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From the Editor:

I am pleased to include in this issue two of the papers from the July Study Group meeting. The first is Vivien Foster's appraisal of Christianity and environmental economics, which, being about green issues, has a suitably colourful title! The second paper is by Donald Hay and concerns the way Christian economists should think about technological progress. Finally I have also included a short review by myself of a collection of papers from an Institute of Economic Affairs conference on the subject of God and the marketplace.

I have also recently received the Fall 1994 issue of the North American ACE Bulletin, which contains further papers and discussion from their meeting last January on the subject of "What Should Christian Economists Do?"

I can report that next year's ACE meeting will once again take place in Jesus College, Oxford in early July. The dates are 3rd-4th July 1995. Further details will be available nearer the time.

I have received various books for review so if you would like to contribute a review to the Journal I would be pleased to hear from you. As always I am also keen to hear from anyone who has a paper to contribute or is "sitting" on a paper from an early study group meeting that has not yet appeared in the Journal.

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FROM ESCHATOLOGY TO SEWAGE TREATMENT:
AN ECONOMIC APPRAISAL OF GREEN CHRISTIANITY[1]

Vivien Foster

1. Introduction

This paper is concerned with exploring the intersection between Christianity, economics and environmentalism. There are a number of motivations for such an exercise. The first of these is that the sheer scale of contemporary interest in environmental issues is itself a challenge to determine what the Christian response to them should be. This is particularly so given that Christianity has sometimes been blamed for the metaphysical origins of the problem.[2] It is striking that Christians have been comparatively silent on the 'environmental crisis', very much in contrast with the strong stance that has been taken on a variety of other social issues - in particular, distributive justice, and reproductive ethics.

Perhaps an important reason for this reticence is that there is sometimes perceived to be a conflict between the dictates of environmentalism, and these other more traditional Christian social concerns. Any Christian position towards the environment will therefore have to be grounded in a thorough understanding of the complex interactions between consumption, demographics, and environmental degradation. It should also encompass an awareness of the distributional impacts of alternative environmental policy prescriptions. The need to clarify these interconnections provides a second justification for the discussion provided in this paper.

Finally, in the absence of active Christian participation in the debate, a rich spectrum of philosophical positions towards the environment have been developed, each with their corresponding policy prescriptions. This literature has not yet been adequately scrutinised by the theological community.[3] Yet, if Christians are to select between these various schools of thought, or decide whether others need to be developed, then it is essential that their underlying philosophical assumptions be clearly spelt out and thoroughly evaluated. What is particularly interesting about the existing literature, is that it includes a number of innovative attempts to graft

ethical considerations into economic analysis. These are of interest in their own right, and have potential applications well beyond the scope of the environmental debate.

The remainder of this paper is organised as follows. Section 2 provides a brief overview of Christian thought on the natural world. Section 3 examines the policy implications of environmentalism and assesses their compatibility with traditional Christian social ethics. Section 4 provides a taxonomy of existing environmental quality prescriptions, and attempts to adjudicate between them from a Christian perspective. Section 5 draws together the main conclusions of the paper.

2. Christian Thought on the Natural World

This section provides a very brief overview of Christian thought on the natural world. Two literatures can be distinguished. On the one hand, there is a substantial body of classical theological writing, with its associated contemporary commentaries. On the other hand, there are a number of ecclesiastical tracts and popular paperbacks, which attempt to take a more practical approach to the subject.

The classical literature is primarily concerned with understanding the theological status of the natural world. Is nature good or evil ? Is God transcendent or imminent with respect to nature ? Was nature created for its own sake, or merely as an arena for God's interaction with humanity ? Does nature participate in the Fall of man, and in the redemptive action of Christ ? What is nature's ultimate eschatological destiny ? The underlying motivations of this literature are therefore philosophical rather than practical. The central focus is creation theology (concerning God's relationship with nature), rather than environmental management (concerning human interaction with the natural world).

A thorough treatment of these basic theological questions lies well beyond the scope of this paper. However, they are noted here, because the answers that are given to them play an important role in shaping the overall ethos which is to govern man's involvement with his natural environment. In particular, whether this ethos should be one of utilitarian exploitation or careful

respect.[4]

Of some interest in this context, are two contemporary studies (Fox, 1983; Santmire, 1985). Although strongly contrasting in style (Santmire's book is a balanced evaluation of the classical literature, while Fox's work is more of a radical polemic which draws somewhat haphazardly on classical texts), the two do share something of a common methodological approach. Both attempt to categorise individual thinkers according to the degree of theological prominence which they give to the creation.

In Fox's language, "creation theologians" are to be distinguished from "fall-redemption theologians". Whereas, the latter are seen as preoccupied primarily with the implications of original sin for the relationship between God and humanity, the former are thought to focus more positively on the "original blessing" embodied in God's creation.

In Santmire's work, both the terminology, and the lines of differentiation, are slightly different. The distinction is to be drawn between those thinkers who reflect "the ecological motif" versus those who reflect the "spiritual motif". The difference between the two is to be found in the extent to which man's ultimate theological destiny is thought to lie either within nature or beyond it. The "spiritual motif" is grounded in the theological metaphor of ascent, whereby man, in his spiritual quest, must ultimately rise above the natural world and leave it behind. The "ecological motif", on the other hand, builds upon the theological methaphor of migration to a good land. From the Old Testament, it draws upon the centrality of the promised land in God's dealings with the people of Israel. From the New Testament, it relies particularly on Paul's writings about the apocalyptic renewal of the natural world.

What is striking is that these two authors reach opposing conclusions about the positions of individual thinkers ! Most notably, Fox sees Augustine as the arch-proponent of "fall-redemption theology", whereas Santmire presents him as a preeminent example of the "ecological motif". (It should be noted, however, that Fox's interpretation of Augustine has been severely criticised (Atkins, 1992)). A similar difference of opinion exists over Aquinas, whom Fox classifies as a creation theologian, and Santmire deems to occupy a somewhat ambiguous position midway

between the "ecological and spiritual motifs".

The wisdom of classifying classical thinkers simplistically along these lines is doubtless questionable. However, the value of such studies is that they serve to illustrate the range of opinion, and the degree of ambiguity, which unquestionably exist within the Christian tradition (sometimes within the writings of a given author). This ambiguity perhaps finds its origins in the disjointed nature of the creation narrative itself (Wilkinson, 1980; Hay, 1989), where man is at first instructed to subdue and rule over the earth (Genesis 1:28), and subsequently enjoined to till and keep the garden (Genesis 2:15).

However, it is important to recall that both of these injunctions come prior to the Fall, which itself brings about a radical alteration of the relationship between man and his natural environment. God's punishment for Adam's disobedience can essentially be characterised as the introduction of scarcity into the world: first, the scarcity of resources (implied by the need to work hard for a living), and second, the scarcity of time (implied by the advent of human mortality). It is the first of these forms of scarcity that is of primary interest here: "...the ground will be under curse. You will have to work hard all your life to make it produce enough food for you" (Genesis 3:17). This is in stark contrast with the superabundance of Eden, where Adam is surrounded by fruit-bearing trees, and where work appears to have more in common with recreational gardening than with subsistence agriculture. A slightly different implication of the Fall that has been noted by some authors (Wilkinson, 1980; Hay, 1989), is the danger that sinful man will abuse his position of stewardship over the natural world.

Thus, in the post-lapsarian world, there is likely to be a conflictive dimension to man's interactions with his environment. This conflict is both a direct consequence of human sinfulness (in the sense that Fallen man abuses his position of stewardship), and an indirect consequence of human sinfulness (in the sense that scarcity is itself a consequence of the Fall). Since scarcity is the very *raison d'etre* of economic science, it is clear that economic considerations will have an important impact on man's relationship with the natural world. (One might even say that the curse of Adam is the need to concern himself with economic matters.)

Attention now turns to the second of the two theological literatures identified above: the more practically oriented ecclesiastical tracts and popular paperbacks. The central problem which these authors face is one of how to move from creation theology to concrete prescriptions for environmental management. The transition is far from straightforward, and is managed only with a limited degree of success. It is difficult to make generalisations about this literature. However, a number of different strands can at least be identified, sometimes within the writings of individual authors.

The first of these is in many ways the most straightforward. The focus is on the implications of the environmental crisis for the lives of individual Christians, and for the Church itself. There are exhortations to adopt a less materialistic lifestyle (in harmony with the traditional virtue of asceticism), and to play a more active role in ecological movements (General Synod Board for Social Responsibility, 1986; Cooper, 1990; Atkins, 1994; Norcott, 1994). The guiding principle is one of responsible stewardship at an individual level.

A second strand in the literature tackles the issues at a somewhat higher level, by framing over-arching policy prescriptions. Prominent themes are a just distribution of resources, a sustainable approach to development, and the limitation of population growth (Wilkinson, 1980; McDonagh, 1990; Gosling, 1992; Palmer, 1994). They are well summed-up by the title of the World Council of Churches' movement for "Justice, Peace and the Integrity of Creation".

However, it is perhaps the third strand of this literature which comes closest to grappling with the fundamental issue of precisely how much environmental degradation is acceptable. For example, the General Synod Board for Social Responsibility, 1986, suggests a number of criteria: first, an appraisal of whether environmentally-damaging development is deemed essential; second, an assessment of whether all the alternatives have been explored; and third, an analysis of whether the resulting good exceeds the resulting damage. Yet this balancing approach is somewhat at odds with statements elsewhere in the document to the effect that environmental degradation is sinful. Such blanket indictments are problematic in the sense that human activities must necessarily interfere with the environment to some degree.

Turning to statements from the Vatican, recent papal encyclicals have begun to move away from the traditional, unqualified endorsement of human dominion over the natural world (see for example, *Populorum Progressio*), and towards a recognition of the dangers entailed by over-exploitation of the environment. Particular concerns which have been raised (see notably, *Sollicitudo Rei Socialis)*, are the inter-connectedness of ecological systems, the limited supply of natural resources available to satisfy the needs of present and future generations, and the adverse effects of industrialisation on the quality of life. While these statements remain predominantly anthropocentric, they acknowledge the need to consider the negative side-effects of economic development (McDonagh, 1990). Once again, there is something of a balancing approach.

The somewhat indeterminate character of these various recommendations is hardly surprising given the nature of the classical literature in which they are rooted. From a practical perspective, the problems with the creation theology literature are twofold. First, as has been illustrated, the primary, secondary, and tertiary theological texts seem to generate ambiguous messages, with some apparently condoning utilitarian exploitation of the natural world, and others apparently demanding careful respect for the environment. Second, in both cases, the prescriptions do not seem to go much beyond defining a rather vague ethos to govern human interactions with the natural world. It is never entirely clear precisely what is to be understood in practice, either by "utilitarian exploitation", or by "careful respect".

This is not necessarily a criticism of creation theology *per se*. It is not, after all, the function of theology to generate optimal resource depletion rules. Moreover, it would be somewhat anachronistic to expect to find concrete environmentalist prescriptions in texts which predate the "environmental crisis" by many centuries. Contemporary environmentalism must be understood as the product of a period in history when the overall scale of human economic activity has become large in relation to the absolute carrying capacity of the planet - using up about 40% of the net primary product of land-based photosynthesis (Daly, 1991). That is not to say that there have not been serious localised environmental problems in the past, but rather that these have not previously been of such a magnitude as to collectively endanger the functioning of the ecosystem as a whole (Kennedy, 1993).

However, it *is* a criticism of any attempts to derive policy prescriptions too directly from creation theology in a simplistic "forward-looking" fashion. This is because the creation theology literature simply does not provide enough concrete material for this to be done in a very meaningful way. More fruitful, might be a "backward-looking" hermeneutical approach, which would involve first exploring the practical policy implications of secular environmentalist prescriptions, and then establishing whether they give rise to any inconsistencies with the most incontrovertible and unambiguous precepts of Christianity. It should also encompass a rigorous assessment of the philosophical assumptions underlying the different environmental management rules which have been proposed by a variety of different schools. The existing literature has probably progressed further with the first of these tasks than with the second. Some attempt is made to conduct both of these exercises in Sections 3 and 4 below.

3. The Policy Implications of Environmentalism

As illustrated in the equation below, environmental degradation is the product of three forces: population, consumption and technology. Broadly speaking, any ethic which seeks to place a limit on environmental degradation, necessarily requires policy measures that make an impact either on population, or on per capita consumption, or on the nature of technology.

environmental degradation

=

population

x

per capita consumption

x

environmental degradation per unit of consumption

There are a number of reasons why an equation of this kind gives an overly simplistic representation of this complex set of relationships. First, by treating environmental degradation as

a single composite measure, it blurrs important distinctions between local, regional, and global environmental problems, and fails to distinguish between natural resources and environmental quality. Second, it conceals critical interconnections between the three variables identified. For example, a given population increment in a high-income country will be more environmentally damaging than the same population increment in a low-income country. To be precise, "the average American baby represents twice the environmental damage of a Swedish child, three times that of an Italian, thirteen times that of a Brazilian, thirty five times that of an Indian, and two hundred and eighty times that of a Chadian or Haitian" (Kennedy, 1993). On the other hand, a given unit of consumption may be more or less environmentally damaging depending on whether it is consumed in a low-income or a high-income country. The poverty-environment hypothesis (Pearce and Warford, 1993), for instance, suggests that the meagre consumption levels of some of the world's poorest people may sometimes have disproportionately large environmental impacts, because they are forced to subsist on marginal lands within fragile ecosystems. Moreover, the consequent environmental degradation may undermine the livelihood of these people and thereby plunge them into further poverty. It is also known that energy efficiency in developing countries is substantially lower than that in the industrialised world. In fact, at present "China is half as efficient in energy use as India, which is less than one tenth as efficient as the UK or the USA" (Holdgate, 1994).

For all its limitations, an equation of this kind does provide a helpful analytical framework, and goes some way towards making an immensely complex issue at least remotely tractable. Perhaps more important, in policy terms, than the static relationship outlined above, is its dynamic equivalent stated below, which serves to illustrate what these fundamental relationships imply for the deterioration or improvement of environmental quality over time. The simplest case to consider is one where the policy objective is to prevent any further environmental degradation taking place at all, which is one potential interpretation of the concept of sustainability. In terms of the equation below, this would be like setting the rate of environmental degradation equal to zero. The implication of this is that the potential for technological improvements places an upper bound on the permissible rate of growth of population and per capita consumption. That is, the sum of economic and population growth rates must be equal to the rate of environment-enhancing technological change.

rate of environmental degradation

=

population growth rate

+

rate of growth of per capita consumption

-

rate of environment-enhancing technological change

At some risk of caricature, it is possible to classify different types of environmentalists according to which of these three parameters they view as providing the primary solution to the problem. First, resource optimists and apologists for the capitalist system tend to put their faith entirely in technological progress, believing that human ingenuity will always be capable of accommodating growth in population and per capita consumption. Second, left-leaning environmentalists tend to favour a curtailment of economic growth, accompanied by redistributive measures in favour of developing countries. Finally, more conservative greens tend to take a neo-Malthusian line, blaming environmental degradation almost entirely on population growth.

This tendency to focus on one or other aspect of the solution doubtless reflects the unpalatable nature of the available options, and seems to indicate a degree of selective blindness within each of these different groups. Whether there will indeed be enough room for manoeuvre to be able to avoid taking up any one of these three policy measures is, in any case, an empirical, rather than an ideological, question. Some assessments of the situation (World Commission on Environment and Development, 1987), suggest that all three options will need to be kept open.

Technology

Reliance on environment-enhancing technological change is undoubtedly the least controversial of the three options identified, and does not appear to raise any serious problems from a Christian perspective.[5] However, it should be noted that improvements in environmental

productivity may come at the expense of labour productivity, thereby putting downward pressure on per capita consumption. Therefore in practice, technological change and per capita consumption are likely to be interconnected.

It is important to note that technological change is essentially what has accommodated economic growth and population growth in the past. It explains why, in defiance of Malthusian predictions, "during the nineteenth century as a whole, the British population grew fourfold, whereas the national product grew fourteenfold" (Kennedy, 1993), (thereby allowing per capita consumption to grow more than threefold). Two hundred years after Malthus, the dire predictions may sound uncannily similar, but the scale of the problem is undoubtedly rather different. The populations of developing countries are growing at a faster rate than that of nineteenth century Britain, and the baseline level of world population from which they are growing is more than five times higher (McDonagh, 1990). Moreover, as mentioned above, the current scale of human activity relative to the carrying capacity of global ecosystems is unprecedented.

Daly, 1994 provides a simple calculation which helps to illustrate the implausibility of relying exclusively on technological change as a resolution of the environmental crisis. He notes that population growth is expected to double over the next forty years, while per capita income in rich countries is about twenty three times what it is in poor countries. If the policy goal is to simultaneously bring poor countries up to rich country living standards, and to avoid further environmental degradation, efficiency would need to improve by a factor of forty six. Not only is this many times higher than historical rates of improvement, but these historical rates have been largely made up of improvements in labour and capital efficiency, which have tended to come at the expense of resource efficiency.

For all of these reasons, it is unlikely to be possible to solve the problem entirely by technological means. This forces a consideration of the more troublesome options of restricting consumption and population growth. Effectively, the environmental constraint introduces a short-run trade-off between the number of people in existence, and the level of per capita consumption.

Per capita consumption

Viewed from the perspective of the wealthy, limiting consumption would appear to be highly consistent with Christian teaching on material possessions. For obvious historical reasons, Jesus does not discourage the accumulation of wealth explicitly on environmental grounds. However, the fact that he does so as a means of avoiding idolatry, greed, and injustice, carries indirect environmental ramifications in a contemporary context. This is not to say that unbridled consumption would be acceptable in the absence of environmental constraints. The monastic tradition testifies to the fact that voluntary poverty has always occupied an important place within the spectrum of Christian spirituality (Walters, 1992). (Indeed, it is pertinent that Saint Francis, who is famed for his sense of harmony with the natural world, is equally renowned for his love of poverty.)

However, viewed from the perspective of the poorest developing nations, the notion of limiting consumption is altogether a different issue. If there are to be any limits on economic growth, Christian principles suggest that they must be accompanied by substantial redistributive measures.

Referring back to the first equation above, it should be noted that redistribution *per se* does not affect the extent of environmental degradation at any point in time, since the *average* level of per capita consumption remains unchanged, it is only the *pattern* of consumption that changes. Over time however, a more equitable distribution of resources, by eliminating extreme poverty, may impact favourably upon the rate of population growth and the efficiency with which natural resources are used. As a thought experiment, it is instructive to imagine what a completely egalitarian distribution of resources would imply. In 1993, world per capita GNP was $4,280. As a point of reference this lies somewhere between per capita GNP for Mexico and Argentina. However, curiously, there are hardly any countries whose income level corresponds to this figure, the closest one being Gabon. The figure can also helpfully be compared with the equivalent averages for low income countries, $390, middle income countries, $2,490, and high income countries $22,160.

Daly, 1994 provides a helpful elucidation of the relationship between income growth in

high income and low income countries, against the background of environmental scarcity. His argument is that, in the presence of a finite environmental endowment, rich countries will need to limit their consumption of resources and use of environmental support systems, in order to "make space" for economic growth in the developing nations. This argument, among others, serves to invalidate traditional "trickle down" theory, according to which the development of low income countries is best served by economic expansion in high income countries, with a view to providing the former with a larger market for their exports.

An important additional consideration that is often overlooked in the theological literature, is that environmental policies themselves may often carry adverse distributional consequences, both for low-income countries, and for low-income groups within high-income countries. There are at least two aspects to this problem.

First, there is the question of what degree of environmental quality society should aim for over and above what is deemed absolutely necessary, according to scientific, ethical, or economic criteria.[6] Conventional economic wisdom suggests that environmental quality is a luxury good (in the technical sense). Enthusiasm for environmental preservation is therefore thought to be strongest among high-income groups in high-income countries, and even there to fluctuate pro-cyclically in its intensity. It should be noted howver that, this position is based (to a surprising degree) on anecdotal evidence, and disregards important counter-examples such as environmental movements by tribal peoples in developing countries. However, it highlights the potential problem that high income groups (or countries) may lobby for a higher proportion of social expenditure to be dedicated to environmental preservation, at the expense of other projects which may yield greater benefit to lower income groups (or countries).

A related issue is the fact that low-income groups may be concerned with different dimensions of environmental quality to high-income groups - for example, the protection of their children from the health effects of toxic industrial discharges, as opposed to the preservation of the "yellow-bellied sapsucker" from impending extinction (Merchant, 1992).

Second, there is the question of how any desired level of environmental quality should be

achieved. One of the central conclusions of the economics literature, is that environmental resources will tend to be under-priced in a free market (Coase, 1960). A common environmental policy prescription is therefore to ensure that natural resources, such as water and energy, are priced at levels which reflect their full environmental cost. However, Pigovian taxation of this kind is regressive in nature and will consequently give rise to undesirable social consequences. Indeed, consumption of natural resources tends to exhibit comparatively low price-sensitivity *except* among the lowest income groups, so that the environmental benefit may come largely at their expense. (The recent political controversies in the United Kingdom over the imposition of Value Added Tax on domestic fuel, and the more widespread metering of domestic water consumption, are cases in point.)

That is not to say that environmental policies must necessarily have adverse social consequences. They could be designed in such a way as to avoid these effects. The targeting of energy-efficiency subsidies towards low income households is one familiar example. More futuristically, tradable permits schemes potentially offer a means of fine-tuning the distributional impacts of environmental policy. One application which has been suggested, in the context of global warming, is to allocate carbon dioxide permits to countries on the basis of their population and the global average level of per capita emissions. The argument is that developing countries would find themselves with a surplus of permits which could be sold to the industrialised world, generating a substantial amount of revenue.

Population

The validity of curbing population growth as a means of containing environmental degradation has been accepted by a number of Christian authors. However, for the Roman Catholic church, measures of this kind come into potential conflict with traditional teaching on birth control as laid down in Pope Paul VI's encyclical *Humanae Vitae*.

While the problems of population growth, and the consequent pressure on resources, are acknowledged at the outset of *Humanae Vitae*, the encyclical concludes by insisting that there are "other ways in which a Government can and should solve the population problem". It suggests that

these alternative means should be directed at the fundamental root causes of the problem, which it identifies as "misguided governmental policies, [...] an insufficient sense of social justice, [...] a selfish accumulation of material goods, and [...] a culpable failure to undertake those initiatives and responsibilities which would raise the standard of living of people and their children".

More recent statements (Coote, 1994) suggest that the Roman Catholic church is not opposed to birth control *per se*, but has strong views on the methods by which this is achieved. At the individual level, natural family planning is advocated as the ideal approach to birth control. However, given the controversies surrounding the viability and reliability of natural family planning, critics might argue that this restriction is so severe as to undermine the effectiveness of any attempts to limit family size. At the level of government policy, the church is suspicious of the motives of mass population control programmes, particularly when these rely on extreme measures such as abortion or compulsory sterilisation.

The traditional position has been challenged from within the Roman Catholic church. McDonagh, 1990, acknowledges that population growth is neither the sole cause nor the sole remedy for environmental degradation. However, his insistence on the necessity of some population growth measures stems from his appreciation for the empirical proportions of the problem, and also from his view that contraception is a more humane approach to population control than the Malthusian checks of famine and disease, likely to result from over-population.

Perhaps one of the difficulties underlying this debate is that fertility decisions have been traditionally regarded as belonging to the domain of private morality, whereas in a crowded world procreation inevitably takes on an important social dimension.

The consequence of rejecting population growth as a means of containing environmental degradation, is to make per capita consumption the primary policy variable. To take a highly simplified example, if the policy objective were to prevent further environmental degradation and there were no environment-enhancing technological change in the short-run, the implication would be that per capita consumption would have to fall at the rate of population growth. With a global per capita consumption of $4,280 in 1993 terms, as indicated above, any significant decline

below this level is not something to be viewed lightly. Therefore, even if population control measures are treated as a last resort, after all other measures have been attempted, it is not inconceivable that some such steps would ultimately have to be taken.

This section departed from the premise that an ethic of environmental preservation cannot be viewed in isolation. That is because it will inevitably carry wide-ranging implications for spheres of human activity that have historically been governed by other ethical considerations. An important test of environmentalism - from a Christian perspective - is the extent to which its implications are consistent with more traditional Christian ethical concerns, whose biblical origins may be less ambiguous than those of the environmental preservation ethic.

The analysis has revealed a mixed picture. Technological change appeared to represent an ethically-neutral approach to the problem, but is unlikely to be sufficient on its own to resolve the environmental crisis. The limitation of consumption seemed to be highly consistent with Christian teaching, at least as far as the wealthy are concerned, but carried the implication of substantial redistribution as a means of meeting the needs of the poor. It was also noted that environmental policies may potentially give rise to conflicts of interest between high and low-income groups, and, if poorly designed may lead to adverse distributional consequences. Finally, the control of population growth is likely to prove problematic for the Roman Catholic church.

4. A Taxonomy of Environmental Quality Prescriptions

The preceding section focused on the practical consequences of any policy measures to contain the rate of environmental degradation. That whole discussion carefully evaded the issue of how much environmental degradation should be permitted; yet that is precisely the fundamental question of environmental economics. Until it is satisfactorily addressed, it is difficult to put empirical magnitudes on the scale of the environmental problem, and on the extent to which the different policy options identified above will be required to remedy it.

Like creation theology, environmental economics needs to be understood in the context of

the questions which it is designed to answer. How many trees should be cut down ? Should all rivers be clean enough to support salmonid fisheries ? Should coal-fired power stations be fitted with flue gas desulphurisation units ? What measures, if any, should be taken to control carbon dioxide emissions ? As these questions illustrate, the emphasis is very much on informing specific practical decisions. Moreover, these are decisions which cannot be easily evaded; they will necessarily have to be taken even in the absence of an agreed, appropriate decision criterion.

This section provides a taxonomy of the different environmental quality prescriptions which can be identified in the existing literature, with a view to exposing their underlying assumptions. They are presented as a series of cumulative analytical and philosophical steps along a spectrum which runs from traditional economics to deep ecology, and are summarised mathematically in an appendix. In order to adjudicate between them from a Christian perspective, a number of criteria will be brought to bear. Of particular interest will be: the extent to which each of these views can be characterised as a utilitarian, anthropocentric view of the creation; the role of preferences in determining the prescribed level of environmental quality; and the degree to which environmental quality may be traded-off against other goals.

Traditional economics

The baseline position for this taxonomy is a rather caricatured portrayal of traditional economics, pre-externality theory. The environment is viewed solely as a source of raw materials for the production of man-made goods and services, and as a depository for the resulting wastes. Consumers are interested exclusively in the consumption of these man-made goods, regardless of the environmental consequences.

This position is entirely utilitarian and anthropocentric. The level of environmental quality is determined indirectly by the current generation's preferences for man-made goods. The logic of this value system is ultimately to allow unlimited environmental degradation. The issue of trade-offs beween environmental quality and other goals is virtually non-existent. This is because environmental quality is only valued indirectly, in so far as it is capable of supporting the production of man-made goods.

Conventional environmental economics

The crucial innovation of conventional environmental economics is that the environment is allowed to enter the utility function directly. In other words people care both about the quality of their environment, and about their consumption of man-made goods, whose production leads indirectly to environmental degradation. An important trade-off has therefore been introduced into the analysis: people must weigh-up the benefits to be gained from industrial production against the environmental impacts which result. As a result, it is usually "optimal" to tolerate some degree of pollution, rather than to aim for a completely pristine environment (Baumol and Oates, 1975).

What is of particular interest in this context is the way in which the costs of environmental degradation are measured. Because they must ultimately be weighed-up against the benefits of industrial production which are calibrated in monetary units, some form of explicit monetary valuation of the environment is required. This monetary valuation may be obtained through a variety of techniques which involve measuring the strength of preferences for environmental quality in real or hypothetical markets. For example, the value of peace and quiet can be gauged by examining adjusted price differentials between houses directly underneath the Heathrow flight path, and similar property in a more tranquil location. Or, the value of a day spent alongside a clean river can be measured by asking people how much they would be willing to pay as an entry fee to the site. One implication of the environmental economics approach is that it makes consumer preferences the ultimate determinant of the level of environmental quality which should be preserved. In some contexts, this may be problematic, given the complexity of the scientific issues involved.

Non-use-augmented environmental economics

The third position (described rather inelegantly here as "non-use-augmented environmental economics") follows the same analytical framework as before. The only difference lies in the nature of the preferences used to determine the optimal level of environmental quality.

Under conventional environmental economics, these are the narrow, anthropocentric preferences of the current generation. Non-use-augmented environmental economics recognises that these preferences may have a wider motivation. This is based on the empirical observation that people often exhibit a willingness to pay for environmental improvements that will be of no direct benefit to themselves. This willingness to pay has been termed non-use value, and a number of motivations have been postulated for it (Pearce and Turer, 1990).

They are of particular interest here because they encompass a move away from self-interested, anthropocentric preferences: bequest value, reflects a wish to conserve the environment as an inheritance for future generations; and existence value, reflects the belief that people derive benefit from the knowledge that a pristine environment is being preserved, regardless of whether they will ever benefit from it directly. However, it should be noted that these values - although less self-interested and anthropocentric than those of conventional environmental economics - continue to be measured through the medium of the preferences of the current generation.

This approach is also illustrative of one device for incorporating ethical considerations into economic analysis, namely the expansion of the utility function to encompass altruistic preferences, backed-up by willingness to pay. There are, however, a number of practical and philosophical problems associated with this device, in particular, the legitimacy of using willingness to pay as a measure of the strength of ethical beliefs. It has been argued that actions motivated by ethical considerations are counter-preferential in the sense that they reflect commitment to a particular ethical ideal, which may entail acting in such a way as to reduce one's own personal welfare. This is incompatible with the foundations of cost-benefit analysis, where it is assumed that people will act so as to maximise their own welfare (Sen, 1977). The implication is that it may be inconsistent to give weight to such values in a cost-benefit analysis of environmental quality standards.

Sustainability-augmented environmental economics

Whereas the preceding position sought to acknowledge the important inter-generational character of decisions about environmental quality by incorporating bequest value into the

utilitarian calculus, "sustainability-augmented environmental economics" addresses the same issue in a rather different way. The interests of future generations are to be safeguarded by the introduction of a constraint: it is no longer legitimate to weigh the benefits of industrial production against its environmental costs, if there is a danger that environmental quality is to fall below the ethical minimum embodied in the sustainability constraint (Pearce *et al*, 1991). However, where environmental improvements are concerned, it remains legitimate to trade-off the benefits against the costs. The sustainability approach therefore introduces an asymmetry into environmental management; it is essentially a form of bounded utilitarianism.

Two important questions arise in this context. The first question is practical, and concerns the determination of the level of environmental quality to be protected by the sustainability constraint. Some advocates of sustainability have envisaged a pragmatic approach where the constraint is set at the current level of environmental quality. The problem with this is that it gives undue weight to what is essentially an arbitrarty starting point.

The second question is philosophical, and regards the issue of whether the sustainability constraint represents a superior device for grafting ethical considerations into economic analysis than that of incorporating non-use values. The key difference between the two is that the latter always permits trade-offs, whereas the former only does so in the case of environmental improvements. The implication of disallowing trade-offs is to place infinite value on the preservation of the prescribed level of environmental quality. Any amount of human well-being may be sacrificed with a view to preventing environmental degradation below this level.

Whether or not this is a legitimate prohibition depends on two issues. First, it depends on the nature of our ethical responsibilities towards the environment. In particular do we view future generations as having negative rights not to have the quality of their environmental capital degraded, or are we merely under a positive duty to have consideration for future generations in our environmental decision-making.[7] Sustainability constraints are more compatible with negative rights than with positive duties. Second, it depends on the level at which the sustainability constraint is set. If it is set somewhat arbitrarily at the environmental *status quo*, then it seems unreasonable to completely rule out the possibility of trade-offs. If on the other hand the

sustainability constraint is determined with reference to a scientifically-determined absolute planetary carrying capacity given present technological capabilities, then the prohibition on trade-offs would appear to have a greater justification.

Deep ecology

Deep ecology rejects the utilitarian, anthropocentric view of nature which is intrinsic to all the various shades of environmental economics outlined above, with its consequent willingness to trade-off the costs and benefits of environmental degradation (Merchant, 1992). One way of characterising deep ecology would be to say that it focuses exclusively on the constraints which should restrict man's impact on the natural world.

These constraints are to be distinguished from those embodied in the sustainability approach which were motivated solely by human inter-generational equity. In deep ecology, it is more of a case of equity between species. Humanity should not exceed its planetary carrying capacity, thereby leaving space for other forms of life. The implication is, presumably, that there should be a much smaller scale of human economic activity than that envisaged in the sustainability approach. Thus, although sustainability and deep ecology have been presented in this taxonomy as contiguous approaches there is in reality a considerable distance between the two.

The main practical problem with deep ecology as an approach to environmental management, is one of defining in concrete terms what is meant by planetary carrying capacity. The issue does not appear to have ever been fully clarified.

What is immediately striking about this taxonomy of positions is that it is possible to get as far as sustainability without relinquishing a utilitarian, anthropocentric view of nature. (It would seem that there is little in environmental economics to trouble even the most blinkered "fall-redemption theologian" !) All that environmental economics effectively does is to point out that unbridled environmental degradation may prove counter-productive for the present generation, and inequitable towards the next. Depending on how stringently the requirements of inter-generational equity are defined, some form of environmental economics would appear to fit well with the

utilitarian view of nature identified in the theological literature. It is also in harmony with the balancing approach, which was discernible in some of the contemporary ecclesiastical tracts reviewed above.

However, utilitarianism was not the whole story. Can environmental economics, in any shape or form, satisfy the demands for careful respect of the natural world also identified in the theological literature ? Or does creation theology belong beyond sustainability in the greener realms of deep ecology ? The move from sustainability to deep ecology, would imply that both utilitarianism and anthropocentrism should be discarded. The parallel notion that humanity should curtail its activity to "make room" for other species, must be embraced.

Utilitarianism has certainly been roundly rejected as a Christian basis for welfare economics (Hay, 1989). There is therefore something apparently inconsistent about relying, in our interactions with nature, on a philosophical framework which has been discredited as far as human interactions are concerned.

As Hay points out, one of the fundamental problems with utilitarianism, from a Christian perspective, is its definition of the ultimate good. According to utilitarianism states of the world are desirable to the extent that they bring about human well-being, which is interpreted by welfare economics to mean the satisfaction of personal preferences. This is clearly at odds with the Christian notion of the ultimate good as love of God and neighbour. The satisfaction of personal preferences is problematic, in Christian terms, both because it is essentially a selfish exercise, and because the preferences themselves are likely to be characterised by sin.

To what extent does this criticism carry over to utilitarianism as a means of adjudicating between environmental outcomes ? Given that human preferences are marred by sin, there is clearly something flawed about making these the prime determinant of environmental quality. However, the problem is that the commandment to love God and neighbour does not encompass human interactions with nature. It is not therefore immediately obvious what is nature's ultimate good, and consequently what is the criterion that should be used in dealing with it. Thus, while the rejection of utilitarianism appears to be appropriate, it is not entirely clear what would replace it.

The concept of stewardship comes closest to providing a theological framework for human dealings with nature. The problem lies in operationalising this concept at a practical level.

As far as anthropocentrism is concerned, the creation narrative unquestionably gives man a special place within nature by virtue of the fact that he is created in the image and likeness of God. To that extent it is anthropocentric. However, as the creation theology illustrates, anthropocentrism in this context does not necessarily imply a licence to exploit nature in a utilitarian fashion.

It is difficult to reach a firm conclusion on the basis of this discussion. There appears to be a strong case for saying that theologians, of whatever persuasion, should support sustainable development. But there may also be a case for saying that creation theologians should go further and align themselves with the deep ecology movement.

In the spirit of the preceding section, however, it is important to recall the practical implications of either of these philosophical positions. The world is not currently anywhere near the level of environmental quality potentially implied by the sustainability position, let alone that envisaged by deep ecologists. To begin to even move in that general direction, the present rate of environmental degradation would need to be reversed, not merely stabilised. In the context of a rapidly expanding and impoverished world population, that is rather a tall order.

5. Conclusions

The discussion has illustrated that theology plays an important role in determining the overall ethos which is to govern human interactions with nature. However, there is a considerable degree of ambiguity towards nature in the theological literature. Some strands of thought are capable of supporting the utilitarian treatment of the issue to be found in the environmental economics literature, while others have more in common with the deep ecology perspective.

Economic analysis can go some way towards resolving this ambiguity by identifying the practical consequences of an environmentalist ethic. These may then be evaluated for their compatibility with the wider body of Christian social teaching. The immediate practical implication of environmentalism is the need to foster environmentally-sensitive technological

change. However (depending on what level of environmental degradation is deemed acceptable), limitations on the growth of population and per capita consumption will almost certainly be required as well. These may prove problematic from the point of view of social justice and reproductive ethics.

The strikingly different nature of the questions which motivate creation theology and environmental economics has been contrasted, and the problems associated with trying to move directly from one to another were identified. If there is to be constructive dialogue between creation theologians and environmental economists some intellectual middle ground needs to be indentified; a new set of questions which are somehow capable of bridging the gap between eschatology and sewage treatment. It has been suggested that this middle ground consists in working backwards from secular prescriptions to theological principles, rather than the other way around. Thus, an environmental economist's theological research agenda would probably include the following questions. What is the nature of the ethical demands placed by considerations of inter-generational equity ? To what extent is it legitimate to weigh-up environmental degradation against human well-being ? Does utilitarianism provide a legitimate philosophical basis for analysing environmental issues ? Should monetary values be used to measure the strength of altruistic preferences for environmental quality ? How are micro-level reproductive ethics affected by macro-level environmental constraints ?

It is to be hoped that this economic appraisal of green Christianity might engender a theological assessment of green economics.

Endnotes:

1. I am grateful to participants at the 1994 ACE Study Group meeting for their helpful remarks, and to Donald Hay and David Albert Jones O.P. for peer reviewing the paper. However, the responsibility for any remaining errors rests with me. Further comments are invited.

2. The argument is that, through its anthropocentric focus and its exhortations to procreate and subdue the earth, the first chapter of Genesis has historically provided a theological justification for the sacrifice of the natural world in the interests of human economic development. This aspect of the creation narrative will be discussed further below.

3. For a promising start, see the special edition of *Studies in Christian Ethics*, 7/1, which is devoted to the theme of "Ethics and Ecology".

4. One might question why an instrumental and transient view of the creation necessarily justifies its utilitarian exploitation.

5. For a much fuller discussion of the issues raised for Christianity by technological change, see Donald Hay's paper in this Issue.

6. The discussion of these criteria is deliberately postponed to the following section.

7. For an interesting discussion of this and other issues relating to the meaning of sustainability and its ethical justifications, see Palmer, 1994.

Appendix

Traditional economics

maximise $U = f[Q]$ subject to $Q = g[X, E]$

with $dU/dQ > 0$; $dQ/dX > 0$; $dQ/dE < 0$

Conventional environmental economics

maximise $U = f[Q, E]$ subject to $Q = g[X, E]$

with $dU/dQ > 0$; $dU/dE > 0$; $dQ/dX > 0$; $dQ/dE < 0$

Non-Use-Augmented Environmental Economics

maximise $U_i = f[Q_i, E_i, E_j]$ subject to $Q = f[X, E]$

with $dU_i / dQ_i > 0$; $dU_i / dE_i > 0$; $dU_i / dE_j > 0$; $dQ/dX>0$; $dQ/dE<0$

Sustainability-Augmented Environmental Economics

maximise $U_i = f[Q_i, E_i, E_j]$ subject to $Q = f[X,E]$, $E > E^*$

with $dU_i / dQ_i > 0$; $dU_i / dE_i > 0$; $dU_i / dE_j > 0$; $dQ/dX > 0$; $dQ/dE < 0$

Deep Ecology

$E > E^{**}$

where i self

j	others (in current or future generations)
U=f[.]	utility function
Q=g[.]	production function
Q	man-made goods and services
X	man-made factors of production
E	level of environmental quality
E^{*}	level of environmental quality required by sustainability constraint
E^{**}	level of environmental quality compatible with carrying capacity

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BANKING ON TECHNOLOGY? TECHNOLOGICAL CHANGE AND CHRISTIAN ETHICS FOR ECONOMIC LIFE

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1. Introduction

People are always more frightened by things that they do not fully understand. In this respect, technology is not well served by science fiction. The view that technology is "out of control", or possibly controlled by persons who are either mad or bad, is popularly held; though paradoxically it is often held by those who most enthusiastically embrace new technologies which increase their comforts, or provide them with new diversions in life. The truth, as so often, is rather more prosaic than fiction. In this paper, our objective in sections 2 and 3 is to expound what economists have discovered about the process of technological change and its contribution to economic growth in an economy such as the UK. An ethical evaluation then follows in section 4, in which we address some of the fears most often expressed about technological change: does technology determine how we live our lives; does technology destroy jobs; does technology destroy the environment? It will come as no surprise to Christians that our ethical conclusions are equivocal: technology, like so many other aspects of the human project or story, has the capacity for both good and ill. But the emphasis is not on technology *per se*, but on how we develop it and apply it. It is a distrust of human beings, rather than a distrust of technology, which accounts for our fears.

2. The Contribution of Technology to Economic Growth

[1] This is a lecture given at Heriot Watt University, Edinburgh, in February 1994, at the invitation of the Science, Religion and Technology Project of the Church of Scotland, on the theme of Technology and Belief.

2.1 Accounting for growth

Studies of economic growth in the advanced economies in the 1960s discovered that the growth of output at the macroeconomic level cannot be accounted for by the growth of capital and labour inputs alone (Denison (1967)). Even when adjustments were made for the quality of capital, and the increasing skills of the labour force, a sizeable unexplained residual remained, which was too large to be attributed either to errors in measurement or to defects in the methodology. This residual is total factor productivity growth (TFPG): measurements of TFPG for a number of OECD countries for three time periods beginning in the 1960s are given in Table 1.

Dubbed "the coefficient of ignorance" by some economists, the existence of TFPG was a challenge to empirically minded economists to develop explanations. The main explanation advanced in the 1960s was exogenous technical progress. The idea was that scientific advances, when translated into new technologies, generated improved methods of production (in the sense that they were more productive) and new products for consumers. For the most part, this was seen as an exogenous process because it was believed that scientific research was largely autonomous, so that the rate of new discoveries was outside the normal economic processes. Technical progress could be likened to "manna from heaven" as far as the productive sector was concerned. However, this explanation encountered an immediate difficulty which is illustrated by the data for 1960-73 in Table 1. If the sources of TFPG are largely exogenous, how can the very considerable international differences be accounted for? If TFPG depends on "manna from heaven", why is it so unevenly distributed? Two ancillary explanations were brought to bear. The first was the idea of "catching up": an economy which starts at a low technical level can, in principle, make additional gains, in terms of rates of change (TFP growth) as it rapidly assimilates existing technologies from more advanced economies. This explanation was advanced to explain the dramatic TFPG rates achieved by Japan in the 1960s, as they incorporated advanced technologies from the United States. The second explanation is that of changes in the productive structure of an economy. For example, an economy can grow faster if it has spare resources in a low productivity sector which it can transfer to a high productivity sector. This kind of explanation was advanced for France and

Italy in the 1960s, where traditional agriculture was being modernised releasing workers for higher productivity modern sectors, especially manufacturing. (The contrast was with the United Kingdom or the United States, where the reduction in the agricultural labour force had been completed before the Second World War).

The next challenge to the exogenous technical progress explanation came in the growth

Table 1

Total factor productivity growth in the business sector in selected OECD countries (% p.a.)

	1960-1973	1973-1979	1979-1988
United States	1.6	-0.4	0.4
Japan	6.0	1.5	2.0
Germany	2.6	1.7	0.7
France	4.0	1.7	1.6
Italy	4.6	2.2	1.0
United Kingdom	2.3	0.6	1.8
OECD economies	2.9	0.6	0.9

Source: OECD Technology/Economy Programme, *Technology and the Economy: the Key Relationships*, (Paris 1992), Table 25.

experience after 1973, when TFPG fell very sharply in all the major economies (see Table 1). The explanation advanced for the period 1973-79 is that oil price shocks had an adverse effect on economies that relied heavily on oil as an energy source and industrial material, especially the US. The high price of oil rendered a range of manufacturing processes uneconomic, no matter how technically advanced they were. So there was a reversion to less efficient techniques that used oil less intensively, as well as a general deflationary effect of lower common demand, leading both to lower TFPG and lower growth in general.

Plausible though this story is, it can scarcely explain the continuing low TFPG in the OECD economies in the 1980s, by which stage surely they should have absorbed the oil shocks fully. Solow (1989) has pointed to the paradox that TFPG should have remained low in a period when major changes in technology associated with computers and robotics generated considerable investment in new equipment in the 1980s. Various explanations have been adduced for the

paradox. One is that despite the amount of attention the media afforded to the computer and information technology revolutions, the scale of introduction of new techniques in production remains small relative to the existing stock of machines incorporating older technologies, but are still being operated because their fixed costs are "sunk". A second explanation also focusses on the speed at which new technologies may be introduced, but identifies the lack of apparently skilled labour as an obstacle to rapid adoption of advanced techniques. If this hypothesis is correct, then one might expect the associated TFPG to be spread out over a considerable period of learning. A third explanation is the problem of measuring TFPG in service sectors like finance, business services and distribution systems, where information technology has probably had the most significant impact.

2.2 New growth theories

The difficulties of explaining the historical record, if TFPG is attributed solely to exogenous technical progress, has prompted a search for alternative explanations. The unifying element in these explanations is a belief that technical progress is endogenous to the productive economy, and not simply taken from science and technology as "manna from heaven". Three strands of explanation have been offered, focussing respectively on capital accumulation, R and D spillovers and human capital. It is suggested that capital accumulation has two effects on productive potential: one is to increase the capital stock, the other is to incorporate the latest technology in the new capital. The faster an economy invests, the more rapid the diffusion of new techniques within the productive sector. Furthermore, technological advance is cumulative, each advance providing the platform for the next one: so an economy which invests more generates more opportunities for future advances. Scott (1992) has been one of the most persuasive exponents of this view. Indeed, he believes that this explanation can demonstrate that the TFPG approach is methodologically incorrect. A crucial aspect of that approach is the measurement of the growth in capital stock. The normal procedure in calculating the growth of capital is to take the gross value of the additions to capital stock, and to deduct an estimate of the depreciation of the existing capital to arrive at a new value. Scott argues that the deduction is inappropriate. Modern capital stock rarely wears out; it is simply made obsolescent by technical progress and changes in relative prices, and therefore has no economic value when it is scrapped. To deduct a notional

depreciation value from gross investment is a mistake, since it presumes that the depreciating capital stock has the same economic value as investment which incorporates the latest techniques. The appropriate measure of capital growth is therefore the ratio of *gross* investment to the value of the (depreciated) capital stock. Using Scott's method, the measured growth rates of capital stock are invariably much higher. With this adjustment, the unexplained residual in growth accounting is eliminated i.e. TFPG is approximately zero. One implication of Scott's approach is that one might expect increasing returns to investment at the aggregate level of the industry. However Oulton and O'Mahony's research (1994) on a sample of UK industries in the period 1968-76 can find no evidence for increasing returns.

The second explanation focusses on investment in R and D. Technical progress is by no means "manna from heaven": it has to be worked for by investment in scientific and technological research, both in the public sector and in the private sector. Private R and D has a direct effect via the incorporation of new technologies and the development of new products by individual firms. However, there are also indirect effects, "spillovers", on the productivity of other firms in the same or related markets. Firms can learn from each other. Cohen and Levinthal (1989) have modelled R and D as part of the learning process for the firm. They argue that "spillovers" are only available to firms that invest in R and D to enable them to understand and benefit from the advances of other firms. This proposition is given some empirical support in their own work: it could also explain Geroski's finding (1991) that the level of spillovers in a sector seems to be related to general R and D expenditure, and not to the imitation of specific innovations.

The third explanation emphasises the role of human capital. Skills and specific training improve the ability of the workforce to make use of technical knowledge to improve existing products and processes, and to innovate. This has been identified as a key factor in Japan's economic success: their workforce has been able to absorb Western technology, and to make substantial improvements upon it. Furthermore, a better trained labour force will also improve the productivity of other factors of production: for example, manufacturing equipment will be better utilised and better maintained if the operators really understand how it works. Assuming that this explanation is correct, the variations in economic performance can be traced to the quality of education and training in different economies. In this respect, the studies by Prais and his

collaborators (e.g. Prais and Wagner (1985), Prais (1987)) at the National Institute for Economic Research have indicated the weaknesses of the UK educational and training systems, compared to other OECD countries (except the United States), in ensuring that young people entering the workforce have acquired the skills they need.

3. The Microeconomics of R and D

The previous section has indicated that investment in R and D and a technically trained skilled labour force are now believed to be the prerequisites for growth in advanced economies. In this section, we explore further the endogeneity of R and D by examining in some detail what is known about the microeconomics of the production and utilisation of scientific and technical knowledge. The examination will highlight the key issues as perceived by economists, notably the nature of the incentives to R and D and problems of market failure.

3.1 The science and technology base

Fundamental to R and D activity is "common knowledge" in science and technology. The incentive to the production of common knowledge is the building of a reputation by the researcher, not financial reward. Reputations are based on the ability to attract research funds, and publication records. There are two models for the funding of this research activity. The first is the university research model, where public funds are made available to good research and researchers on the basis of peer review of the track record and publications of the researcher and the scientific value of the research. Such systems are in place in all the advanced OECD economies, though in recent years the emphasis has shifted somewhat from "science for science's sake" to a requirement that the research should be more responsive to industrial and other users. The second model is that of a government funded research establishment, with research programmes that are more focussed or "vision-directed". NASA in the US is a spectacular example of the model; many other lesser institutions exist in all the advanced economies, often linked to defence or the nuclear industry. It is an interesting fact that funding for both these models has generally diminished in recent years as a percentage of domestic R and D in OECD economies. Two explanations have been adduced for this trend. The first is that basic science and technology

have always been expensive, and have tended to become more so, as the sophistication of the equipment and the experiments scientists wish to perform increase. Most governments have also noted that scientific research is a worldwide phenomenon: this raises the possibility that even if science spending is cut in an economy, the private sector will be able to free ride on science and technology produced overseas. The second explanation is that it reflects an increased willingness of the private sector to pay for basic research, perhaps to give it better access to, and understanding of, basic research done elsewhere. But private sector funding of basic research has not been sufficient to make up for the reductions in government funding. There are further reasons for being concerned about reductions in government funded basic research. One is that the private sector, quite naturally, is not so willing to permit the researchers to publish the results of their research: there is some evidence that this is already happening in the United States. In the long run this is likely to generate duplication of research. It also means that research is increasingly dominated by commercial considerations, and not by the pursuit of knowledge for its own sake. To give one example, it is very unlikely that much of the early basic research on lasers would have been undertaken if commercial considerations had been to the fore, since lasers were for a long time regarded as no more than an interesting toy. A further problem in relying on the private sector for basic research is that very few companies will be able to afford wide-ranging basic research programmes. Small and medium sized firms will be particularly disadvantaged in this respect. Finally, there is a continuing need to train scientists and technologists in research techniques at the frontiers of knowledge. That training is best achieved by being involved in research at a doctoral or post-doctoral level. It is unlikely that companies will be willing to incur those training costs on a sufficient scale. There are therefore good arguments for a continuing major commitment by government to basic research in universities and research institutes.

3.2 Private sector R and D : invention and innovation

In contrast with basic science, where the incentives for the researcher are publication and reputation, private sector R and D is motivated by the financial returns to invention and innovation. Traditionally, private R and D has been seen as consisting of a linear sequence: research, development, production and marketing. Studies of organisational behaviour in R and D have suggested that an interactive model would be more appropriate. The process often begins with the

perception of a market opportunity or of scope for a process innovation. This is followed up by a search for a workable design which will involve interaction between research and all stages of development, production and marketing, including reference back to the science base. Technical solutions, it has been noted, are often inhibited by the lack of basic scientific knowledge: OECD (1992) notes the examples of alloys, ceramic materials and computer architecture. The suggestion is that the organisation of R and D in the United States and Europe has often been based on the linear model, resulting in R and D departments that are remote from the production and marketing activities of the firm. Japan, by contrast, has organised on the basis of the interactive model with the result that R and D has been generally more productive.

Economic analysis has generally distinguished between R and D as an activity of firms, and the returns to innovation. Empirical studies of R and D activity have focussed on the size of firms, and on technological opportunity. Private sector R and D, of a formal kind, is concentrated in large firms, and is financed by retained profits, outside finance not being generally available for R and D projects. A priori, the expectation is that there are economies of scale in R and D. Large operations can hire better scientists and technologists, can economise in the use of specialised equipment, can set teams to work in parallel on urgent projects, and can spread risk by holding a portfolio of projects. (The high "success" rates of projects, typical of large R and D departments, suggests that risk is reduced by choice of projects and by careful management.) But the evidence for economies of scale is hard to come by. Evidence does suggest, however, that a given size of R and D effort is more successful in a small or medium sized firm, than in a large firm. In an exceptionally interesting study of major innovations in the UK, Pavitt and Patel (1988) found that about one third of these innovations in the period 1970-9 came from firms with less than 1000 employees, but these firms only accounted for 3.3% of the formal R and D expenditure! (see Table 2). The same study showed the significance of technological opportunity, with mechanical engineering, electrical engineering and chemicals accounting for more than half the innovations by firms with more than 1000 employees. Interestingly, for smaller firms, instruments replaced chemicals in the list. It is evident that the opportunities created by basic science and technology are important in stimulating private R and D activity.

The source of returns to R and D is priority in innovation. A new product creates a

potential for monopoly profit, at least for a while: a new process gives the firm a competitive advantage relative to its rivals. The source of advantage over imitators may be the "learning curve" rather than any protection from imitation afforded by intellectual property rights such as patents. In so far as such advantages are substantial, they may lead to "patent races" (or simply

Table 2

Comparison of level and composition of technological activities in British innovating firms

Firms size (number of employees)	1-999	1,000-9,999	10,000+
percentage distribution of business enterprise R & D expenditure (1975)[1]	3.3	16.4	80.3
% distribution of significant innovations (1970-9)[2]	34.9	18.1	47.1
Top three sources of in-house knowledge for the innovations (percentage of total)[2,3]	design(27.5) development(27.5) operating-staff(15.7)	development(42.1) design(30.3) research(14.5)	development(40.3) research(36.3) design(17.0)
Top three sectors of principal production of innovating firms (percentage of total)[2,4]	ME(40.1) IN(11.7) EE(10.7)	ME(28.9) CH(15.0) EE(13.7)	EE(29.9) CH(14.1) ME(11.8)

1 Source: Business Monitor MO14 (1975).

2 Source: SPRU Innovation Survey. For details, see Townsend et al. (1981).

3 Identified sources are research, development, design, production engineering, operating staff, other.

4 CH is chemicals, EE is electrical engineering, IN is instruments, and ME is mechanical engineering.

Reproduced from Pavitt and Patel (1988)

races to innovate, where a patent system does not exist or is ineffective), with the possibilities of duplication of research effort, and innovation occurring too early from the point of view of social cost-benefit analysis.

There is evidence to show that there are substantial spillovers in R and D, suggesting that protection of innovations may be quite weak. For examples, Bernstein and Nadiri (1989) in a

study of cost-reducing R and D in US chemical, petroleum refining, machinery and instrument engineering sectors found that firms benefitted as much from rivals' R and D as they did from their own! Another study by Jaffe (1986) also found that rivals' R and D expenditure had significant positive effects on a firm's rate of patenting of innovations. Since spillovers are obviously a disincentive to do private R and D, it is odd that they seem to be largest in the most R and D intensive sectors: however the explanation may be that suggested by Cohen and Levinthal (1989), namely that a firm needs to be doing R and D in order to benefit from potential spillovers from its rivals.

One particular form that spillovers may take is imitation by a rival. Mansfield (1977) looked at 48 major innovations in 4 US sectors, analysing the process of imitation. On average he found that the cost of imitation was about 70% of the cost of innovation, and that the time taken was also about 70% of the innovator's R and D period. These figures were increased by about 10-11% where the innovation had been patented: patenting only increased the imitation lag by a few months. Over 60% of the innovations had been fully imitated within four years of innovation. Information leakages between firms were found to be such that on average it only took 12-18 months for news about a major product or process development programme to leak out to rivals. So the imitation process by no means had to wait until the innovator had completed its R and D programme. From the point of view of private incentives to do R and D, these findings are not encouraging: it seems that the period over which the innovator is able to enjoy the sole fruits of his R and D is likely to be short. However, for growth in the economy as a whole, rapid diffusion of innovations is good news. This difference between private and public interest is an important issue for public policy, to which we now turn.

3.3 Public policy issues in R and D

R and D has come to be seen as an essential ingredient in economic success, with a key role being accorded to private R and D. There is a widespread belief, for example, that Britain does too little R and D for the long term health of the UK economy (Buxton et al (1994) Part III). A number of general points can be made about why private R and D may be too little for the public good. First, there is the fear that because R and D is risky, risk averse managements may make too

little provision for it, especially if the stock market is thought to be "short-termist", discounting long term returns to innovation too much. Second, firms naturally do not take into account the spillovers created by their R and D in deciding how much to spend: yet those spillovers are clearly a public benefit. Third, rivalry between firms may lead to duplication in R and D, or to speeding up R and D in order to win a patent race. In principle both of these could involve waste of specialised R and D resources. Fourth, as already noted, rapid imitation and diffusion of an innovation is a disincentive to private R and D, but a public good. It would be nice to be able both to preserve the private incentive, and to ensure rapid diffusion.

Proposed solutions for these problems fall into three broad categories, all of which have been utilised in the OECD economies generally. In principle, subsidies could solve the problems that private R and D cannot appropriate returns due to spillovers and imitation and that R and D may be too risky for the private sector. Either firms would receive R and D subsidies (perhaps in the form of tax breaks), or successful innovators could be given immediate cash rewards for innovations, so long as these innovations were made public with the freedom to imitate. In practice, there are serious difficulties of implementation: how are the projects to receive subsidies to be chosen, and how is the level of subsidies/rewards to be decided? Moreover, there is some evidence (King and Robson (1992)) which suggests that R and D subsidies do nothing to increase total R and D spending by firms. They just reduce their own allocation of funds!

The second solution is the establishment of a system of *intellectual property rights*, such as patents and copyright. If the system can be made to work, the patent holder has a legally protected monopoly of the innovation for the prescribed period, which should be a sufficient incentive. Once that period is up, then the innovation may be copied freely. Once again, there are serious potential difficulties: what should the rules be about what kinds of information may be patented? How long should the patent give protection to the innovator? What should be allowed as the scope of a patent (for example, should a drug patent be allowed to include a range of substances, or should it be restricted to the actual specific substance used for therapeutic purposes)? How can patents be enforced (especially internationally)?

A third solution to the problem is permitting firms to establish *research joint ventures*.

This prevents the potential waste of competitive R and D ventures, internalises any externalities or spillovers and gives the participants equal access to any innovation which results. The disadvantages are that incentives are less, since there is no monopoly power created by the innovation, and that the joint R and D facility will not be in close contact with the production and marketing operations of the firms involved, so that the interactive aspect, described above, is lost. This separation of research and exploitation of innovations is particularly emphasised by EU competition law. Article 85(3) provides for a block exemption for research agreements between firms, but expressly forbids cooperation in marketing. In effect, the research and development has to be conducted at arms length from the participating firms.

4. Ethical Considerations

4.1 The creation of wealth

The consensus of the economics profession is that technological change is an important contributor to the growth of the economy. As we saw in section 2, technological change, linked to the creation of a skilled labour force, is seen as the key to understanding total factor productivity growth, which in turn has been a major contribution to economic growth in the OECD countries. The purpose of growth, within the framework of economics, is to increase incomes per capita. The benefit is seen to be giving people more of "what they want", rather than any pretence that material wellbeing is *the* secret of human happiness.

Although the ethical framework is very different, this assessment of growth is (or can be made to be) consonant with Christian understanding of the human race, and its place and role in the natural order, as set out in Genesis 1 and 2. First, we note that the human race is created in God's image (1:26,27): at least part of the meaning of that description is that humanity is God's vicegerent in respect of the created order. The special position of the human race is explained by the repetition of "created" in 1:27. Second, the human race is given dominion over the created order (1:28,29). As Genesis 2 makes clear, we are given dominion in order to provide for our needs for food and clothing. But we are stewards, not owners, with a responsibility to care for the environment, and by no means to destroy what belongs ultimately to God. Third, the means by

which we exercise our stewardship is work (2:15), in order to make use of the abundance of the natural order. Indeed, the biblical view is that work is integral to human nature, as the means by which we exercise our stewardship. Put into this theological context, the scientific enterprise and the creation of new technologies are to be welcomed as part of our continuing exercise of stewardship, to which we were appointed by God. The creation of wealth is in no way inconsistent with Christian ethics.

But there is no doubt that for many, Christian and non-Christian alike, technology and technical change is regarded with suspicion, if not fear. They suspect that technology determines how we live our lives, that technological change destroys jobs, and that technology has contributed substantially to the deterioration of the environment. We need to consider these in turn.

4.2 Does technology determine how we live our lives?

Is technology "out of control"? One response is to note that we get what we ask for: no firm is going to spend on R and D unless it believes that there is a market for its product. Technology can scarcely be blamed for human materialism and greed, even if that materialism is successfully manipulated by firms in order to "create" markets for new products. But that said, there are some concerns:

(i) There is a possibility that some products, which would be useful, are suppressed. One evidence of this is the existence of patent "thickets". For example, it is reported that the Xerox Company in the US held almost 1000 patents, but 60-70% of these were not used. Some had been acquired by takeover of rivals; others, it was alleged, were registered to preempt potential rivals. The defence of "thickets" is that they occur where the patent rules require the patent to be narrowly defined, so that only by registering a range of patents can an innovation be afforded any real protection from imitators. It is evident that this is an important issue in the design of patent rules, and also for competition policy, if there is a danger that patents are being used to stifle competition.

(ii) Products may be less useful than they might be. One example is "lock in" effects, of

which the QWERTY keyboard is the most famous example, Despite the fact that this arrangement of keys is far from optimal (little fingers are called upon to operate frequently used keys, for example), the design which goes back to the invention of typewriters has never been changed. A more technical example is "network externalities", where different types of equipment conform to a common standard and can therefore be used together in a single system. A good example is computing equipment. The difficulty here is that competition between suppliers may result in alternative systems which are (often deliberately) made incompatible. The firms gain from the lock in effect on their customers, who will find it difficult to switch to another supplier. Again, this is an issue which has exercised the competition authorities considerably.

(iii) Some products may have undesirable side effects (negative externalities in consumption). Each person will have their own list of pet hates: noisy lawnmowers, cars in city centres, mobile phones on public transport, smokers anywhere, ghetto blasters, hi fi equipment.... But the problem here is not technology, but rather the selfishness and thoughtlessness of those who use these things.

(iv) Galbraith (1972) advanced the thesis that technology gives too much power to technology intensive firms, which are able to dominate markets and to dictate to consumers. However this neglects the evidence for creative destruction as new technologies replace old. A firm can only retain market power if it is able to continue to innovate in ways that meet the requirements of markets, a lesson which IBM has had to learn the hard way.

4.3 Does technology destroy jobs?

In popular thinking the idea that technology destroys jobs is regarded as self-evidently true. Given that Christian ethics for economic life lay a considerable stress on work as human vocation, both for its own sake and to provide for our needs, technological unemployment is a serious matter. However, if we look again at Table 1 a paradox emerges. The period of high total factor productivity growth in the OECD countries, 1960-73, corresponded with the period of the *lowest* recorded unemployment rates: by contrast in the period 1973-88, TFPG was low, but unemployment was at record post-war levels! In cross-country comparisons the same paradox

emerges: Japan has the highest TFPG, but also the lowest unemployment rates in OECD economies. If we consider a longer historical record, 200 years or more going back to the beginning of the Industrial Revolution, we note that a period of continuous technological change has not resulted generally in the emergence of mass unemployment: there have been periods of high unemployment (as now, for example), but no secular increase. How has this come about? The answer seems to be that "technical progress" raises incomes, leading to higher spending, thus creating demand for more goods: so long as this "virtuous circle" can be maintained, then there is no need for technical change to result in unemployment in the long run. In the short run, though, the story can be different. Technical change is often associated with major sectoral shifts, with employment falling in one sector, but growing in another sector. The difficulty is that those displaced from one sector may not have the skills to be employed in the other, or they may live in a different region. So high sectoral or regional unemployment may emerge and persist for many years. This suggests that policy makers should be alert to the costs of adjustment to technical change which may fall quite disproportionately on small groups of workers. Before leaving this topic, it is worth noting that technology has done much to improve the quality of life and the environment *at work*.

4.4 Does technology destroy the environment?

Few people would now deny that there is an ecological crisis - CO_2 and other greenhouse gases, environmental degradation, pollution of rivers and oceans - and that the misuse of technology must share some of the blame for what has happened. One problem is that we are not very good at predicting the impact of our activities on the environment. CFCs are a good example of what can go wrong. In fact, they were thoroughly tested and declared to have no harmful effects on living matter: it was only later that the impact on the ozone layer was discovered, a possibility that no-one had thought of. The second problem is the scale of economic activity. The gross world product has grown by a factor of about 20 in the last 100 years, as the population has tripled. It is tempting to blame technology for all this, as a "force" outside human control: but, of course, that is an evasion of human responsibility. We create technology and we put it to work: we need to be more responsible for what we do. That should include taking more effective action to control pollution. Taxes are probably more effective than controls, since they create powerful

financial incentives to seek for less polluting technologies. We also need to do more to control population growth, but that issue lies beyond the scope of this paper.

4.5 Babel

To this point, we have aired a number of issues arising from technological change and have shown them to give rise to genuine concerns. However, we have not begun to touch on the deeper concerns expressed by Christian writers as diverse as Schumacher (1973), Goudzwaard (1979) and Ellul (1964), for whom the question of technology is not just an analysis of particular problems, but something which affects our whole culture and the way we live and work. The story of Babel may help us to appreciate some of these deeper concerns. The story appears in Genesis 11. Much has happened since Genesis 1 and 2. The human race has rebelled against God and Fallen. The broken relationship with God is symbolised by the expulsion from Eden. Cain becomes a wanderer and a fugitive on earth, rootless and lost, the archetype of fallen humanity. So, in Genesis 11, a group of wanderers are seeking security. They come together (vv 3,4), and resolve on a great project, a prodigious feat of engineering. They plan to build not just a city to dwell in, but a tower with its top in the heavens, a tower to make a name for themselves, a tower to dominate and control those around. This project provokes a response from God. The Creator comes to see what his creatures have planned and are in the process of carrying out (v5). He notes the danger of the enterprise for humanity, for nothing they propose to do will be impossible for them (v6). So God acts, not by destroying the tower, but by stimulating such confusion that they desist from their grand project (v7).

The relevance of this story to the theme of this paper needs little underlining. First, it reminds us that while the human race cut loose from God retains dominion over the created order, exploitation and destruction are likely to characterise economic activity rather than the concept of stewardship in Genesis 1 and 2. Second, without the security that comes from relationship with God, the human race will seek its security in its own projects, of which technology is a significant part. Technology is the means by which we seek to tame and control our lives and our future. Third, reliance on technology and material things becomes built into the very roots of our culture, as Ellul has so sharply observed. The economist's vision of technology focusses on the productive side of a society, and neglects spiritual or cultural aspects entirely.

5. Conclusions

In approaching the evaluation of technological change, this paper has sought to explain its role in the growth and development of an economy like the UK. If the studies of total factor productivity growth are to be believed, it has been a major contributor to the growth of the advanced economies in the post War era. However, the variation in its contribution across different economies, and in a single economy over time, suggests very strongly that it is not "manna from heaven", but rather the result of resources devoted to R and D and to training. For this reason, the focus of analysis has become more microeconomic in the recent literature. The study of the private incentives for R and D has in turn indicated scope for public policy interventions to correct what are perceived to be inadequate or inappropriate incentives. All this analysis is predicated on the assumption that technological change is, at least in principle, a good thing ("progress").

In a Christian ethical perspective, technological change can be evaluated positively as part of our stewardship of the natural order. In addition it can be shown that at least some of the frequently expressed ethical concerns are based on a failure to understand the economic processes at work. The fear that technology must destroy jobs is a case in point. However there remains an entirely proper set of ethical concerns which are neatly summarized by the story of Babel: technology gives the human race greater scope not only for good but also for evil, and we need to be constantly alert for instances of the latter. But the blame lies with ourselves, not with technology.

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REVIEW: God and the Marketplace: Essays on the Morality of Wealth Creation, Jon Davies (ed.), Institute of Economic Affairs Health and Welfare Unit, Choice in Welfare, No. 14 (1993), 145pp (£4.90)

Andrew Henley, Department of Economics, University of Kent at Canterbury.

Much to its credit the Institute of Economic Affairs has sponsored the publication of a number of volumes on the moral basis (or otherwise) of economics. In the last issue of the ACE Journal (No. 17), Esmond Birnie gave us an extremely thorough and perceptive review of John Gray's IEA monograph on the moral foundations of markets. "God and the Marketplace" is a collection of papers taken from an IEA sponsored conference held in Newcastle in July 1992. A number of the papers take their starting point from Michael Novak's "Spirit of Democratic Capitalism" which was also introduced to an English readership by the IEA in 1991. Indeed Michael Novak was the key guest at the Newcastle conference and this volume contains a short paper by him, which provides a good summary and development of his earlier more extensive work. The other authors range widely across the theological perspective. However none of the authors might be termed praticising economists first and foremost; one (Geoff Moore) in a member of Newcastle Business School and an Anglican lay reader, and another (Vin Arthey) is a producer of religious TV programmes and contributes a short survey of this form of programming at the very end of the book.

In the past I have found much of what the IEA has published to be too thinly disguised apologetic for untrammelled free-market capitalism. I was therefore very encouraged that this volume is very balanced. Cautionary notes are sounded, *inter alia*, by Simon Robinson in a paper which compares and contrasts the concept of freedom in Novak and Tawney, by Richard Roberts in a paper which offers a critical survey of the Novak book, and by John Kennedy in a paper which constrasts the Anglo-Saxon neo-liberal viewpoint with concepts of the "enabling" state to be found in the continental European view of the social market economy.

In many respects the papers in the collection are very diverse. The editor has attempted to divide them into two halves, section 1 entitled "A Theology for Capitalism" and section 2 entitled "Capitalism with a Theology". These headings were rather grand and my optimism gleaned from the contents page was rather tempered as I read on. To summarise the book is clearly a difficult task and the editor chooses to avoid the risk of misrepresenting anyone by not attempting to write a conclusion to the collection. By the same token the introduction is at times a bit anodyne. For example, Jon Davies points to a symbiotic relationship between God and the marketplace in that "religion" provides a place of rest and sense of perspective from the hurly-burly of the market. In fact my main criticism of the collection is that much of the discussion lacks an explicit theological basis, and what is implicit is drawn rather selectively from many sources. Novak's own paper entitled "Eight Arguments about the Morality of the Marketplace" draws these arguments largely from secondary sources such as recent work by the likes of John Gray and Richard Harries and from John Paul II's encylical "Rerum Novarum". How does Novak interpret the bibical material, particularly that from the Old Testament? John Jukes (Roman Catholic Bishop of Southwark) accords the papal encyclicals and New Testament teaching with rather more equal and pre-eminent weight, but the Old Testament is largely side-stepped as being "complex".

If the Biblical theology in section 1 is for my taste a bit selective, then, with the exception of Geoff Moore's paper, section 2 is entirely devoid of hard economic analysis. In fact section 2 is really more about how the businessman might apply Christian moral teaching to the cut-throat competitive environment of the "real world". Here we are entering the vast and muddy waters of of the study of business ethics and it would be difficult for any author to do justice in a few short pages. Geoff Moore and James Francis draw on some excellent examples from North East England; the former examining Traidcraft plc and Shared Interest Society Ltd, the latter drawing on personal experience as the Bishop of Durham's advisor on non-stipendiary ministry.

Despite these reservations, this is book to be welcomed. It is easily accessible to a wide readership and most will find something in it to provoke thought, even if they are not

always in agreement with the authors. Finally let's encourage the "new" IEA to continue to stimulate debate and discussion between fellow-travellers and sceptics within its own pages, particularly on this important subject.