a relevant policy alternative. At least it should be considered in the evaluation of policy principles dealing with pollution and resource allocation.
The authors do recognise the possibility of complementarity between physical production and 'clean environment', but this is mentioned only incidentally [1, p.5] and is ignored in the discussion of policy alternatives.

Existing waste disposal systems have been shown empirically to have important external effects [2].

This may be due, for example, to the necessity of exploiting lower quality reserves of raw materials.

Wastes with a high primary resource price are extensively recovered through recycling; the precious and semi-precious metals as well as copper and uranium are already recycled. Aluminium, oil and iron are also possible candidates for increases in recycling.
REFERENCES


ENVIRONMENTAL QUALITY AND RESOURCE ALLOCATION:
A PROPOSED FRAMEWORK FOR ANALYSIS

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Paper to be presented at 17th Australian Agricultural Economics Society Annual Conference.

Australian National University,
At nearly all stages during the gestation of this paper we have benefited from communications with other people. Our greatest debt is to Geoff Brennan, for fruitful discussions and his many perceptive comments and ideas on a preliminary draft of this paper which stimulated us to a complete rewrite. Doug Cocks also made constructive comments on the preliminary draft, helped with several useful discussions and provided some needed encouragement as we entered the "bell lap". Our thanks are also due to Sharon Kaspru who was responsible for obtaining the references and compiling the bibliography. In the early stages of preparation we benefited from discussions with various members of the BAE, CSIRO and the Department of Primary Industry (Pesticides Branch).

Finally, during part of 1972 we were able to participate in a series of seminars on population and pollution of resources which were organized by John Pitchford. John Pitchford is also currently leading several reseach projects dealing with various macroeconomic aspects of the theory of natural resources, population, and pollution control. We have benefited generally from the stimulus of this work despite our somewhat different approach to, and perspective on, the problem. Unfortunately, a time constraint did not allow us to benefit fully from comments on our paper by this group.

We thank, however, Bruce Forster for commenting on section IV of our paper.

Errata

p. 4 line 5 'tangible' should read 'intangible'.

p. 13 2nd last line 'effluent' should read 'affluent'.

"Everything I like is either illegal or immoral, pollutes the environment, or increases the population".


INTRODUCTION

An ever increasing popular and technical literature has been concerned with persuading us that the welfare of mankind is threatened by several emerging problems. In the broadest of generalisations the basis of these threats can be seen as consisting of a combination of the pressures of population growth, the rapid exploitation of known reserves of exhaustible resources, and a significant deterioration of the quality of the natural environment.

The purpose of the present paper is to submit to further examination just one of these problems - that of environmental quality disruption. From the start, however, it was obvious that the task of providing a comprehensive coverage of all aspects of this problem in one paper would be impossible except in terms of largely meaningless generalisations, and the best strategy emerged in our view as that of focussing primarily on one particularly important source of environmental quality disruption, the so-called problem of pollution.

Our primary objective has been to provide a broad conceptual economic framework within which the pollution problem might be analysed, and appropriate means of reducing the impact of pollution on society’s well-being discussed. It seemed to us, indeed, to be particularly important that this should be our objective, because at this point in time the Australian economics profession in general has devoted little effort to the analysis of the issues involved relative to the potential importance of the problem. Moreover, most of the international literature on economic aspects of the pollution problem seems to proceed on a relatively ad hoc basis, and we have been unable to find any
The fact that the paper is theoretically rather than empirically oriented arises from two influences. In the first place, both time and informational constraints were operative: a significant empirical contribution appeared unfeasible. Moreover in the second (and in some ways more importantly) without a firm theoretical underpinning, empirical work is methodologically suspect at best, and it seemed to us that empirical work lay some way beyond what we have attempted to do.

The plan of the paper is as follows. Section I presents background material, with special reference to the agricultural sector, which aims to provide an overall perspective on the environmental quality issues in general. The remaining sections turn to the more specific questions raised by the so-called pollution problem. In section II we attempt to define pollution as an economic problem, while in Section III we attempt to determine both the extent to which the "economic" problem of pollution requires political intervention because the market fails to solve it, and the extent to which the political mechanism can be expected to achieve what the market cannot. Section IV presents a discussion of alternative pollution control procedures available to governmental authorities, and attempts to specify
the sort of criteria which should be considered to enable appropriate choices to be made. The final section contains concluding comments.

I

BACKGROUND

The production of physical goods in the modern industrial economy is becoming increasingly independent of the traditional natural resource sector. More and more, technology is expanding the ways by which the fundamental building-blocks (atoms, molecules, and energy) can be manipulated to provide the basic inputs for industrial production. In the wake of this trend there has been a perceived deterioration in the quality of natural environments. In most developed countries, the demand for, and supply of, services provided by natural environments is now a matter of major concern.

The general problem of environmental quality disruption might be most readily viewed as a compound of three related influences - increasing pollution, increasing congestion, and an increasing value attached to recreational and other services provided by the natural environment. It is, indeed, in many respects particularly important that the tri-partite nature of the current problem be recognized, not the least of which arises from the need to formulate policies for improving environmental quality that recognize the essential interdependence of these problems. For example, the (partial) solution to both pollution and congestion problems provided by proposals to diversify the location of industrial and urban centres may be in substantial conflict with the need to preserve existing environmental amenities.

However, the heuristically convenient separation of these three dimensions of the problem tends to mask some considerable conceptual difficulties involved in distinguishing between them. It is difficult, in the first place, to give any significant economic interpretation of the problem of pollution except by regarding it as involving a conflict between various possible uses
of the natural environment - most conspicuously between the use of the environment as a means of disposing of the unwanted by-products of production and consumption activities and its use in providing other services many of which are of a more or less tangible nature. In this sense, it is difficult to see that any meaningful, or operational, distinction can in fact be drawn between the problem of pollution and the fact of a rising value attached to environmental amenities. To an extent the same is true with respect to congestion, for in this case the problem may involve too many users of a given amenity, again suggests a rise in its social value which also of course stimulates an increased demand for uncongested amenities.

In the second place, at the analytical level there is a very close affinity between the problems of pollution and congestion since both are characterised by the problem of externality. As Rothenberg [69, p.114] puts it,

"Both represent the unkind rub of human activities on one another, where there is no intermediation of a market to enable affected parties to confront their tormentors"

In this sense pollution and congestion in their extreme forms are at opposite ends of a spectrum involving problems where individuals interfere with one another's well-being while using a common resource or facility. Pure congestion involves all users of the common facility interfering equally, in some sense, with one another, while pure pollution involves a distinct cleavage between users of the facility who interfere with others (but are not interfered with themselves), and those who are merely passive recipients of the interference. The most practically relevant cases, however, fall between these extremes in which, in general, all users interfere with others, and share in the interference themselves, but in which degrees of interferences differ between users.

While it may be difficult to always maintain the distinction between the various dimensions of the overall problem we have nevertheless attempted to do so. The environmental quality
problem as a whole is so complex that policy discussion requires some way, initially, of separating out major problem blocks which can ultimately be brought together to form a consistent total perspective, and the pollution-congestion-value of amenities distinction, if somewhat blurred around the edges, seems as useful as any.

(a) Urban Pollution and Congestion

Most of the concern with congestion and pollution is associated with the densely populated urban areas. It might be thought that in Australia the average ratio of land area to people is so high that pollution would not be a serious problem. This is not true, since most of Australia’s population is distributed between a small number of large conurbations. Thus urban pollution and congestion problems are of a similar type and magnitude to those prevalent in most other developed - but more densely populated - countries. That this is so, is being reflected in a steadily increasing flow of government and other publications which consider various dimensions of the pollution problem in Australia.¹

While, for some purposes, it is convenient to consider urban pollution/congestion problems separately from those faced by the rural sector, many of the urban problems have very important implications for rural areas. Firstly, worsening urban congestion and pollution problems will exert continuous pressure on non-urban land for their amelioration via the establishment of regional growth centres (and 'dirty' industries) in what have traditionally been rural locations. Although the land area required for these new cities may be quite small they will have an influence which extends substantially beyond their geographical boundaries. Secondly, rising urban congestion and pollution is likely to result in a continuously increasing demand for environmental recreational/amenity services in rural locations - especially in rural areas within easy reach of urban centres. A not unlikely trend would be for more farms in these locations to provide an expanding array of recreational/amenity services for urban dwellers as an adjunct to - or complete replacement of - their traditional farming operation.²
In a somewhat separate category are the direct adverse effects that industrial pollution may have on some forms of farm production. For instance, some forms of industrial pollution reduce yields and quality of market garden and orchard produce commonly grown close to urban centres. Of considerably greater importance is the fact that many of the food, fibre, and wood product processing industries are located in, or near, urban areas and would appear to be among Australia's heaviest polluting industries. If pollution control procedures were to be introduced for these industries, the cost burden could be distributed in any one of a number of possible ways – most of which would exert demand influences for the relevant products at the farm gate level.

(b) Rural Environments

Rural environments provide the site for food and fibre production, timber production, and various industries of an extractive nature. In their natural state, moreover, they contain a large part of our reservoir of genetic stocks, and are nature's laboratory for experiments in biological evolution. In addition, they function as assimilative sinks for the disposal of residuals. Finally, and very importantly, natural environments provide an array of recreational/amenity services which may be consumed with, or without, complementary inputs, such as cars, boats, camping gear and so forth.

The main concern of the paper is with that part of the rural environment which is related to – and affected by – the disposal of residuals from production and consumption activities. However, any separation of the various competitive demands for the array of services provided by natural environments is necessarily somewhat forced and artificial, so close and crucial are many of the interdependencies between them. The most important of these relate to the competitive demand for the use of the rural environment as a site for agricultural production, as an assimilative sink for the disposal of agriculture's residuals, and as a provider of recreational and amenity services.
(i) Demand and Supply of Environmental Amenities

Modern agriculture imposes an ever increasing demand on the use of the environment for the purpose of the disposal of its residuals. At the same time an apparent increase in the demand for environmental amenities is taking place. This latter demand is commonly attributed to such factors as; growth in per capita incomes and a presumption that the demand for environmental recreational pursuits is highly income-elastic; increases in urban population and congestion and the associated increase in demand by urban dwellers for contact with unspoiled natural environments; changes in preferences for environmental amenities. 7

An additional, if somewhat different, demand influence one is able to discern in both the academic and popular literature on the environment, is what has been referred to as 'option-demand'. That is, the demand for preservation of natural areas and features often reflects not so much a desire to have them immediately accessible to oneself, but rather a desire to have them available in the future for oneself or future generations. Option-demand may exist even though there is no current intention to use the preserved area and, in fact, the option may never be exercised. 8

While most writers consider that the demand for environmental recreational services has increased, the supply side is much more difficult to disentangle. We can certainly observe that good quality natural environments are being polluted and sometimes destroyed by urban-industrial expansion or commercial development. However, not all forms of development necessarily impair rural environments. For instance, many people would claim that some forms of agricultural development improve the character of landscapes, through providing increased colour and texture contrasts. Moreover, the effective supply of natural environments is being increased through improvements in technology, travel, and more efficient management of national parks. A closely related problem, but one which is unfortunately beyond the scope of this paper, is the extent to which deliberate "conservationist" policies should be implemented to increase,
or maintain, the supply of natural recreational/amenity services.  

(ii) Agricultural Production and Residuals

Agriculturalists have generally ignored the large ecological framework in which farming is conducted. This may, in large measure be explained by the fact that over many centuries the natural environment has proven to be extremely resilient to the exploitive character of commercial agriculture. Over the last few decades, however, in order to meet the food and fibre demands of a rapidly expanding world population, farming has become more specialized and substantially more dependant on a wide array of inputs produced by the industrial sector. The technology incorporated in these inputs has greatly expanded man's ability to manipulate his immediate food-producing environment. At the same time a "new" threat has emerged. The application of many of the industrially produced farm inputs is causing serious biological problems, and in some instances, is threatening the vital self-adjusting nature of the ecosystems which agriculture exploits.  

The main residuals (pollution) produced "on-farm" result from intensive agricultural practices. These forms of pollution have evoked considerable concern in the United States and Europe, where intensive agriculture is more commonly practiced than in Australia. There are, nevertheless, particular regions in Australia (such as the irrigation areas) and certain agricultural practices (such as heavy use of pesticides on some crops) which cause significant residuals problems. In general though, taking Australian agriculture as a whole our reading of the literature does not suggest that there are very significant "on-farm" pollution problems at the present time. It seems to us that pollution caused beyond the farm-gate by various agricultural processing industries at the present time is probably of more significance than "on-farm" pollution. However, we should stress that this whole area is characterized by a high ratio of concern to facts.

At this point we could attempt to classify and describe the main forms of agricultural pollution. Such an exercise has,
however, already been partly undertaken by others\textsuperscript{12} and it would seem more useful to outline briefly the alternative criteria by which agricultural pollutants could be classified. This will hopefully provide some insight into alternative pollution control policies which we discuss in some depth in a later section. One procedure would be to classify pollutants on the basis of the inputs that generate them - for instance, fertilizers, pesticides, and irrigation water. Or they could be classified according to the type of by-product produced as a residual - for instance animal wastes, and crop residues. Additionally, classification might be organised according to the environmental media through which the residual is transmitted, degraded, or stored - that is, air, water, or land; or according to the ultimate receptors - human beings, animals, plants, and inanimate objects. These classification procedures provide information relating to the form, mode of transmission, and ultimate receptors of residuals which may then be used to formulate appropriate pollution control policies.

Concluding Comments

The object of this section has been to provide broad generalisations on the nature of the environmental quality problem, especially as it impinges on the agricultural sector. It will be obvious at this point that the question of formulating policy approaches to all aspects of the problem is far beyond the scope of a single paper. As we indicated earlier we have chosen to devote our attention to one important subset of the overall problem - the pollution problem - and to attempt to provide a consistent framework within which that issue, at both the urban and rural level, can be fruitfully approached. It is to this task that we now turn.
II

POLLUTION AS AN ECONOMIC PROBLEM

The fundamental economic problem, or at least the problem with which economists have primarily concerned themselves, is that of maximising society's welfare in the light of the constraints imposed both by the natural world and by man's limited knowledge of the ways in which the gifts of nature can be converted into useful consumption items. While economists have been concerned to ensure that the processes of production and consumption are organised in such a way that we get as much as we can from what we have, scientists and technologists have been concerned to ensure that we have as much as we can, both by attempting to increase the resource base from which we operate and by attempting to increasingly substitute knowledge for material inputs in extraction and production processes.

However, in the frantic drive to increase the productive capacity of the system, one prevailing constraint has received little attention from economists - that is the constraint implied by the Law of Conservation of Mass. This fundamental law of natural science insists that the processes of production and consumption may only modify, and not destroy, the matter (the material inputs) employed in these activities: except to the extent that reuse or reclamation is feasible and economical, production and consumption processes inevitably involve the conversion of productive inputs (including oxygen from the atmosphere) into an equivalent mass of non-productive residuals that must somehow be disposed of. While it may be natural to think of extractive and productive activities as the primary sources of residuals creation, consumption activities are at least equally as important. In the first place, of course, the satisfaction of consumption desires is ultimately the raison d'être of productive activities; and, in the second, while consumption may be the ultimate objective of economic activity, it is not - and necessarily not - the end of it, for the act of consumption merely transfers mass from a form in which it is edible
(or yields other - less direct - consumption services) into a form in which it is not. In this sense the need for residuals disposal arises both directly, and indirectly, as a consequence of the satisfaction of the demand for physical consumption goods.

Until recently, however, the disposal of residuals was not regarded as a serious economic problem and that this should have been so is presumably attributable to the fact that such disposals had not interfered substantially with our other production and consumption activities.14 Disposal is effected, of course, simply by the discharge (either deliberately, or as the result of natural processes) of the unwanted residuals into the atmosphere (as gases or waste energy), into the waterways (as sewage, or as industrial residuals suspended or dissolved in water), or onto the land (as rubbish, scrap, junk, garbage and so on). The volume of residuals to be disposed of in this way could be estimated, very roughly, by calculating the annual production of basic materials and assuming that recycling and net accumulation of stocks of materials or final products will not cause this figure to differ very significantly from the volume of residuals ultimately arising. Estimates of this nature have been made for the U.S.A. by Ayres and Kneese [9], but there can be little doubt as to the essential irrelevance of their figures for the Australian situation.15 Moreover, the general relevance of such calculations is also doubtful. The aggregate volume of residuals discharged becomes (economically) important only when their disposal affects other activities in the system, and, for this reason, since up to a point an explicit choice can be made between the various media (land, air and water) as receptors of residuals, the way in which residuals are disposed of and the location of disposal may be at least as important as the aggregate volume requiring disposal.

The essential point is, of course, that the media into which residuals are discharged have a basic assimilative capacity. That is to say, the environment at large is capable of transporting, dissipating, diluting, degrading or storing to some extent all types of residual generated by man's production/consumption.
activities, though its capacity to do so may be affected by natural phenomena (temperature, wind-speed and stream flow variations, for example) or by deliberate human intervention (such as augmenting stream flows, treating residuals before discharge, or such relatively simple things as building higher chimney-stacks). Up to a point, the natural qualities of the environment thus provide us with a means of disposing of residuals in an essentially costless fashion - that is, in a way which involves no conflict between man's use of the environment as a sink for residuals disposal, and such other uses for it as he may have. It was presumably, moreover, the real or imagined absence of such conflicts that provided the justification for regarding residuals disposal as of no economic interest.

Concomitantly, it must be the real or imagined presence of conflicts between the various (valuable) uses of the environment created by the disposal of residuals that has generated the belief that "pollution" is an economic problem. It is difficult to be precise about the nature and extent of the conflicts, in part because the nature of the "other uses" of the environment are not clearly or completely specified, but also because hard facts, and even convincing theories, are in short-supply. However, it is clear that an almost endless list of potential or actual damage caused by residuals could now be compiled, ranging from potential threats to man's existence, through scarcely less potentially devastating (though less specific) threats of ecological instability, right down to relatively minor damage to buildings and the like. For our present purposes, however, all these influences might conveniently be referred to as elements of the demand for a "clean environment", so that the conflict to which we are referring can be characterised as a conflict between the consumption of one sort of commodity (i.e. physical or produced commodities) and another (a clean environment).

That such a conflict should have arisen or have become increasingly conspicuous over time might be explained largely in terms of economic and demographic trends that are clearly
identifiable in most developed societies. In the first place, increasing population and rapidly changing technology have enormously increased the productive potential of most societies, leading in turn to increased per capita income and consumption. But while the technology of production has been rapidly changing, little stimulus has been given to changes in the technology of residuals disposal. Since the media into which residuals are discharged are to a large degree "common property" resources, no incentive exists for users to economise on their use: improvements in the technologies associated with reuse or reclamation of residuals, and with treatment of residuals before disposal, for example, yield little or no private benefit in a world in which residuals disposal is, to all intents and purposes, free of direct charge. Thus, the increased volume of production and consumption has led to a directly comparable increase in the volume of residuals for final disposal, with little - if not negative - change in the quality of residuals discharged. This trend has of course, been compounded by the increasing concentration of population and industry, so that the increased volume of residuals requiring disposal has also tended to become concentrated within well-defined air-sheds, water-sheds, and/or geographical locations.

These facts certainly suggest that the demand for use of the environment for residuals disposal has increased. However, we cannot immediately conclude that the supply of environment for all other uses has suffered a concomitant decrease. As we have previously observed there have been many changes (growing wealth, improved means of travel and so on) that have effectively expanded the supply of environmental amenities for many purposes. On the other hand, of course, if there is conflict between increased residuals disposal and other uses of the environment it is important to know what has happened to both the demand for and supply of the environment for other uses. Whatever has happened to the supply of clean environment, it does seem likely that the demand has increased. That is, it does seem likely that increasingly affluent societies are likely to be prepared to devote an expanding proportion of their resources
to securing a clean, comfortable, and ecologically stable environment for themselves and for future generations. At least at an a priori level this gives considerable support to the notion of an increasing conflict between residuals disposal, and other uses of the environment.

What these changes really amount to is the fact that whereas in the past there has been enough clean environment to satisfy all the demands for it, this no longer remains true. The Law of Conservation of Mass has become an effective constraint in the sense that an explicit choice must be made between consumption of one sort of commodity (physical) and consumption of another (clean environment).

Such choices are, needless to say, the essential subject matter of economics, and it is rather comforting for the economist to be able to point out that for him the pollution problem emerges as one amenable to quite standard economic reasoning. This is not, in any sense, to belittle the magnitude or importance of the pollution problem, nor even necessarily to claim that the economist's techniques are adequate for the task, in hand, but merely to point out that, looked upon in this way, it is apparent that there is nothing inherently more difficult about the pollution problem than many others to which the economist has applied his doubtful expertise.

In establishing the economic nature of the problem at issue, the economist would also be aware that to identify a problem as one of choice, is not necessarily to identify it as one requiring an explicit social choice, that is, one demanding the explicit application of public policy.
POLLUTION AS A PROBLEM OF SOCIAL CHOICE

Many - indeed perhaps most - social choices are not made explicitly as such. Rather, they emerge as the summation of the results of a large number of decentralised market decisions. In this context, there is nothing inherently inefficient about the decentralisation of decision-making: indeed, quite standard and widely applied, theorems of welfare economics insist that in many cases the resulting choices are in fact the best conceivable ones. In such cases, co-ordination of the decisions is achieved neatly, and at least cost, by the market mechanism.

On the other hand, it is equally clear that some choices are not appropriately left to the co-ordinating forces of the market, or at least it is not obvious that market solutions represent the best or least cost decisions. In these circumstances the social choices may be, or may require to be, made explicitly as social choices, through political mechanisms. But, as we shall re-emphasise at a later point, it is not immediately apparent that the resultant choices will better represent, as it were, the aggregate desires of society: the question of whether the political mechanism makes better choices than the market mechanism depends not only on the precise nature of the political decision-making process, but also on the nature of the commodity, over which the choice is being exercised. For example, the very characteristics which disrupt the smooth working of the market mechanism may also preclude efficient choices being exercised through the political mechanism.

Thus, in focussing on the (so-called) pollution problem from a policy viewpoint, we might ask two sorts of questions - firstly, what are the characteristics of pollution that are likely to make it difficult for the market to make a satisfactory allocation of resources to the output of "clean environment",
and secondly what are the characteristics of the political mechanism as an allocator of resources to alternative uses, and to what extent is its performance in this context likely to be superior to (or different from) the market's?

(a) Market Failure

In the case of pollution problems what appears likely to result in failure of decentralised market processes to ensure an ideal choice between the competing uses of the environment is the fact that such problems are characterised by externality. Externalities are often said to arise whenever the well-being of one economic unit is affected by the activities of other units - that is whenever utility and/or production functions exhibit interdependencies. However, from the viewpoint of identifying the existence of externality with the failure of the market mechanism to make appropriate (allocative) choices rather more is required than mere interdependence. Clearly many activities involve interdependencies, but not all of them involve market failure problems. Indeed the existence of markets depends upon the existence of interdependencies and the function of markets is to internalise the interdependencies. In simple terms an example of what we have in mind is the observation that our welfare is increased by the productive activities of others, but at the margin we pay for their products what they are worth to us, so that the social contribution of their activities is matched by the payments they receive. It is only when appropriate compensation is not forthcoming - when interdependencies are not internalised - that externalities exist. More precisely, and perhaps more descriptively, externalities exist whenever decision-makers do not take into account relevant costs or benefits of their actions, which benefits and costs, if they were taken into account would result in different, and socially preferable, choices being made.

The application of these notions to the economic problem of residuals disposal is however, perhaps not so obvious as it might at first seem. Certainly to the extent that externalities
do exist they can be associated with interdependencies between the production/consumption of physical goods (which involves residuals disposal) and the consumption of what we have termed clean environment. By the same token, what exists is not a single interdependence but a compound of inter-related interdependencies which we could classify according to environmental media involved (atmosphere, lithosphere or hydrosphere) and/or according to ultimately affected "parties" (humans, animals, plants or inanimate objects). However, we cannot immediately conclude that we are faced with problems of externality, for up to a point the market permits, and indeed positively encourages, adjustments by individual economic units which resolve or mitigate the conflict of demands. For example, individuals may make their demands for a clean environment effective by changing their residential location, or by installing air cleaning or conditioning devices in their homes, and will do so if this constitutes their least cost response to the interdependencies. Moreover, to take another related example, those individuals who demand pollution-free food or water provide a stimulus through the profit motive to other to provide the commodities to satisfy these demands, as witnessed by the availability of bottled "pure" water and of "uncontaminated" foods.

What is characteristic of these adjustments is that they involve attempts to internalise the interdependencies at the point where residuals appear as an unwanted input into other production/consumption activities, rather than at the point where the residuals arise as an inevitable output (by-product) of the production or consumption of physical goods. The extent of such adjustments of course is limited in the first place by technical feasibility considerations, and ultimately by their economic viability, and if adjustments above and beyond these seem to be economically desirable the emphasis must be shifted to tackling residuals disposals at source, where they occur simultaneously with the production and consumption of physical goods. However it is at this point that market inefficiencies -
genuine externality problems are most likely to emerge since adjustments of this sort inevitably involve co-operative agreements among the relevant individuals in circumstances where such cooperation seems likely to break-down.

In the market context, and given the common property nature of most dimensions of the natural environment, any changes in residuals outputs which are desirable will be achieved only by the "polluted" parties offering compensation to the "polluter" for any adjustments he makes. Any such adjustments can be regarded as socially desirable if the marginal damage suffered by the polluted individuals exceeds the marginal cost to the polluter of changing his output, and indeed such adjustments could only occur through market mechanisms in so far as the implied net benefits exist. However, it is unlikely that the co-operative agreements - the bribes - will be appropriately arranged because the benefits of such agreements are non-excludable - that is, the benefits of reduced pollution arising from a bribe offered to the polluter by one individual accrue to all affected individuals even though they have made no contribution to the cost of reducing the pollution level. Each individual thus obtains a "free-ride" (cost-free benefits) at others' expense and, of course, has an incentive to obtain as substantial a free-ride as is possible. If, as will typically be the case in pollution problems, the numbers of individuals involved is large, then each individual will be aware that any attempt on his part to obtain a free-ride, by "revealing" a zero preference for pollution reduction even though he may suffer substantial damage from residuals, will have a negligible impact on the negotiated outcome and is thereby given a very definite incentive to fail to reveal his true preferences. Not surprisingly since everyone is equally aware of these facts the market is doomed in these circumstances to produce an inefficient allocation of resources between physical commodities and clean environment despite the presumed existence of benefits to everyone from a successful internalisation of the interdependence.
The main thrust of this observation is, of course, that if the government is to succeed where the market fails, it must be able to overcome the difficulties inherent in the non-excludability problem associated with tackling residuals disposal at source. To this end, of course, governments have available to them a wide variety of policy instruments ranging from their ability to manipulate the legal system within which the market operates, through to their ability to manipulate the market process via the imposition of taxes and subsidies. Before turning to a discussion of the instruments available, and their relative success in achieving an efficient allocation of resources between physical goods and clean environment we turn to the second of our two more general questions - is there any reason for believing that explicit social choices, made through the political mechanism, will result in better choices than the market mechanism?

(b) Political Failure

It is typically presumed in economic policy discussions that where the market proves to be an inefficient co-ordinator of decisions, the government should step in to remedy the market's failings. As a value-judgment, such a view would presumably meet with widespread approval, but it is an altogether different matter to establish the positive proposition that where the government does intervene, its decisions will be superior to those made in the market: political mechanisms themselves may be imperfect in co-ordinating decisions. Certainly the real-world political framework appears to bear little relationship to the omniscient, infinitely benevolent government implied in much of the policy literature, and in this sense the answer to the question "can the government do better than the market?" is not at all obvious.

In fact, the performance of the government in economic policy matters has been subjected to a certain amount of analysis in the recent past. Unfortunately, however, most of the theoretical issues are nowhere near to being resolved so that any attempt on our part to deduce conclusions about the likely
performance of the government with respect to pollution control must necessarily be tentative. Nonetheless, given the importance of the pollution problem (as well as the importance of the issues to be raised for policy discussions of all sorts) an attempt to indicate some of the more important features of the political mechanism's operation appears worthwhile.

There is one sense in which the usual presumption that government intervention will be oriented towards improving the allocation of resources is understandable. When we say that the market fails to efficiently allocate resources what we generally mean is that there is a possible change in allocation which would make some individuals better-off, and none worse-off: if this is so then there would appear to be benefits to elected governments (in terms of improvements in their popularity, or probability of being re-elected) from improving the allocation of resources where the market decisions are inefficient. Indeed, if it were true that all government decisions required unanimous support from the electorate then this observation would have substantial relevance. At least one assumes that no-one would give their support to policies which made them worse-off, so that, overall those changes in policy which occur would involve improvements in resource allocation in the sense that some individuals will be made better-off, and none worse-off.

However, once we recognise that government need only strive for majority, and not unanimous, support then we must also recognise that both the motivation and ability of governments to seek improvements in resource allocation are likely to be weak for at least two important reasons:

(a) Given that the politicians, who compare political parties, are motivated, roughly speaking, by much the same aims as most "ordinary" individuals, and hence that they are not likely to be more than usually altruistic, it would seem likely that political parties would aim to improve the efficiency of the allocation of resources only in so far as political processes
(and especially interparty competition) constrains them to do so. In fact, however, a party can be elected or ensure continuing support by redistributing income in favour of electorally important or dominant coalitions of individuals in society. For this reason we would expect that political competition is at least as likely to take the form of "bribing" such groups of individuals (floating voters, farmers, the unions, businessmen and so on) by offers of specific tax concessions or subsidies, as it is to involve pressures to improve the allocation of resources. Ultimately, under majority rule, even a policy platform offering a perfectly efficient allocation of resources can be defeated by another platform offering an appropriate redistribution of income.

(b) To the extent that incentives do exist for governments to attempt to improve on the allocation of resources determined by the market mechanism, they are constrained by the information that is made available to them about individual's preferences. However, the information made available to the government through voting behaviour is likely to be deficient for a number of reasons. In the first place, for example, since an individual voter recognises that his vote is unlikely to be decisive, he will (quite rationally) tend to seek little information about the benefits of publicly provided services, or at least will not obtain as much information about them as he would about equivalent goods or services available in the private market. In the second place, voters have only one vote with which to express their preferences over competing packages of policies (policy platforms): they are not in a position to reveal their preferences over specific projects, or the intensity with which those preferences are held. For these sorts of reasons the ballot-box is likely to be a poor source of information for government, and they will be obliged to rely
fairly heavily on less direct sources of information provided by lobbies, formal enquiries, letters to members, and so on. However, while these sources provide additional information, the quality of that information is unknown, and may often reflect peculiarities in the cost-sharing (tax) arrangements: anyone will demand more of a publicly provided service if it will cost them little or nothing.

Considerations of this sort certainly confirm what was perhaps intuitively obvious anyway: that with regard to pollution control (or indeed any other major policy area) the government is not at all likely to achieve what the market cannot - that is, the most efficient choice between physical goods and clean environment. But it also gives us reason for treating with considerably more caution than is usually done the presumption that the government will nonetheless improve on the market's results. The government has, of course, one advantage over the market: through its coercive powers (through taxation) the government can force everyone to contribute to the cost of pollution control, and in this sense has a means of coping with the "free-rider" (non-excludability) problem that is the prime cause of the market's failure. However, to improve on the market outcome the government requires some knowledge of individuals' preferences to enable it both to calculate a more efficient level of pollution control and to calculate an appropriate system of taxes to finance it, and it is precisely this which is the source of the political mechanisms problems.

We would not, however, want to go so far as to suggest that the government will not effect some measure of improvement in the market's choice between clean environment and physical goods, for as well as providing the government with the ability to coerce individuals, the political process provides one other improvement over the market in the pollution case. By responding to the desires of a coalition of individuals the government obtains a degree of co-operation which (as explained earlier)
would be missing in the market where each individual attempts to free-ride at others' expense. Clearly, moreover, the more homogeneous the preferences of the individuals in society the more likely it is that preferences of the dominant coalition will be fairly representative of those of society as a whole, and hence that the government's response will be substantially better than the market's. Unfortunately, we have little reason for supposing that the pollution issue is one on which there is a great deal of agreement. At least, that is, we regard the pollution question as involving more intense divisions of opinion than many other current issues, and hence we suspect that the performance of the political mechanism is likely to be correspondingly poorer: we cannot be certain, though, whether this is likely to involve too much, or too little pollution control.

This catalogue of difficulties inherent in the political mechanism convinces us that we should not expect too much of the government as a decision-maker in relation to pollution control. This is not to say that the government cannot be expected to improve at all on the market, and clearly the better informed it is, the greater are its chances of achieving a significant improvement. The economist's role would, then, appear to be to attempt to inform the government about its main options in controlling pollution, and to suggest a set of criteria by which an appropriate choice between them might be made. It is to an outline of this task that we now turn our attention.

IV

POLLUTION CONTROL

Assuming that the government is to take action with respect to controlling the disposal of residuals rather than simply leaving the market to its own devices, we can identify two distinct sorts of action that it may take. Firstly, it can use its power to alter the legal framework within which the market system works, as a means of providing a set of circumstances within which the market may operate more efficiently; or,
(alternatively or in combination with alterations to the legal system) it can intervene more or less directly in market processes through taxes, subsidies, regulations and so forth, as a means of attempting to ensure a more efficient choice within any given legal system.

We shall consider these alternatives more or less in turn. After discussing what might be done to the legal system, we turn to a consideration of policies directly bearing on pollution control, proceeding in two stages: the first stage involves a rather ad hoc discussion of the various instruments available, identifying what can be said about them on general theoretical (efficiency) grounds, while the second involves an attempt to outline what can be said about the relative desirability of the various options when administrative and other practical constraints are taken explicitly into account. Although we cannot claim, at this stage, to have developed a complete set of criteria for choosing between the alternatives, we at least believe that the discussion provides a consistent framework for further analysis.

(a) The Legal System and Pollution Control

Discussion of pollution control procedures has sometimes suggested that a great deal of blame for pollution problems can be attributed to the legal system. The economic sense in such observations might be explained as follows. The process of exchange which characterises market transactions essentially involves the exchange of property rights to assets, or the services of assets owned by the transacting parties. This of course is most easily seen in the case of a barter process, but the only substantive difference in modern market systems is that money is interposed as the medium through which the exchange of property rights is effected. However, if the exchange system (the market mechanism) is to function efficiently it must be possible to neatly define and enforce all property rights. If, for example, we cannot prevent others from benefiting from our activities (that is if we cannot enforce a property right over the benefits of our activities) then they can avoid the need to exchange some
of their property to obtain the services of ours. This is, of course, precisely the problem we noted earlier as the "free-rider" problem arising from non-excludability, and in this fundamental sense those problems arise from an inability to enforce property rights.

The relationship of these observations to the pollution problem lies in the fact that much of the natural environment is not subject to private property rights. In most respects the environment is a common property resource, equally available for use by all, and it appears to be this which has inspired the belief that the use of the legal system to define private property rights would provide one way of improving the allocation of resources to pollution control. However, what would be required would be not simply the definition of rights, but also the means of enforcing those rights. The purpose in defining property rights would be to provide a basis from which negotiations between polluter and polluted could emerge to internalise the interdependence. However, so long as it is difficult to perceive infringements of rights or to prove damages, and while large numbers of economic units are involved, the negotiation and policing of agreements between the damaging and damaged parties remain in a technical and economic sense infeasible.

It is in this light that proposals for an "Environmental Bill of Rights", awarding a property right to a clean environment to individuals in society, must be seen. Already modest beginnings with such Bills have been made in some States in the United States, and their major purpose seems to be to make the burden of proof in environmental suits (under nuisance and property laws) less demanding. If they are successful, they will provide some incentives to polluters to control the damage they cause, or to offer compensation to affected individuals, and in this sense much will depend on the success of prosecutions under the Bill, the costs of prosecutions, and the size of damages awarded. The worst possible outcome, however, would be for these Bills to replace the present situation with a
no-pollution mentality: zero damage from residuals will rarely be economically desirable.

The likelihood of changes in the legal system bringing about substantial improvements in the market mechanism's performance would seem to be slight, and there is a fair presumption that major improvements will require the government to make use of more direct means of intervention in the market's operation - that is, the government will have to use its regulatory and fiscal powers.

(b) The Use of Fiscal Instruments and Regulations in Pollution Control

Of the several possible ways of proceeding through the discussion of the alternative tax/subsidy/regulatory policies that might be pursued by governments we have adopted the following two-stage procedure: first, we consider the major alternatives largely in terms of the conventional Paretian efficiency framework, attempting to indicate the extent to which they provide appropriate incentives (and continuous pressure), for firms to reduce the pollution damage they inflict on others; and, secondly, we turn to consider the economic and political limitations imposed on the use of these instruments by information problems, administrative costs and other practical constraints. In this way we attempt to provide some indication about appropriate criteria that might ultimately be applied to the choice between the alternative policies.

In a technical sense there are (if we follow the classification adopted by Bower & Spofford [15]) four basic methods of controlling pollution: reduction in the volume and/or improvement in the quality or time pattern of residuals generation; modification of residuals after generation; improvement of the assimilative capacity of the environment; or application of protective measures at the point where damage is inflicted on the ultimate receptors. Our analysis is primarily concerned with the first two of these methods, so that in a sense we are implicitly assuming that optimum modifications to the
assimilative capacity of the environment and final protective measures are being undertaken.

The various pollution control policy options, to be discussed, may be further distinguished by whether they operate primarily through the price mechanism, or are more in the form of direct regulations or prohibitions on pollution levels. Within the first category it is helpful to make a further distinction based on the point in the production/consumption process at which the policy is applied. Taxes may for example, be levied on: pollution as an output, as with the environmental pricing and standards procedure; on outputs jointly produced with pollution, as with a production tax on, say, the sugar processing industry; or on inputs with a high pollution productivity, such as some pesticides.

In the somewhat ad hoc discussion of these policy options which follows, it should be kept in mind that there is a fundamental interdependence among the various residual streams. Different combinations of pollution control policies are, therefore, likely to lead to quite different relative burdens being placed on the various residuals-receiving environmental media. Thus, where reference is made, say, to an environmental standards and unit tax system achieving a target abatement in water pollution at minimum social cost, there is an implicit presumption that there is no offsetting increase in 'socially damaging' air or land pollution.

An interesting, and seemingly promising development, in recent literature is based on the premise that most environmental common property resources are of a 'multiple purpose - multiple user' nature and that the interdependencies, referred to above, are frequently quite crucial. Most writers in this area recommend that regional environmental/pollution problems should be tackled through a collective choice mechanism in the form of a Regional Agency. These agencies would have a managerial/control function, the first step of which would usually be to develop an economic-ecological model in order to explain the functional relationships which describe the interdependent character of the whole production-consumption-waste-assimilation-ecological
system. This is essentially a 'fact-finding' exercise which, hopefully, will provide the agency with sufficient information on how the system works and so enable it to formulate appropriate policy measures.27

We are unfortunately unable to pursue this avenue of research in the present paper. However, our discussion of the individual tax/subsidy/regulation instruments is relevant because it is largely these instruments that will be combined in various ways to form complete pollution control policy packages.

THE "IDEAL" PIGOVIAN TAX & EMISSIONS TAXES.

It emerges from the literature on externality problems that a particularly attractive (and perhaps the most ideal) form of government intervention would be for it to impose the so-called Pigovian tax28 on polluters. This tax is levied on a pollution-generating activity with a rate schedule determined by the marginal net damage caused at each activity level.

Since the tax rate is related directly to the damage caused, this approach ensures an "optimal" output of residuals in the most general possible sense. That is, firms are not only induced to lower their production levels in order to lower their residuals output, but are also offered positive incentives to minimise the damage they cause per unit of output produced. Producers might, for example, be encouraged to "treat" residuals before disposal, to reallocate disposal between the receptive media, or to change their techniques of production to minimise the impact of the tax by minimising damages caused per unit of output. Moreover, research into new damage-minimising production techniques would be made a more profitable activity.

While the properties of the Pigovian tax are impressive, the difficulties involved in its use are at least equally impressive. The base of the tax is not such tangible variables as the firm's output level or its input of particular resources, nor is it based on the volume of discharge of particular residuals, but, rather, the tax is to be calculated specifically according to the damage caused by the firm's activity.29 Since, as we have pointed out, the firm can vary the form of its activity to reduce the damage caused, any attempt to relate the tax to
emissions, output, or inputs used, must represent a substantial departure from the principal advantages claimed for the tax. Moreover, to calculate the optimal tax what we require to know is not so much the current marginal damage caused by the firms activity, but rather what damage the activity will cause when the level and organisation of the activity have been adjusted in optimal fashion. Not surprisingly, it is now widely accepted that this ideal pollution tax will usually be administratively and informationally infeasible.

In this light, the variation on the ideal tax represented by emissions taxes appears much more attractive. In fact, taxes imposed on emissions of particular residuals retain many of the features of taxes based on damages caused by those residuals. In particular, of course, they provide firms with direct incentives to adjust their production techniques, or to install control devices, so as to minimise the impact of the emission tax on the firm's profitability. On the other hand, several factors militate against the efficiency of these taxes. Unless emissions of all damaging residuals are taxed at appropriate rates, and all points of emission subjected to monitoring, firms will have an incentive to change their techniques of production, to those which generate relatively more of untaxed residuals, or to change their points of discharge to those which are unmonitored. Moreover, the "appropriate" rates of the taxes, required to achieve optimal adjustments by firms, must be determined by the damages caused by the emissions, so that ultimately the calculation of these taxes is plagued with broadly the same information problems as damages (Pigovian) taxes.

These obviously significant difficulties in approaching the "ideal" solution to pollution problems have stimulated discussion of other approaches to pollution control which retain many of the features of the ideal taxes, but replace the notion of optimal levels of pollution control with the notion of an acceptable level of control. Of these we consider the "environmental pricing" proposal, and the "pollution quotas" scheme.

ENVIRONMENTAL STANDARDS

(i) Environmental Pricing

The environmental pricing approach as proposed by Baumol and Oates [12] involves the specification of a set of
standards that will ensure that an 'acceptable' level of environmental quality is achieved. It needs to be stressed from the outset that the standards would be chosen according to somewhat arbitrary criteria. For example, on the basis of information concerning the effects of polluted water on human health, fish life, and recreational pursuits, a decision may be made that the biological oxygen demand (BOD) of the organic waste contained in a river should not exceed a level of X. The authority would then levy a set of taxes on firms emitting wastes into the river at a rate of \( t(y) \) units per gallon of discharge. The rate of tax paid by each firm, \( t(y) \), would vary according to the BOD value, \( y \), of an individual firm's effluent. Each firm would thus be given a financial incentive to reduce its volume of effluent discharge and to improve the quality (BOD value) of the discharge. A possible refinement would be to allow the value of \( t \) to vary according to such factors as a firm's location, and with seasonal conditions insofar as the waste assimilative capacity of the river is a function of seasonal conditions. Such refinements will, however, usually quite drastically increase the information required by the authority.

Ignoring the above possible refinements, the authority should obtain sufficient information from iterative adjustments in the tax rate to enable it to estimate appropriate tax levels for the achievement of a target level of water quality. Moreover, it would be possible to adjust the initial target standards if their attainment were to prove unexpectedly expensive, or inexpensive.

The use of unit taxes has the important optimality property of ensuring that the target standards are realized at least-cost. So long as firms aim to minimize costs for any given output level, each firm will reduce emissions to the point where the marginal opportunity cost of a further reduction in emissions is equal to the tax. Since, in relation to the quality of their discharge, all firms in the region are subject to the same tax, the marginal cost of reducing pollution will be equalized across all firms and activities. Thus, it is impossible to reduce the aggregate direct cost of the specified decrease in pollution by any rearrangement of the emission reduction. Any alteration in the resultant pattern of pollution
emissions would involve an increase in pollution output by one firm, the value of which to the firm would be less than the cost of the corresponding reduction in pollution emissions by some other firm.

Moreover, in a dynamic context unit taxes have the advantage of exerting continuous pressure on the polluter to improve his waste treatment process. A greater incentive for technical innovation is thus maintained with a unit tax system than with direct controls where the polluter has no incentive to do more than meet the legal standard.

The standards and environmental pricing approach will not, in general, lead to Pareto efficient levels of the production activities and the corresponding socially 'optimal' level of pollution. The cost saving that can be achieved through the use of unit taxes may, however, be substantial. Kneese and Bower [54], in a study of possible control methods in the Delaware estuary, estimated that, compared to a direct control system requiring each polluter to reduce his pollution by a fixed percentage, a system of unit taxes achieving the same level of pollution abatement would be only half as costly.

(ii) Pollution Quotas

An alternative procedure for attaining the specified environmental standards would be to create pollution quotas equal to the aggregate target level of emissions. An economic unit would be legally bound to hold quota rights equal to its annual waste discharge. Initially the pollution rights could be allocated by auction, or distributed in proportion to the volume of existing firms current emissions. Thereafter, the quotas would be freely transferable and, through the establishment of a market in quota rights, an exchange value for pollution rights would be determined.

The research work on transferable production quotas for agricultural output is directly applicable, mutatis mutandis, to pollution quotas. Accordingly, the following discussion is brief. Firstly, we may note that a transferable quota system will, like unit taxes on emissions, lead to an efficient pollution
mix among firms and activities. That is, aggregate abatement costs for the target level will be minimized. An advantage of the quota scheme, as compared with the environmental pricing proposal, is that the price of quotas (the equivalent of the unit taxes) will adjust automatically to the level required to achieve the environmental target. In contrast to the trial-and-error experimentation that will generally be required with a system of unit taxes, the outcome with a quota scheme will be more certain and the authority's decision costs lower.

Several refinements to the basic quota scheme are possible. For example, futures markets in quota rights could be established, and/or anti-pollution groups could be permitted to buy quota rights which they had no intention of exercising. The latter refinement could prove useful since it provides some indication of the demand by conservationists to reduce pollution below the target level. This demand, however, may be very misleading due to 'free-rider' influences.33

Satisfactory operation of unit taxes or pollution quotas, as a vehicle for operating an environmental pricing scheme, requires that emissions can be monitored at a reasonable administrative cost. There are few significant forms of 'on-farm' pollution in this category that we are aware of. Probably the best example is the large scale feedlot raising of cattle which is now beginning in Australia, with all its attendant problems of animal waste disposal. At present, the main potential for applying an environmental pricing scheme to pollution generated by agricultural production, probably lies beyond the farm gate. Many of the agricultural processing industries are very important sources of pollution, particularly water pollution. These include the processing of: forest products, sugar, dairy products, meat, and fruit and vegetables. In Queensland detailed estimates of the BOD and solids, in pounds weight per annum, are available for most of these processing industries.34

The main forms of 'on-farm' generated pollution not amenable to monitoring and measurement are the highly dispersed discharges from fertilizers, pesticides, and irrigation. The feasible policy options for these forms of pollution would appear to be production taxes, input taxes, and direct regulations.
PRODUCTION TAXES

It is frequently suggested that a tax should be imposed on the output of goods when their production generates harmful residuals. From the standpoint of economic efficiency and incentive to innovate, an output tax represents a particularly crude control procedure. The primary weakness of this tax is that it provides no incentive to substitute production techniques which generate lower damage per unit of output for those creating higher per unit damage. Furthermore, output taxes offer no incentive for pollution reducing technical innovation, or for the use of pollution control processes that do not directly reduce private costs of production. It is also worth noting that if an input with a high pollution productivity is an inferior input in the production process, the imposition of an output tax may lead to an increased pollution output.

Some defend an output tax on the grounds of its administrative advantages. However, a tax levied according to the relative pollution productivity of inputs offers similar administrative advantages and is superior in terms of resource allocation and incentives to innovate. An output tax would be an appropriate policy only in unusual situations, such as where there are no input substitution possibilities in production, and there is a technically-fixed relation between output and pollutant emissions.

INPUT TAXES

The prime virtue of input taxes is their administrative feasibility. In particular, input taxes may be the best control procedure for situations where the monitoring of pollution emissions is technically impossible, or would involve very high administrative costs. For example, for highly dispersed discharges such as runoff water carrying agricultural fertilizers or pesticides.

With an input tax a firm would reduce its pollution emissions, not simply by reducing production as with an output tax, but also by changing the input mix. Providing an appropriate rate(s) of input tax(es) is selected, the post-tax resource allocation will be more efficient than that which would prevail with an output tax. A government, of course, would never have
sufficient information to levy 'optimal' input taxes. This would require detailed knowledge of the relative pollution productivity of the various resources, the elasticity of output supply, and the elasticity of substitution between resources. Even with such information, input taxes will not generally assure a Pareto efficient resource allocation, since they provide no incentive to use emission-control equipment to improve the quality of emissions and/or reduce their volume. In some instances, the least-cost way of reducing pollution may be to continue to use the same input-mix, but install emission-control equipment.

There is another procedure that is fairly closely related to input taxes - namely, subsidization of pollution control equipment. This procedure assumes particular significance in the light of the experience of the Australian Senate Committee on water pollution [5, pp.111-120]. Tax concessions and subsidies on pollution-control equipment were the most commonly proposed forms of pollution control made by firms giving evidence before the Committee. Perhaps the most important point to make here, is that a subsidy on pollution-control equipment is, on its own, of little value. Unless firms are penalized in some way for waste emissions, they have little incentive to install equipment which neither adds to revenues or reduces productions costs, no matter how small the post-subsidy equipment cost may be. However, it is possible that tax concessions and subsidies of this sort, in conjunction with public opinion which is critical of polluting activity, may induce firms to install pollution-control equipment to improve their public image. Alternatively, firms may fear that inaction will lead to more stringent control measures at a later time.

DIRECT GOVERNMENT REGULATIONS

The policy options for pollution control that we have considered up to this point .11 have some component of government regulation or control. The element of regulation is, however, channelled through the market (price) mechanism. In contrast, with policies of direct government regulation the price mechanism is completely supplanted by a system of centralized controls.

Economists largely regard direct regulations (including prohibition) as naive solutions to externality problems, while
this form of intervention tends to be particularly favoured by governments. Economists are anxious to avoid recourse to the use of a system of direct controls in the place of systems utilizing the price mechanism, because of the well known inefficiencies of direct controls. In particular, a government will seldom, if ever, have the formidable amount of information necessary to allow it to instigate a system of direct controls that will attain a reduction in pollution at least social cost. Also, direct regulations and prohibition have additional social costs in the form of policing and administrative costs which are not incurred with the market mechanism. The cost of policing and enforcing pollution regulations and prohibitions may be reduced by imposing fairly punitive fines (and/or gaol sentences) on offenders. Where the probability of detection is low fairly punitive fines will usually be required as an effective deterrent if the regulations are to be successfully enforced.

Despite our reservations with respect to the use of direct government controls there are situations where we believe this form of intervention may be the best available alternative, particularly for those forms of pollution characterized by considerable risk, uncertainty and high information costs. To illustrate this point we may consider, briefly, the interesting economic problem posed by the use of some pesticides.\textsuperscript{35} In general, the pesticide situation has been characterized by fairly rapid changes in technology leading to the development of new pesticides, new practices, and generally changing situations. Moreover, we have only very limited knowledge of the effects of many of these pesticides on food chains and ecosystems. In these circumstances, a comprehensive system of regulations, prohibitions and carefully defined property rights may be the best instruments available to governments to control their use. Regulations may be first imposed at the development and manufacture stage.

Certain characteristics which are likely to generate substantial negative externalities (such as high toxicity and high persistence) may be identified and legislation passed which would prevent the marketing of any pesticide whose toxicity and persistence levels were above a specified maximum. Next, something less than "full" property rights may be given for some pesticides in commercial use. Property rights could be restricted by carefully specifying the conditions under which a pesticide could,
and could not, be used. For instance, by restricting use to licensed operators only, specified crops, and certain times of the year. Finally, governments may legislate for maximum acceptable levels of pesticides in foodstuffs and enforce the legislation by a comprehensive monitoring system. Justification for the above forms of intervention is largely dependent on the information and administrative costs of the alternative pollution control procedures, and we turn now to a general discussion of these issues.

Information and Administrative Considerations in the Choice of Pollution Control Policies

With the policy options specified, and some of their important features (advantages as well as disadvantages) identified we now focus on the more specific question of what can be said generally about the choice among them. In other words, what attributes of the various policies are likely to be important in ranking them on a better-worse scale? Our discussion is, of necessity, brief, but it should at least serve to highlight those issues which require further thought.

The efficiency characteristics of control procedures are, without question, of prime importance. However, as our outline of the policy options has already emphasised, there are at least two other critical attributes of the policies: first, their informational requirements; and secondly their administrative costs and measurement requirements.

The crucial significance of informational and administrative costs in the choice of an appropriate pollution control policy is perhaps best illustrated by ranking the various procedures in order of preference, initially assuming perfect information and zero administrative costs. Clearly the ideal target for regulation (tax) is the marginal pollution damage functions themselves (i.e. Pigovian taxes). Next, is the activity of polluting - the pollution emissions as measured by some technical criterion, such as BOD, which will, to a greater or less extent, be correlated with the marginal pollution damage function. There will seldom, if ever, be a one-to-one correspondence between these functions. And this is why, needless to say, Pigovian taxes are theoretically superior to variable emission taxes and environmental pricing and standards (via unit taxes or quotas).
Finally, various activities that are related, in varying but less direct ways, to the act of pollution may be the policy target. Thus the order of preference in terms of resource allocative (including innovative) criteria is: Pollution damage (Pigovian) tax; variable emission taxes, environmental pricing and standards via unit taxes on discharge or quotas; an input tax; a production tax; and direct regulations and prohibitions.

However, when information and administrative costs are incorporated the ranking might easily be reversed. When we are faced with situations involving little information, and a high degree of uncertainty (such as in the pesticides case) the only feasible approach may be to impose stringent regulations on the production or use of products which are identifiable as the source of the problem. Certainly, too, taxes on outputs of goods, or inputs used will be easier to administer than taxes on emissions or damages caused. But, in general, we cannot be specific about the extent to which the information and administrative problems will reverse the ordering established by the efficiency criterion. The best we can do is to scrutinise some of the more important issues involved, and to this end we now consider information problems in general and measurement problems in particular.

(1) Information Problems

One important type of information problem concerns the identification of the benefits and costs of a change in the pollution level per se. It is generally argued - and seems to be widely accepted - that calculation of the appropriate Pigovian taxes on pollution output is informationally infeasible, and that a combination of quantitative and qualitative restrictions on pollution (the environmental standards approach) will therefore be necessary. What this immediately implies is that the "standards" approach requires less information, or that the information required is less costly to obtain, than for the Pigovian tax option. However, this type of argument seems to us to be suspect in the following sense. What we require to know in order to calculate the Pigovian taxes is the marginal social damage function; for the standards approach on the other hand it would seem to be important to know something about both the social damage function, and the "social cost of pollution control" function so as to be sure that meeting the standard will involve an improvement in the allocation of resources. Certainly without knowledge of
this sort there is an inherent danger that pollution control will be taken too far in the sense that the cost, in terms of consumption foregone involved in meeting the standards may exceed the cost of damages imposed in the uncontrolled situation: the arguments involved would certainly seem to require some further consideration.

The second sort of informational problem is concerned with ensuring that the "least-cost" method of achieving pollution control is adopted. There are in fact two particular problems: to ensure that the "rights to pollute" are allocated efficiently among firms; and to ensure that firms are given the (continuous) incentive to achieve least cost reductions in pollution levels themselves. As we suggested in our discussion of the various policy options, the achievement of these objectives requires that the taxes or fines employed be related directly to the pollution level, and more specifically to the damage caused - hence the attractiveness of Pigovian taxes and the unit taxes involved in environmental pricing, or the establishment of markets for pollution quotas. However, it also is clear that an additional requirement is that the location of the firm, the location of the residuals disposal point (height of chimney etc.) and the form or quality of the wastes generated be variables taken into account in setting the taxes, fines and so on. This requirement is, needless to say, particularly demanding in terms of information requirements, and there is a clear danger that with inadequately formulated policies some pollution problems may be exacerbated. For example, where air pollution is being taxed, the water pollution problem may be substantially increased. With the predominant ignorance that pervades this area, the problem-by-problem approach to government intervention that is typically proposed may prove inferior to more general policies, such as across-the-board taxes on all physical outputs.37

Measurement Problems

The measurement of pollution emissions to ensure that standards, regulations, or pollution quotas are being met, or to establish tax liabilities, raises problems not only for determining the feasibility of the adopted policy option, but also for determining the appropriate degree of pollution abatement, one particular
issue, however, that seems worth considering is whether the measurement costs differ substantially between the use of taxes and quantitative restrictions to reduce pollution. That a significant difference does exist is often implied in the literature, and presumably the relevant reasoning is that while taxes require more or less continuous monitoring of the pollution level of every firm, quantitative restrictions can be policed by occasional measurements of the pollution output of a few firms selected at random, with punitive fines calculated to maintain disincentives to exceed the pre-determined pollution level. What this argument ignores is that while the measurement costs to governments is reduced, the cost to firms are increased: if the fines are appropriately punitive, the quantitative restrictions will require firms to monitor their own pollution output. To establish the usual assumption that quantitative restrictions are less costly we would need to argue that there is an asymmetry in measurement costs according to whether firms or governments are responsible for the measurement, and it is not at all obvious that this is so.

Concluding Comments:

From the preceding discussion it becomes apparent that it is not easy a priori to indicate which policy options are likely, in general to emerge as the "second-best" when information and administrative problems are taken into account. Moreover, there are other important factors which have, in both an economic and a political sense, an important bearing on the choice of the policy approach. The most important of these issues that we have not taken into account is, perhaps, the distributional consequences of the different policy options. It is, in fact, difficult to discuss these consequences except in very general terms because we have little idea of who ultimately bears the burden (the real income loss) of the taxes, subsidies, regulations and so forth that are normally proposed. The distribution of the real cost burden of a particular pollution control program will be dependent on the
pattern of change of factor and product prices that it causes. Despite the difficulties involved in assessing the distribution of the benefits and the cost burdens of pollution control programs, it is nonetheless true that considerations such as the maximization of social welfare, and ultimately the political acceptability of particular policies will depend fairly crucially on the incidence, as well as the form, of the government's intervention.
FOOTNOTES

1. See, for instance, [4, 5, 6, 7, 8, 33].

2. Income tax concessions tied to the development of land for agricultural production introduce a bias against using land to provide natural recreational/amenity services. It is common for so-called "Hitt Street" farmers to benefit from these tax concessions. Moreover, the rural land they acquire is frequently within easy reach of urban areas. It is precisely this land which is likely to be most in demand to provide recreational/amenity services.

3. For some evidence on air pollution as it relates to agriculture in Australia and the United States see [17, pp. 27-29] and [4, pp. 113-126].

4. See [5, pp. 45-47].

5. Throughout this paper we use the words "rural" and "natural" interchangeable. The words refer broadly to all non-metropolitan areas.

6. For a discussion of the economic significance of our reservoir of genetic stocks see Krutilla [57]. We do not discuss this aspect of the natural environment in the present paper.

7. Davidson et. al. [34] have made some interesting suggestions regarding the formation of preferences (demand) for recreational pursuits involving the amenities provided by natural environments, but whose consumption depends predominantly upon the prior acquisition of specialized skills gained from experience. The most important point they make is that learning-by-doing will stimulate future demand for these environmental amenities, and that present and future demand functions are therefore, interdependent.

8. It seems possible that an option-demand may even exist for persons who place a value on the mere existence of biological and geomorphological variety and its widespread distribution.

9. For some interesting work on various aspects of the economics of conservation see [29, 41, 57, 58, 76].

10. For a discussion of the problem of environmental stress and threats to the self-adjusting nature of ecosystems see [28, 72].

11. For work on the various dimensions of on-farm pollution overseas see [1, 17, 38, 46, 59, 75, 80].

12. See, [17, 30, 81].
13. Two points arising from the previous two sentences require some emphasis. In the first place, the constraint on economic behaviour is not the Law of Conservation of Meso itself, but rather the residuals which arise as a consequence of its operations, and in the second, reuse and reclamation postpone rather than eliminate the need for residuals disposal.

14. We should perhaps emphasize that we are not suggesting that pollution is a new problem, and the following observations on 14th Century London quoted by Kneese in [55] indicates that it is not even a strictly post-Industrial Revolution problem. "By the killing of great beasts, from whose putrid blood running down the streets and the bowels cast into the Thames, the air in the city was much corrupted and infected, whence abominable and most filthy stinks proceed, sickness and many other evils have happened to such as have abode in the said city, or have resorted to it". Today's problem is, however, of a different order of magnitude and complexity to earlier pollution episodes, and the problem is in a sense compounded by the apparently increasing willingness of individuals to forego a substantial amount of physical consumption for psychic and other benefits of a pollution-free environment.

15. Their figures suggest in fact that in 1965 basic materials production in the U.S.A. was 2,492 million tons, of which over 600 million tons were agricultural products (including forestry, fishery and wildlife products). The subsequent comments in the text apart, the agricultural sector is likely to be concerned with the residuals generated by their production activities only in so far as they occur as on-farm residuals, letting processing and consumption activities deal with their own residuals problems.

16. The famous Greek economist Aristotle saw the problem involved here very clearly when he wrote: "For that which is common to the greatest number has the least care bestowed upon it". [2, p. 44].

17. We refer the reader back to our discussion in Section I of the demand and supply of environmental amenities. The central problem here revolves around the difficulty of obtaining operational measures of demand and supply of environment services.

18. The literature on externality problems in general is by now very substantial. Among the more important contributions are those of Coase [27] and Buchanan and Stubblebine [20], while Mishan [60] has recently presented a survey of the literature containing an extensive bibliography. Some thoughts on the relationship between externalities and pollution are contained in Ayres and Kneese [9] and Rothenberg [69] for example. However the ideas contained in our section are somewhat different in some respects to traditional views, but provide a more consistent, and more appropriate, approach to the externality problem.
19. It is possible, however, that inefficiency might arise in the case of adjustments at the "input" point, so that government policy might be required to ensure efficient degrees of abatement of pollution as an unwanted input.

20. The compensation referred to here is a sort of bribe or side-payment to polluters to induce them to alter their behaviour - to reduce their pollution. To call them bribes (with all that word's moral overtones) seems unfortunate since in an economic sense they are no different from prices paid for goods and services in the market.

21. "Positive propositions" are taken to be judgments of fact, as opposed to value judgments. The difference between these two judgments is that judgments of fact are capable, at least in principle, of being refuted by empirical observation while value judgments are not.

22. The major contributions are the work of Dows [35] and Buchanan and Tullock [21]. More recent contributions can be found in issues of the journal Public Choice.

23. If we adopt the hypothetical compensation approach, however, this assertion would need to be somewhat more guarded.

24. The relationship between externality problems in general and the legal system is subjected to careful examination by Coase [27]. Parish (Australian Economic Papers, June 1972: "Economic Aspects of Pollution Control") also has an interesting discussion of Coase's propositions as they relate specifically to pollution control.

25. The major exception involves land, over which private property rights are widely defined. However, with land it may be difficult to enforce one's property rights in many instances since one has to be able to identify the offender(s). Moreover, some land areas are regarded still as essentially communal property.

26. Probably the best exposition of this approach is that given by Kneese [51].

27. For papers which consider simultaneously economic and ecological goals see [24, 51, 83, 84].

28. The taxes are named after Pigou who first proposed their use. For these, and all other taxes, we (implicitly) adopt the assumption that the pollution problem is the only source of inefficiency in the system. Just how crucial this assumption appears depends very much on one's views about how to deal with second-best issues.

29. Note, too, that we have to identify not simply aggregate pollution damage (at the margin), but, in fact, the contribution of each individual firm to that damage.
30. Of the fairly large literature on these pollution control procedures, the papers by Beazley and Gates [12], Zerbe [87], and R.K. Parish (Australian Economic Papers, June 1972: "Economic Aspects of Pollution Control") were instrumental in helping to formulate our ideas for this section.

31. The discussion of taxes for various pollution control procedures applies directly, mutatis mutandis, to the payment of subsidies to firms reducing their pollution emissions, or inputs, or outputs. The main differences between taxes and subsidies lie in their distributional consequences. However, some of the distributional effects have implications for resource allocation. First, from the viewpoint of economic efficiency, emission taxes have the important advantage of yielding revenue in a manner that does not have the resource misallocative effects that characterize most taxes. By contrast, subsidies will usually be financed by raising taxes which will, in turn, generally introduce economic inefficiency elsewhere. A further disadvantage with subsidies, is that the base level of emissions from which reductions are to be measured must be determined for each firm. This involves additional informational costs, and creates an incentive for firms to inflate their reported base levels of emissions.

A final point relating to distributional/allocative effects is that the distributional incidence of various policy options is closely linked with their political acceptability. This being so, distributional and resource allocative effects become, in a sense, inseparable.

32. For an early discussion of pollution quotas see Dales [32].

33. Free-rider effects are likely to arise since individual 'conservationists' (with a high demand for a clean environment) may rationally choose not to become members of a cooperative "quota buying" conservation group because they assume their own individual contribution would have a negligible effect on the quantity and quality of clean environment provided.

34. See [5, pp. 45-47].

35. The pesticides which have probably caused the most concern in recent years are those belonging to the chlorinated hydrocarbon group, of which DDT is the most important.

36. In Australia, the Commonwealth Department of Primary Industry performs about 25,000 analyses annually of foodstuffs for pesticide and other residues. This represents a form of "final protection" for the Australian consumer and also helps to ensure that standards set by countries importing Australian foodstuffs will be met. Of course, consumers may (and do) reflect their preferences through the market mechanism via a demand for "organically grown" (pesticide free) foodstuffs.
This argument is explained in a currently unpublished manuscript - "Optimal Policy Choice Under Uncertainty", by G.B. Brennan and T. McGuire, of the Australian National University and Dalhousie University, Respectively.
REFERENCES


