Evolutionary and institutional economics, the dynamics of economic development, and the design of packages of measures to achieve environmental outcomes

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Executive Summary

There are a number of factors that lead managers, firms and organisations to behave differently from in the simplified view of the world which economic modelling of necessity inhabits. These factors explain why, given any change in taxation or other measures, firms in the same industries facing apparently similar incentives and constraints will often react in different ways from each other – with some not reacting at all. These are also, therefore, the factors on which policy makers need to focus to actually alter such behaviour.

To focus discussion, we have grouped these various factors under three categories:

First, the way corporate behaviour is analysed in a management or business school differs fundamentally from the way it tends to be treated in an economics department. Within economics, decisions on pricing and output are determined by costs, demand levels and market structure. Indeed, the term 'decisions' implies a degree of discretion that is not normally assumed to exist. Within management and business schools on the other hand, the focus is precisely on how managerial discretion will be utilised, with what outcomes, given of course the constraints faced; although even here, constraints are rarely viewed as exogenously given as they often are within economic modelling.

Second, the nature of rationality. Managers and firms do not necessarily operate as would be predicted in the profit-maximising model of rationality. There are a number of reasons why this is the case, related to the cost, availability and reliability of information; the ability to process any information that is available (and considered to be reliable); and the ways in which individuals co-operate during the production process.

Third, the behaviour of firms will not only differ from firm to firm, even where there appears to be no difference in the exogenously 'given' determining factors, but will also often differ from country to country, and over time. Thus, for example, the pattern and behaviour of innovation and technological advance between countries has long been argued to depend in part at least on the system of innovation within the respective countries. If the aim is to shift technological development onto a more environmentally sustainable trajectory, we need to look not only at the degree of managerial discretion, and the role that rationality plays in this, but also at the wider systems within which firms are operating.

The paper considers how these different approaches to economic theorising might shed light on developments within the areas of agriculture and waste management. The paper then pulls together the policy implications, and considers what further work might take this discussion forward. Five specific policy actions are advocated:

1: Internalise the free-rider problem that characterises business investment in training, either by subsidising education and training in environmental technologies and management or by encouraging firms to make joint investments in training programmes.

2: Change the corporate governance structure of firms to increase the influence of stakeholders taking a long-term perspective, such as employees and local communities vis-à-vis shareholders that favour short-run profits. This could be promoted by:

i. making environmental reporting for large organisations mandatory; and

ii. giving independent directors responsibility for company policy on environmental matters and sustainable development.

3: Create a cluster of firms in the industry pursuing environmentally friendly production strategies to kick-start diffusion throughout the industry, via:

i targeting existing firms in the industry to encourage them to switch to environmentally friendly production strategies; and/or

ii introducing new firms, perhaps with mutual or community ownership, with environmental sustainability in their Memorandum & Articles of Association.

4: Establish a training programme in strategic environmental management.

5: Engender cultural change and set new norms and standards in environmental management and corporate social responsibility.

1. Introduction

Government throughout the world have for some time now been attempting to influence the behaviour of firms to make them act in more environmentally sustainable ways. However, the reaction of firms to policy initiatives has not always been as expected, given the economic incentives that those firms face, and the changes in those incentives that governments have engineered in order to alter corporate behaviour. This is perhaps most clearly illustrated where there are a large number of firms that face seemingly similar constraints and market opportunities, but that then react differently to a change in government policy, whether affecting taxation or some other instrument. If we could understand why the reaction of firms to policy initiatives are not as expected, given the economic incentives, this would clearly be helpful in informing policy design.

This paper therefore considers the various reasons why economic 'agents' may not react to price signals, or other incentives, as might be expected. Some of the relevant factors have been discussed within the mainstream economics literature for decades – with John Maynard Keynes, for example, stressing the importance of risk and uncertainty, herd activity, and institutional factors in affecting economic decisions. More recent developments within economics have thrown light on the complex nature of economic rationality, through game theory and behavioural economics. The 'systems of innovation' literature has pointed to the importance of national, regional and industrial factors, analysing 'lock in' and other 'deviations' from pure price-signal behaviour. And evolutionary and institutional economics has long stressed the importance of routines, tacit knowledge and culture in making economic change a complex process.[4]

The aim of the paper is to consider the relevance of these various literatures for analysing economic change processes, and in particular, for the design of environmental policy.

2. Corporate behaviour and managerial discretion

The business management literature takes for granted that firms are complex organisms in which management has considerable discretionary authority over the firm's strategy and policies:

> 'It is presumed that firms in roughly comparable situations often will differ in what they do, and that these differences will matter in terms of how they do it. The question of what makes for good policies is what the business management field is all about.
>
> 'In contrast, in most of economics, firms are treated as simple entities… management chooses the policies that will 'maximize' firm profits. The 'question'

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4 For a discussion of the literature on evolutionary and institutional economics, see respectively Mitchell (2001) and Hodgson (2001).

> that is at the centre of concern in the business management field is assumed trivial to answer. And since it is, all firms in the same economic context are presumed to have the same policies – those that are best in that context – and to do the same thing.' (Nelson, 1991a, p. 347)

Most firms are not simple 'price takers', as in the world of perfect competition, but, in the language of neoclassical market structures, operate in what would be more like oligopolistic markets. Such firms are not monopolies – they do face competitors. But they only face a limited number of such competitors.[5] And crucially, the number of competitors is such as to leave them some scope and leeway for considering what prices to charge for their goods and services – rather than being forced to accept the prices determined by a Walrasian general equilibrium outcome. Pricing thus becomes a conscious act – influenced, certainly, by the expected reaction of rival firms to any change that the firm might make to its pricing strategy. But nevertheless, the pricing strategy becomes one part of the firm's overall strategy, along with decisions concerning output levels, investment, technologies, marketing (aimed at shaping preferences) and so forth. It is within these decision making processes and strategies that environmental policy needs to impact.

As well as the idea of perfect competition generally being misleading, so is the neoclassical assumption that firms price according to a rising marginal cost of production. The assumption of 'marginalism' – with economic actors making decisions at the margin, on the basis of rising marginal cost curves – was challenged some time ago by Sraffa (1926, p. 543):

> 'The chief obstacle against which they have to contend when they want gradually to increase their production does not lie in the cost of production – which, indeed, generally favours them in that direction – but in the difficulty of selling the larger output of goods…'

Similarly, Kaldor (1972) argued that 'at the empirical level, nobody doubts that in any economic activity which involves the processing or transformation of basic materials – in other words, in industry – increasing returns dominate the picture'.

Rather, firms tend to price according to a mark-up over normal operating costs.[6] The resulting price will thus be above the long-run marginal cost; this makes the perfect competition required by the theory of competitive equilibrium impossible. Hence while it is argued above that many markets and industries will be oligopolistic, the fact that prices are above marginal cost means that the alternative to oligopoly cannot in any case be a Walrasian competitive equilibrium. Thus Hicks (1939) admitted that 'unless we can suppose that marginal costs generally increase with output at the point of equilibrium… the basis on which economic laws can be constructed is shorn away.'[7]

Policy decisions based on an assumption of increasing costs – which allows output and price levels to be calculated at the margin – will therefore be based on a false premise. If, as is likely, costs are not rising, there will be no intersection of the cost and revenue curves, hence no deterministic outcome for output and price levels. Rather, output will be determined by demand and the growth of the market. And prices will be determined by a mark up over

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[5] In a survey of almost 1000 companies in 1995, nearly two thirds had fewer than ten serious competitors; see Kitson & Michie, 2000, p. 146 for further detail and discussion. This paper also discusses the relationship between competition and co-operation, pointing to the importance of productive co-operation between firms, which is not necessarily anti-competitive collusion.

[6] For an empirical investigation of this, see Coutts *et al.* (1978).

[7] This is quoted by Thirlwall (1987), which also discusses the various objections made by Lord Kaldor to neoclassical equilibrium theory.

normal operating costs. Increasing the degree of competition to the market may or may not bring more benefits than costs. But it will not create a world in which marginal cost curves slope upwards. Policy based on such assumptions will not, therefore, become any more appropriate just because the degree of competition increases.

In terms of the macro economy (as opposed to the level of individual firms), an important concept is that of cumulative causation and dynamic economies of scale. Kaldor (1972) argued that neoclassical economics focuses attention on the '*allocative* functions of markets to the exclusion of their *creative* functions – as an instrument for transmitting impulses to economic change'.[8] It is precisely the discretion that managers and firms do have that gives them the ability to take decisions to get ahead of the game, to adopt new processes and develop new markets. With increasing returns to scale, the tendency will always be for firms that manage to expand their output to thereby gain a competitive advantage, turning competitive markets into oligopolistic ones.

This area of discretion, and the ability to create new markets, relates to another key difference between mainstream neoclassical economics on the one hand, and an institutional or evolutionary approach on the other, namely, the role of tastes and preferences. Are preferences and tastes given (exogenous) or amenable to change (endogenous)? In mainstream neoclassical economics, tastes and preferences are generally taken as given. Institutional economics, on the other hand, will see them as being heavily influenced by institutional factors, pointing to the importance of routines, conventions and culture. Evolutionary economics in addition takes all these factors as evolving over time. Tastes and preferences cannot be assumed to be constant. But neither are they unimportant or trivial; they are part of the inherited institutional and cultural context that contributes to cumulative causation and path dependency in economic processes.[9]

In terms of creating more environmentally sustainable behaviour amongst consumers and producers, changing these routines, conventions and culture are obviously key. There are a number of ways in which public policy can attempt this – and to some extent already is doing so. First, culture can be influenced by general awareness efforts, including through education and information. Second, firms may be unaware of the alternative routines available, and of the economics of switching to these. Such alternatives could be uncovered and illustrated through 'environmental audit' work in companies, where alternatives are identified, costed and set out. Third, as discussed in the following section, if the behaviour of just a small group of firms can be effected, then this can have wider impacts through its demonstration effect, illustrating that alternative routines and conventions are not only possible, but profitable.

3. Economic rationality, business strategy and public policy

There is a further set of reasons to be cautious of designing policy on the assumption that agents will respond as rational profit maximisers. There is a large literature on rationality, part of which questions the degree to which individual actors are motivated by such calculations. There are also questions regarding the degree of knowledge that actors will have and their ability to use such knowledge to compute the necessary actions to maximise profits or utility. Hence Herb Simon's concept of 'satisficing' rather than maximising (see for example Simon, 1959). All this, much of which is contained within the mainstream literature, points to the need to act on the factors that actually influence decision making – that is, those

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8 Emphasis in the original.

9 See Hodgson (2003) who points out that preferences and values are changed through learning, yet for much of mainstream economics, there is no role for 'persuaders', only for transmitters of information (p. 160).

factors that lead agents to act other than as profit or utility maximisers. The implication is that we need to act on a range of different factors to achieve changes in behaviour.

3.1 'Market-based', 'command-and-control' and 'non-mandatory' instruments

The literature on environmental policy has traditionally distinguished two types of policy instrument: market-based instruments and command-and-control instruments (Jaffe, Newell and Stavins, 2001). The theoretical foundation for market-based approaches to policy instruments is grounded in the identification of market failures arising from externalities and public goods. Market-based instruments, such as taxes and subsidies attempt to correct for market failures by changing the private incentives faced by firms and individuals. The effectiveness of these instruments depends not just on imposing the right taxes and subsidies in terms of qualitative direction, but also on setting the taxes at the right quantitative level. Given that there are discontinuities in payoff structures, this requires detailed knowledge of the 'tipping points' that make environmentally friendly strategies more profitable than free-riding strategies.

In contrast, command-and-control instruments work directly by regulating strategic options. The success of these types of policies depends crucially on the degree of compliance with the regulations and on the detection and punishment of non-compliance. A number of structural, institutional and cultural factors are important in determining how easy it is to detect and punish non-compliance, and perhaps, more importantly, how likely it is that firms will choose strategies of non-compliance in the first place. For example, the structure of an industry, as measured by the number and size distribution of firms will determine how difficult it is to monitor compliance. As Vogel and Kessler (1998) point out,

> 'In Europe, the difficulty of administering a uniform system of waste disposal has been increased significantly by the large disparities in the institutional structures underlying most national waste management programs, ranging from a few large, centralized public companies in Denmark, to dozens of small private firms in Great Britain (Brand 1993: 242-244). Not surprisingly the latter have proven much more difficult to monitor.' Vogel and Kessler (1998, p. 25)

Institutional factors, such as the frequency of use of legal action by residents living next to land fill sites and the decisions of the courts regarding the imposition and extent of penalties under 'nuisance laws' also shape the strategies used by waste disposal firms (Tromans, 2002). Plainly the use of litigation differs across countries, regions and type of actor (firm, local authority, individual) but as Tromans (2002) and Kellet (2002) point out, both the structure and use of the legal system are important in shaping environmental outcomes.

It is important to recognise that the extent of non-compliance is determined not only by the probability of detection and the extent of penalties but also by cultural factors, including firms' attitudes to adopting environmentally damaging or environmentally friendly strategies. Under the standard economic assumption of instrumentally rational behaviour,[10] this factor is ruled out since firms do not care about their actions other than in terms of the payoffs associated with them. However, as North pointed out in his Nobel prize winning work, it is impossible to understand major changes in our system of production without taking into account cultural factors (see North, 1990). The example that he famously cited was the shift from a slave based system of agricultural production in the US to a paid system. North argued that this socio-economic shift cannot be explained purely in terms of the payoffs from one system compared to another, as the slave system had lower costs and higher profits. Other

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[10] The different types of rationality are defined and discussed in Section 3.4 below.

cultural factors played a key part. Likewise, in the field of environmental management, the extent to which firms accept/internalise environmental values and do not wish to be seen to break them, will determine whether they are likely to break environmental regulations when doing so would bring them private gain.

North's insights into the importance of the social and institutional context lends itself particularly to the third type of policy instrument, namely non-mandatory measures. Under instrumental rationality and conventional market-based analysis, non-mandatory measures will fail because they have no impact on the price system and impose no penalties for violation. As a result they do not change the financial incentives facing firms or individuals. However, within the broader context of institutional and evolutionary economics, non-mandatory measures can work by changing the institutional context and the value system within which firms operate. Non-mandatory measures include: (i) voluntary initiatives encouraged by regulatory agencies; (ii) bi-lateral initiatives that involve negotiation between government and firms on non-mandatory regulations; and (iii) unilateral undertakings by individual firms to adopt environmentally friendly strategies (Khanna, 2002, p. 46). Non-mandatory measures may also include voluntary negotiations with groups/networks of firms, trade associations or industries. Other non-mandatory measures include information disclosure and improved corporate governance via increasing the influence of stakeholders (Khanna, 2002, p. 47 and p. 55).

Some non-mandatory measures clearly impose costs on firms, for example voluntary abatement agreements, yet there is empirical evidence to suggest that firms choose to follow them (see Khanna, 2002 for a review of the empirical evidence). Other non-mandatory measures may bring both increased costs and benefits. For example, adopting environmentally friendly strategies in order to improve relations with stakeholders, such as consumers, may be costly in the short run but may bring improved consumer loyalty and increased demand in the long run. Likewise the adoption of environmentally friendly technologies that enhance resource productivity and lower externalities may bring private gains in the long term even though the switching costs are considerable.

At the same time, it is evident that the effectiveness of non-mandatory measures may be greatest when there is a credible threat of more draconian mandatory measures in the absence of voluntary compliance. What is clear is that we need to understand the institutional and evolutionary context if we are to understand how these policies work and how they might best be integrated with price/cost based policies and mandatory policies.

3.2 Game theory, environmental strategies and public policy

The distinction between the three categories of policy instruments can be illustrated using game theory and the *tragedy of the commons* which characterises environmental problems where externalities result in a conflict between private and public (or the collective) interest. Examples of *the tragedy of commons* include a wide range of environmental problems, such as, over-fishing, pollution, recycling, waste disposal and so on. The following payoff matrix provides the generic payoff structure that characterises these environmental problems and the conflict between private and public (collective) interest generated by externalities. The game is restricted to two players though the results can be generalised to any number of players. Two firms in competition are deciding between strategies – one that produces externalities that impose costs on other firms (such as fish stock depletion due to over fishing, or environmental damage that at some point reduces farm yields, or land fill that depletes the available land for disposal of rubbish) and another more expensive production strategy that avoids external effects. Following the standard convention, the first number in each pair represents the payoff (profit) to Firm 1, and the second number represents the payoff (profit)

to Firm 2. The determination of the outcome of the game depends on the relative payoff structure and not the absolute amount of the payoffs. It also depends on whether the game is played once of many times and on the underlying model of rational choice that governs firms' behaviour. The relative payoff structure in Table 1 reflects the fact that it is more costly to firms to engage in production without externalities and that externalities impose costs on others. If we adopt the standard microeconomic assumption of common knowledge (instrumental) rationality – which implies that both firms are profit maximisers and know each other to be so – it is straightforward to find the equilibrium solution to a one-shot play of this game. Firm 1 attains a payoff of 0 or 3 if it adopts the environmentally friendly strategy, and a payoff of 1 or 5 if it adopts the strategy with externalities. The same applies to firm 2. Given that both firms are profit maximisers, both will choose the strategy with externalities, since this strategy offers maximum profits given the profit maximising strategy of the other firm. The Nash equilibrium is therefore (1, 1) which is Pareto sub-optimal. Clearly the preferred outcome would be for both firms to produce without creating any externalities. They would then both receive a payoff (profits) of 3 . However, common knowledge instrumental rationality rules out this possibility in a one shot play or a finite repetition.

Table 1. Payoffs from an environment game between two firms

		Firm 2	
		Strategy with negative externalities	Strategy without externalities
Firm 1	Strategy with negative externalities	(1, 1)	(5, 0)
	Strategy without externalities	(0, 5)	(3, 3)

In other words, assuming perfect information and common knowledge rationality, the dominant strategy is for both firms to adopt the production strategy with negative externalities. Under this Nash equilibrium, which is entirely consistent with non game-theoretic approaches to modelling environmental problems, each player's strategy is a best response to its rival's strategy. The Nash equilibrium also describes a situation of fulfilled expectations by players: each player, knowing that the other is instrumentally rational, expects their rival to adopt the environmentally unfriendly strategy, and in Nash Equilibrium (1, 1) these expectations are fulfilled. Collectively, both firms would be better off if they could adopt the cooperative strategy that avoids the production of negative externalities, but instrumental rationality (profit maximising behaviour) rules this out, leading firms to adopt the strategy that produces externalities and leaving them with a lower payoff. Paradoxically, two 'irrational' players could attain higher payoffs than two instrumentally rational maximisers. As an example, consider two waste disposal firms that are bidding to attain a contract to dispose of industrial waste in a landfill site of fixed capacity. The waste could be disposed of by treating it first to recycle and minimise waste/pollution, or it could be dumped untreated. Recycling and treating the waste costs money and each firm, knowing that the other is a profit maximiser, is able to predict that the other firm will not adopt the environmentally friendly method of disposal in an attempt to undercut their rival and attain the contract. Thus, both firms choose the waste disposal strategy that creates externalities and both use up more landfill than is necessary, leaving less landfill available for them to use in the future.

The same game-theoretic approach can be used to explain lock-in to inefficient technologies. A classic example of this is the QWERTY keyboard. This keyboard was designed to slow down typing in an era when fast typing caused mechanical typewriters to jam. However, once this technology became embedded and workers were trained to touch-

type according to the QWERTY system, the costs of any one firm switching included having to retrain new and existing employees. If we consider the application of this type of problem to environmental technologies we might consider the choice between two strategies: (i) adopt the new environmentally friendly technology or (ii) stick with the existing technology. There are advantages to sticking with existing technology in terms of having pools of skilled labour to draw on and thus saving on training costs. Any firm that chooses to switch will incur additional training costs. If a firm switches while rival firms stick, that firm will have higher training and labour costs and lower profitability. If all firms switch, these costs are reduced as firms are able to draw on a bigger pool of trained managers and employees. Under this relative payoff structure, sticking is the 'dominant' strategy. An obvious policy implication is that some mechanism to provide collective or subsidised training in the use of environmentally friendly technologies would change the structure of the payoffs and resolve the dilemma. In the absence of such provision, firms will free ride on existing pools of labour and will be unwilling to incur the training costs associated with switching to the new technology.

> ***Policy Implication 1:*** *Where the introduction of new, environmentally efficient technology requires significant retraining of employees in the use of new technology, individual firms will be deterred from the adoption of new technology by training costs. There is a role for public policy to internalise the free-rider problem that characterises business investment in training either by subsidising education and training in environmental technologies and management or by encouraging firms – that would otherwise free-ride – to make joint investments in training programmes.*

The two examples of the Prisoners' Dilemma outlined above describe situations where there are negative externalities associated with the actions of individual firms and a conflict between private self-interest and the public interest. In such situations, would inefficient outcomes be avoided, and would firms reach the Pareto optimal, environmentally friendly outcome, if the games were repeated? For example, suppose the game illustrated in Table 1 were repeated twenty times, after a few plays would both firms realise that they would be better off if they both chose the production strategy without externalities? Will firms learn that cooperation pays dividends? Under the assumption of common knowledge rationality, the answer is 'no'. The problem is that any known finite repetition has a final play or terminating game. This final play will be played as if it were a one-shot game. Hence in the last period players will revert to the dominant strategy: production with negative externalities. But once firms recognise that this is the inevitable outcome in the last play of the game, they will see little point in cooperating in the penultimate play, since there are no future plays where having a reputation for cooperation might count. Thus, cooperation in the penultimate play is ruled out. This 'backward induction' argument continues unravelling throughout the entire 20 plays. The fact that there is a final play, and that both players are known to be profit maximisers, means that it is impossible to build up interdependence between successive plays of the game: each play is played as if it were a one-shot game and free-riding rules the day.

Market based instruments attempt to prevent free riding by changing the payoffs via taxes and/or subsidies on individual firms. Command-and-control instruments work by prohibiting or ruling out strategy choices. As Jaffe *et al* (2001) points out there is only limited agreement in the theoretical and empirical literature on the efficacy of these two instrument sets. There is also inadequate knowledge of the combined effects of different policy instruments and of the magnitude of the effects of market-based instruments.

A further limitation of the market-based vs command-and-control analysis of environmental policy is that it fails to consider the cultural, institutional, informational and

evolutionary settings within which firms operate. By changing a number of the underlying assumptions, it is possible to show that the strategy choice of firms is influenced by a variety of factors that do not fall neatly into either the market-based or the command-and-control categories. In particular, there are two further ways to resolve the prisoners' dilemma and attain the cooperative, environmentally friendly outcome. The first is to assume an indefinite repetition, which opens up the possibility of firms using threats and punishments to enforce good behaviour. The second is to abandon the assumption of common knowledge rationality. It is useful to explore both of these paths as they shed light on the possible design of environmental policies.

3.3 Corporate co-operation

In an indefinite repetition of the game it can be shown that firms may adopt the cooperative strategy if they attach sufficient weight to future payoffs and are prepared to use punishment strategies, such as the trigger strategy (TS) or the tit-for-tat strategy (TFT). The idea behind punishment strategies is that firms incur a cost in imposing punishments on their rival now, for the sake of a better future. In an indefinite repetition of the game there are many punishment strategies that firms can use that specify what firms would do in each time period in response to their rivals strategy. Two of the most straightforward strategies are the TS and TFT. The trigger strategy starts by choosing cooperation but will punish any move of non-cooperation by rivals with non-cooperation in all future plays. The tit-for-tat strategy starts by choosing cooperation and then follows the strategy that the other player adopted in the previous period. It is more sophisticated than the trigger strategy as it punishes non-cooperation with non-cooperation but is prepared to follow a move back to cooperation. Hence, the tit-for-tat strategy is 'nice', 'provacable' and 'forgiving' (Axelrod, 1981). It is important to note that both of these strategies may generate cooperative outcomes, however, their use is still dependent on firms being guided by profit maximising behaviour.

With the use of simple punishment strategies such as these it can be shown that private profit-maximising firms may reach and follow an equilibrium path characterised by cooperation in all plays of the game. The key factor that determines whether, with the use of threats and punishments, firms are prepared to cooperate now for the sake of a better future is the weight that players attach to future profitability (or the discount factor). This suggests that policies that encourage firms to take a longer time horizon may be important in encouraging environmentally friendly strategies. Such policies might include changes in the corporate governance structure of firms that increase the influence of long-term stakeholders vis-à-vis shareholders that tend to favour short-run profits.

> ***Policy Implication 2:*** *Change the corporate governance structure of firms to increase the influence of stakeholders taking a long-term perspective – such as employees and local communities – vis-à-vis shareholders that favour short-run profits. This could be promoted by:*
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> ***i.*** *making environmental reporting for large organisations mandatory;*[11] *and*
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> ***ii.*** *giving one or more independent directors specific responsibility for company policy on environmental matters and sustainable development. As with the current requirement under the Combined Code to appoint a senior independent*

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[11] The CEO of the Co-operative Bank is currently the only senior person in the corporate world to be calling for mandatory ethical and environmental reporting for large organisations (see Cook *et al.*, 2003).

director whom shareholders can approach, the independent director with responsibility for environmental issues would be given the task of liaising with stakeholders and shareholders.

While indefinite repetitions can generate environmentally friendly outcomes, assuming individual instrumental rationality, there are two limitations of this approach. The first is that solutions to indefinite repetitions of games rely on the fact that players must believe that there is a chance that the game will last forever. As Hargreaves Heap (1989) has pointed out, players must believe in their own immortality and this assumption does not sit comfortably with the assumption of rationality that underlies the game.[12]

The second limitation is that there are many strategies that may result in Nash equilibria. In fact, it can be shown that any strategy that yields a higher payoff than adopting the non-cooperative move in each play of the game, can form part of an equilibrium strategy. This finding – known as the Folk Theorem – shows that there are multiple Nash equilibria, and that as a consequence it is difficult to predict what will happen in games played over an indefinite time horizon.

Evolutionary game theory has attempted to discover which strategies are most likely to survive and dominate in order to regain determinacy and predictability. The idea behind evolutionary game theory is Darwinian: certain strategies do better than others and firms that adopt those strategies survive. Such strategies may be regarded as evolutionary (or collectively) stable. Axelrod (1981) has shown that tit-for-tat is an evolutionary stable strategy. While the number of evolutionary stable strategies is less than the number of Nash strategies, multiple equilibria remain. For example, the non-cooperative strategy – producing externalities – is also an evolutionary stable strategy. Thus, it is still difficult to determine what conditions might make firms adopt environmentally friendly strategies.

However, Axelrod's work on clustering does shed some light on this question that can be of help to policy makers. Using evolutionary game theory it can be shown (Axelrod, 1981) that for a given population of firms that meet each other in random pair-wise interactions (when for example, they are bidding for waste disposal contracts) cooperative strategies may be spread throughout the population of firms that make up the industry by a small group of firms that adopt environmentally friendly strategies. The reason is that when the group of cooperative tit-for-tat players interact with each other they do very well and pick up the payoff of 3 in Table 1 above. Provided they are of sufficient number, the positive payoff from mutual cooperation supported by the TFT strategy outweighs losses suffered by encounters with opportunistic firms adopting the strategy of always producing externalities. That is, cooperation is attained and externalities are reduced as a result of the adoption of the TFT punishment strategy. Axelrod's clustering result is powerful since it shows that an industry in an equilibrium characterised by all firms playing the non-cooperative strategy can be shifted to a TFT 'cooperative' equilibrium (without externalities) by a small group of firms adopting the tit-for-tat strategy. The size of the group relative to the population depends on the relative payoff structure and the discount factor but for the payoffs shown in Table 1 above, and a discount factor of 0.1, environmentally friendly outcomes can be attained in an

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[12] A further means of escaping the Prisoners' Dilemma is to assume a finite time horizon and imperfect information about the type of player one faces, in particular, uncertainty as to whether they are instrumentally rational. This approach requires either: that non-instrumentally rational players exist; or that instrumentally rational players believe they exist even though they do not. The first option paves the way for alternative models of rational choice since we need to say something about what motivates non-instrumentally rational players. The second option, which has been referred to in the literature as the 'strong rationality assumption' is unsatisfactory because it leads to the contradiction that 'rational' players hold irrational beliefs. As suggested below, policy might usefully introduce such players – firms that would follow the environmentally friendly strategies.

industry of 21 firms by the entry of just 2 environmentally friendly firms adopting the cooperative strategy.[13]

This suggests that policy makers might be best placed to focus their efforts on encouraging a small number of firms to adopt environmentally friendly strategies through targeted technology transfer programmes and subsidies rather than introducing a blanket tax/subsidy policy.

> ***Policy Implication 3:*** *Create a cluster of firms in the industry pursuing environmentally friendly production strategies to allow diffusion throughout the industry, via:*
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> ***i.*** *targeting existing firms in the industry to encourage them to switch to environmentally friendly production strategies; and/or*
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> ***ii.*** *introducing new firms, perhaps with mutual or community ownership, where environmental sustainability is written into their Memorandum & Articles of Association.*

3.4 Rationality

The game-theoretic approaches outlined above explain both why firms end up adopting environmentally unfriendly strategies that are Pareto sub-optimal and how such sub-optimality may be overcome whilst preserving the assumption of instrumental rationality. The second approach to resolving the prisoners' dilemma and other games that capture features of environmental economic management is to abandon the assumption of instrumental rationality. Alternative models of rationality include bounded rationality, procedural rationality, expressive rationality and Kantian rationality.

(i) Bounded Rationality

As mentioned above, this model of rational choice has its roots in the work of Simon (1982) and suggests that agents' rationality is bounded by both informational and computational limitations. As a result, outcomes differ from those that would be attained by unbounded maximising behaviour. However, the model does not break fundamentally with the neoclassical model of instrumental rationality, as agents would like to be instrumentally rational if only computational and information constraints could be overcome.

(ii) Procedural Rationality

This model may be viewed as an adjunct to bounded rationality. Faced with computational limitations, agents follow well-established procedures or norms rather than pursuing strict profit maximising behaviour. Procedural rationality is most relevant when there are multiple equilibria and no additional amount of computational power will help agents in ascertaining which equilibrium will actually be attained. Here, procedural rationality helps by showing how agents use historical norms and customs in a deterministic way to choose strategies in games with multiple equilibria (Hargreaves Heap, 1989, 1992). In this way procedural rationality is distinct from bounded rationality because it shows how *shared* norms and beliefs are functional in resolving indeterminacy. This adds a clear historical and social dimension to the theory of rational choice and equilibrium selection. By contrast, Simon's (1982) account of bounded rationality places emphasis on norms that provide short-cuts in

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[13] See the Appendix for further detail.

situations where computational ability is found lacking but the *commonality* of these norms and procedures does not feature as an integral part of his theory.

The significance of procedural rationality is that it provides a common foundation for coordinating activity. It is because the social, historical and institutional context provides common conventions, procedures and norms that procedural rationality is useful in determining outcomes in games with multiple equilibria. The approach also implies that changes in norms and procedures, lead to changes in equilibrium outcomes. This opens up the possibility of a new set of policy instruments designed to change norms, conventions and procedures.

(iii) Bounded Rationality, Procedural Rationality & Strategic Environmental Management

Bounded rationality and procedural rationality have been employed within the literature on strategic environmental management (SEM) to explain why firms do not adopt environmentally beneficial strategies, even when those strategies would enhance their profitability. Thus, the starting point for the SEM literature is not the standard one characterised by a conflict between private and public interest, but rather the observation that that there are some classes of environmental problems that could be solved and that the solution would also increase firms' profitability (win-win situations). Goldstein (2002) describes how the growth of SEM has reduced costs and raised profits, in contrast to the standard view that there are always trade-offs between environmental protection and firms' profitability. Goldstein's analysis raises the question of why, if SEM offers opportunities to increase profits, do all firms not adopt it? The answer may lie in bounded and procedural rationality. Managers get stuck in existing routines and procedures that cloud strategy formation. Firms that are able to break through this malaise and use SEM will be able to reap the rewards:

> 'The opportunities for this kind of strategic repositioning are thought to originate in broad social and environmental trends. Hart (1997) argues that while "bottom-up pollution-prevention programs have saved companies millions of dollars" (67-68) – with increased cost savings and hence profits coming from reduced waste and energy use – the best is yet to come. He points to the smaller number of firms that have begun reorienting their long term strategies, and plans for revenue growth, around solving sustainable development problems where their basic capabilities give them expertise.' (Goldstein, 2002, p. 497).

This approach suggests that overcoming bounded rationality and historic norms and procedures that tie companies into inefficient and environmentally unfriendly production techniques is essential if the full benefits of SEM are to be realised. It therefore opens up a new branch of policy based on effective training in SEM, and better corporate governance, including greater involvement of stakeholders – customers, employees and local communities, as well as shareholders – to bring pressure to bear on companies to exploit and develop SEM to both improve environmental outcomes and enhance profitability.[14]

Goldstein's study presents empirical evidence from seventeen companies that were active members of a Regional Pollution Roundtable. Of these companies, fourteen introduced SEM projects as a means of enhancing profitability, two companies introduced projects on standard business criteria that turned out to have positive environmental effects although these were not considered at the initiation of the projects, and one company initiated a new project for environmental reasons alone (and not for financial returns). While more empirical evidence would be desirable, Goldstein's case studies do show that environmental protection

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[14] Such an approach would be consistent with the Higgs report, which calls for non-executive directors to be drawn from a wider pool than at present (Higgs, 2003).

and increased profitability *can* go hand in hand. This suggests that non-mandatory policy measures could have an impact on improving SEM.

A further study by Cambridge Econometrics and AEA Technology (Cambridge Econometrics, 2003) used 65 case studies to calculate the cost savings associated with adopting new processes of production that increase resource productivity. The study calculated the potential economic gains that could be realised if these processes were diffused throughout the UK manufacturing sector. Their results indicate UK manufacturing could save £2 to £2.9 billion in costs equivalent to 5-7% of profits in 2000. This amount could approximately double if savings from the cost of producing materials that end up as waste were included.

These two studies are significant because they show that contrary to the standard view of environmental economics which assumes a central conflict between the private self interest of individual firms and the public interest (for example, the ubiquitous externality problem), there are classes of environmental problems where there is no such conflict, but nonetheless, firms are 'trapped' by inefficient technology even when individual firms could increase their profitability by adopting environmentally friendly strategies. The SEM approach suggests there is a clear role for policy to provide practical and far-reaching training in strategic environmental management techniques.

> ***Policy implication 4:*** *Establish a training programme in the theory and practice of strategic environmental management.*

(iv) Expressive and Kantian Rationality

Under expressive rationality (Hargreaves Heap, 1989) actions are determined not only by the payoffs associated with them but also by the 'expression', 'signal' or 'value' of the actions themselves. Thus, firms may choose not to violate environmental regulations even when the private benefit of doing so is positive, because they value the action of compliance. For example, firms may value environmental responsibility and not like to be seen to be damaging the environment. Expressive rationality is grounded in an existentialist view of economic interaction. Agents reflect on their actions and have a desire for self-respect and public regard that may be enhanced or diminished by those actions. It may be argued that this desire could be incorporated into the standard model of instrumental rationality by including the desire for self-respect and public regard in the utility function.[15] However, such an approach would reduce the analysis of rational choice to an ends driven framework and this would be at odds with valuing actions as an expression of what firms stand for and believe (for example, corporate social responsibility) which is the hallmark of expressive rationality.

Kantian rationality is based on the notion that as human beings we are creatures of reason as well as instinct. While our instinct may be to selfishly pursue our preferences, as creatures of reason we are able to avoid this instinctive behaviour and reason that cooperation will bring higher rewards. Kantian rationality identifies universalisable principles, and players adopt these strategies via a process of reason. Hence two Kantian reasoners playing the above Prisoners' Dilemma can attain the superior outcome (3, 3). The Kantians are able to do better than their instrumentally rational counterparts because they follow universalisable principles, and value actions on their merits. Moreover, these actions provide signals to other players that convey information about the type of player they are dealing with.

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[15] Boland (1981) points out that utility theory cannot be disproved, since we cannot know for sure that firms and people aren't always maximising something or other.

Similarly, under procedural rationality the norms, conventions and rules that players follow generate information about the values of players and therefore about the type of player(s) one faces. Given the existence of shared value systems, players can associate themselves with different value systems by virtue of their strategy choice. This insight is reinforced by the empirical evidence from game-theoretic experiments which shows that many players adopt cooperative strategies even in finite repetitions of the game.[16]

Empirical evidence on theories of rationality suggests that instrumental rationality has been found lacking as a basis for an explanatory model of economic behaviour, in that many of its predictions are not verified by experimental data (see Andreoni and Miller, 1993) or even casual empiricism. For example, under a finite time horizon, choice based on instrumentally rational behaviour rules out cooperative or collective action such as trade union membership or individual participation in recycling of waste, and yet, in practice, such behaviour is commonplace. The results from experiments based on the finitely repeated prisoners' dilemma indicate that cooperation is likely and that there are some players who cooperate throughout finite games. Moreover, in their experiments where players played finitely repeated Prisoners' Dilemma type games for cash payoffs, Andreoni and Miller (1993) found that the proportion of cooperative outcomes increased as the games progressed, a result that is broadly consistent with evolutionary theory. Hence, the experimental evidence provides support for the view that some players, contrary to the instrumental model of rational choice, are genuinely cooperative and that others learn to be more cooperative as the game progresses.

Expressive, Kantian and procedural models of rational choice show that even in the case of finitely repeated Prisoners' Dilemma type games it is possible to overcome negative externalities. These models of rationality also demonstrate the importance of cultural, informational and 'learning' policies. It follows that policies designed to change the underlying behaviour of firms (and consumers) from non-cooperative to cooperative can be beneficial. There is evidence for this in the case of both firms and consumers; the work of Teisl, Roe & Hick (2002) for example shows how information policies can be used to favour environmentally friendly production even when there are private costs to firms and consumers.

> ***Policy implication 5:*** *Public policies should aim to engender cultural change and set new norms and standards in environmental management and corporate social responsibility.*

4. Systems of innovation

Richard Nelson argues that the fact that firms differ in their behaviour, and would be expected to differ in their responses to price signals, follows of necessity from the central importance of innovation:

> 'The developing theory of dynamic firm capabilities I am discussing here starts from the premise that… firms are in a Schumpeterian or evolutionary context. Simply producing a given set of products with a given set of processes well, will not enable a firm to survive for long. To be successful for any length of time a firm must innovate. …

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[16] See for example Andreoni and Miller, 1993.

> ‘To be successful in a world that requires that firms innovate and change, a firm must have a coherent strategy that enables it to decide what new ventures to go into and what to stay out of. And it needs a structure, in the sense of mode of organization and governance, that guides and supports the building and sustaining of the core capabilities needed to carry out that strategy effectively.
>
> ‘If one thinks within the frame of evolutionary theory, it is nonsense to presume that a firm can calculate an actual ‘best’ strategy. A basic premise of evolutionary theory is that the world is too complicated for a firm to comprehend, in the sense that a firm understands its world in neoclassical theory.’ (Nelson, 1991b, pp. 68-9)[17]

Likewise, Giovanni Dosi argues that

> ‘A major implication of the characteristics of cumulativeness, tacitness, and partial appropriability of innovation is the permanent existence of *asymmetries* among firms, in terms of their process technologies and quality of output. That is, firms can be ranked as “better” or “worse” according to their distance from the technological frontier.’ (Dosi, 1988, 1155-1156)[18]

Technological innovation is a key driver of economic change. Indeed, for Schumpeter, innovation was the most distinctive feature of a capitalist economy, and this is why the use of equilibrium analysis was, in his view, quite inappropriate for analysing such an economy:

> ‘In appraising the performance of competitive enterprise, the question whether it would or would not tend to maximise production in a perfectly equilibrated stationary condition of the economic process is … almost, though not quite, irrelevant.’ (Schumpeter, 1943, p. 77)[19]

An evolutionary and institutional approach to understanding technical change suggests that *systems* of innovation play a key role – national systems, regional systems, and industrial systems (Mowery and Rosenberg, 1989; Archibugi & Michie, 1998; Michie, Oughton & Pianta, 2002):

> ‘Some institutional economists in the tradition of evolutionary economics refer to ‘systems of innovation’ in which they point to the existence of ‘collective entrepreneurship’ (Lundvall 1992, pp. 9-10), while other institutional economists focus on technological trajectories and paradigms as special kinds of institutions (Dosi 1982, 1988; Perez 1983; Freeman, Clark and Soete 1982; Freeman and Perez 1988).’ (Andersen, 2001, p. 37)

By a ‘national system of innovation’ is meant ‘the network of institutions in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies’ (Freeman, 1987, p. 1). The concept has since been developed more generally for ‘systems of innovation’, including national, regional or sectoral, and encompasses all the important factors that influence the development, diffusion and use of innovations, as well as the relations between these factors.

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[17] Nelson acknowledged that he is largely ‘restating what Chandler, Lazonick, Williamson, and other scholars of the modern corporation, have been saying for some time’. See for example Chandler (1966, 1990), Lazonick (1990), and Williamson (1979).

[18] Emphasis in the original.

[19] Cited in Rosenberg, 1994, which contains an excellent discussion of Schumpeter’s work on economic growth and innovation. See also the proceedings of the International Joseph A. Schumpeter Society Conference, Vienna, 1988, published in the *Journal of Evolutionary Economics*, Volume 10, number 3, 2000.

> 'A central insight provided by the systems-of-innovation approach is that firms do not generally innovate in isolation, but do so in interaction with other organizational actors (such as other firms, universities, or standard-setting agencies) and that this interaction is shaped by (and shapes) the framework of existing institutional rules (laws, norms, technical standards). The approach takes into consideration the actions of both firms and governments. In short, this conceptual approach regards innovation as a process of interactive learning.' (Edquist, 2001, p. 1623)

Adopting a systems approach for considering environmental issues should point policy makers towards considering the whole system of taxation, regulation, innovation and so on. This in turn should prevent unrealistic expectations as to the impact that a single tax or regulatory change, on its own, may have. Changes need to be brought about, for example, in the design stage of new technologies, so the system needs to be viewed as a dynamic one, over time. Economic outcomes depend partly on competition but also on their own past evolution (North, 1990).[20] And technological change does not occur simply in response to price signals (Dosi, 1984).

Freeman has stressed the importance of not only combining economic incentives with legal regulation, but also, firstly, of mobilising public opinion and secondly, encouraging appropriate technical change:

> 'In practice most countries have begun to use a combination of economic incentives and legal regulations. However, the effectiveness of most of these methods depend on:
>
> '1. the degree of public support for the policies. Consequently methods of public persuasion and mobilisation of public opinion also play an important role. Historically, voluntary groups and organisations have made the major contribution to this mobilisation… The success of the environmentalist movement in the 1970s and 1980s has meant that now governmental agencies also often participate in public advocacy and persuasion, albeit not to the extent nor with the same degree of conviction as some 'Greens' might wish.
>
> '2. a continuing high rate of technical change.' (Freeman, 1992, pp. 191-192.)

4.1 The theory of induced innovation

The roots of the theory of induced innovation are to be found in what David (1975, 33) calls a 'fatefully vague passage' in Hicks' *Theory of Wages* (1932, 124-5), in which he suggested that high labour costs might bias the direction of invention or innovation in a labour-saving direction within privately owned firms. In the first edition of *Agricultural Development* (AD1) (1971), Hayami and Ruttan (H&R) adapted the theory to the case of the agricultural sector. Recognising that much agricultural research is undertaken by the public sector, H&R sought to extend the theory into the public domain. Their model attempted:

> 'to include the process by which the public sector investment in agricultural research, in the adaptation and diffusion of agricultural technology and in the institutional infrastructure that is supportive of agricultural development, is directed

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[20] Rosenberg (1994) argues that technological changes are often 'path dependent': 'Additional knowledge of new production possibilities is not costless, nor is the rate and direction of technological change exogenous. Consequently, understanding the particular sequence of events that has shaped the knowledge of the technological frontier is crucial, not only to the historian, but to the economist as well. Technology and science, which are now generally acknowledged to be central to the achievement of economic growth, need to be understood as path-dependent phenomena.' (p. 23).

toward releasing the constraints on agricultural production imposed by the factors characterised by a relatively inelastic supply' (AD1, 54).

Binswanger (1978a) made an effort in *Induced Innovation: Technology, Institutions, and Development* (I.I.) to tighten the theoretical basis of induced innovation and also in I.I., Ruttan (1978) sought to provide a theory which endogenised institutional change within the economic framework. Recognising the fact that much new technology resulted from the work of public sector organisations, this theory tried to account for the establishment of these organisations. The second edition of *Agricultural Development* (AD2) (1985) saw H&R attempting to bring these various new insights together in a tighter theoretical framework.

The theory of induced innovation is part of a wider theory of agricultural development.[21] H&R were concerned that earlier work had been silent on the matter of how new technologies could be generated for the agricultural sector. For H&R, the key questions are what would determine the amount of resources allocated to agricultural research, given that these resources are not traded in the marketplace, and the relationship between technological and institutional change? Their theory, essentially two inter-dependent theories of induced technical change, and institutional change:

> 'attempts to make more explicit the process by which technical and institutional changes are induced through the responses of farmers, agribusiness entrepreneurs, scientists and public administrators to resource endowments and to changes in the supply and demand of factors and products' (AD1&2, p. 4).[22]

Induced technical change hypothesises that technical change occurs in such a way as to economise on factors which are becoming relatively more scarce and hence, more expensive. In their view, research administrators and research scientists can be viewed as responsive to economic indicators in the same way as can a profit maximising firm (AD1, pp. 57-8; AD2, p. 88). H&R hypothesise that:

> 'technical change is guided along an *efficient path* by price signals in the market, *provided that the prices efficiently reflect changes in the demand and supply of products and factors and that there exists effective interaction among farmers, public research institutions, and private agricultural supply firms.*
>
> 'Farmers are induced, by shifts in relative prices, to search for technical alternatives that save the increasingly scarce factors of production. They press the public research institutions to develop the new technology and also demand that agricultural supply firms supply modern technical inputs that substitute for the more scarce factors. Perceptive scientists and science administrators respond by making available new technical possibilities and new inputs that enable farmers profitably to substitute the increasingly scarce factors, thereby guiding the demand of farmers for unit cost reduction in a socially optimal direction…
>
> 'Given effective farmer organisations and a mission- or client-oriented experiment station, the competitive model of firm behaviour can be usefully extended to explain the response of experiment station administrators and research scientists to economic opportunities.' (AD2, p. 88, emphasis added).

This, it should be stressed, is their *hypothesis*: it is not a theory, and it holds explanatory power only to the extent that the hypothesis can be tested and validated. It does, though,

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21 This forms part of a wider theory of technologically generated economic development along lines suggested by Simon Kuznets (1966).

22 A notable omission from this list are philanthropic organisations, such as the Rockefeller Foundation, which have played such a major role in the promotion of agricultural research around the world.

suggest a mechanism by which the efficient path *might* come to be followed, and it seems rather more than a suggestion.

The authors suggest that not all technical changes are induced through a demand-driven process, some being supply-driven as a result of exogenous advances in the state of science and technology (AD1, p. 59; AD2, p. 89). Induced institutional change is postulated to occur in response to similar signals as induced technical change, the two being seen as connected.

5. Environmental examples: agriculture and waste management

In what follows, we look at the examples of agriculture and waste management to highlight the relevance of the above theoretical discussion.

5.1 Technological Change in Agriculture[23]

Several, perhaps most, technologies need to be understood as *systems*. The history of technological change tends to be one of those technologies which 'succeed'. Within market economies, the measure of success tends, of course, to be related to their dominance within the market place. Yet if one adopts a perspective which is more institutionally informed, and one in which the roles of evolution and path-dependence are recognised, it becomes possible to consider alternative realities, which might have come into fruition had history been other than it is. In some cases, the choice from alternative paths can be traced back to 'historical accidents'; in others, such choices can be considered to be influenced by institutional structures, or the desire to shape institutions in a specific manner. This can lead to technologies being chosen such that they fit existing institutions and interests, or enable the development of new institutions and interests.

This implies that in order to understand why things are as they are, the systemic context in which technologies are developed and marketed needs to be understood. One can, to a degree, distinguish between Lamarckian approaches to the understanding of evolution, in which evolution is directed to a particular end (a sort of teleological, 'end of history' approach), and more open-ended approaches, in which evolution follows a particular path, but one which is not necessarily 'better' than others which might have been followed. Discussions concerning 'technological progress' therefore mirror those concerning 'evolutionary progress'. If evolution, or technological development, is open-ended, how can we be sure that all change necessarily implies progress? Surely, the notion of progress has a more metaphysical content than such discussions might suggest, yet it is common to find those who see new technologies through more dystopian lenses to be castigated as 'Luddites'.

The body of literature concerning the negative externalities associated with what many term 'industrial agriculture' forces us to confront the question, why have such methods been employed for so long? This question takes on added significance in the context of debates concerning 'sustainable development', and the emergence, or more properly – and here, history becomes important – re-emergence of a variety of schools of 'sustainable agriculture'.

Despite interest in these 'alternatives', agriculture has stuck more or less steadfastly to a path of increasing industrialisation, and arguably, an unsustainable exhaustion of soil, genetic resources, potash, and nitrates. In many countries, it is a major consumer of increasingly scarce water resources. The efficiency of conversion of energy is low in industrial agricultural systems, and emissions of greenhouse gases are significant. Why, when the intellectual arguments in favour of sustainability appear to have been won, is agriculture still practised in what seems to be a manifestly unsustainable manner?

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[23] The following is a synopsis of a more detailed argument advanced in Hogg (2000)

The main reason cited in the literature is concern for global food supplies. Indeed, in such discussions, industrial agriculture has been shrouded in what Rosenberg (1982, p. 28), borrowing a phrase coined by Fogel, calls 'the axiom of indispensability.' Setting aside for one moment the thorny question of distribution (which no thorough investigation should), it is common to read of the need for more fertiliser and more pesticides in agriculture if the world's growing population is to be fed. But is the choice really so stark that we have no option but to fight, in Beck's words, 'the Devil of hunger with the Beelzebub of multiplying risks?' And if the answer might be 'no', why has this way of doing agriculture been able to fend off the strident criticisms of environmentalists for so long?

It is interesting to note that many authors who write concerning the success of the Green Revolution in helping to improve food security tend to limit their list of counterfactuals to one, this being a continuation of the *status quo ante*. This monochrome perspective ignores all sorts of questions as to whether, and if so how, agricultural science might have been shaped so as to bring forward production techniques other than those ultimately used.

Agricultural Research

It is impossible to dissociate the history of so called High External Input Agriculture (HEIA) from the history of agricultural research. This history has its roots in British and German research stations whose work focused mainly (in early years) on soil chemistry. Many scientists from the U.S. were trained in German research stations and British universities and returned equipped not just with knowledge, but a commitment to the value of agricultural science.

The late nineteenth century promised a shift in focus. The rediscovery of Mendel's work, apparently independently by de Vries, Correns, and Tschermak, in 1900, led to a new interest in a more scientific approach to plant breeding. Even on an issue so superficially uncontroversial as the application of Mendelian theory to genetics, alternative ways of conducting research were emerging. Mendelian theory paved the way for the emergence of two competing approaches to plant breeding, misleadingly referred to as Mendelism and biometrics. Both were compatible with Mendelian theory, as had been illustrated by Emerson and East (1913). Yet in plant breeding, it is generally accepted that the Mendelian approach has held sway over biometrical approaches (Robinson, 1996; Fitzgerald, 1990), and it would appear that the competition is played out in the socio-economic rather than the scientific sphere. The latter is in essence a form of selection, but to equate it with the practices of farmers at the turn of the century would be to belittle advances made in genetics and related statistical techniques.

The key difference between the two emerging approaches as regards plant breeding was that Mendelians effectively sought individual genes which were responsible for certain traits or characteristics. In their interpretation, finding these would enable control over the final form of the plant. Biometricians, on the other hand, recognised that a given characteristic or trait may be controlled by a number of genes at different loci. In order to maximise the expression of a given trait, statistical techniques were necessarily the best. For Mendelians, the natural route was to seek genes for combination into a single variety. For biometricians, on the other hand, the end point might not be a specific variety, but an improved population. Statistical-based selection methods could tolerate diversity, whereas Mendelian approaches implied uniformity.

Historically, the Mendelians would appear to have won the day. Probably the majority of research into plant breeding in formal agricultural research organisations since the 1940s has been carried out in this mode of investigation. Yet the exploration of alternative paths has not been unfruitful, despite the relative paucity of resources devoted to such investigations.

A critical difference between the Mendelian viewpoint, and that of the biometricians, can be summarised as follows. Mendelian views imply a quest for ideal plants, these to be replicated in a given field:

> 'Now the breeder tends rather to formulate an ideal in his mind and actually creates something that meets it as nearly as possible by combining the genes from two or more organisms.' (Hambridge and Bressman, 1936, p. 130)

This quest for ideal plants, or plant ideotypes, has also been fuelled, historically, by the desire of private capital to become involved in agricultural research. First, the case of hybrid maize (the process of heterosis effectively conferring a biological patent upon maize seed), then, the development of plant breeders' rights (PBRs), and most recently, the application of patents to biological material and biotechniques have been powerful institutional innovations enabling the products of agricultural research to be made appropriable. From a situation in which industrialised nations encouraged 'free exchange' of germplasm so as to access materials for plant breeding from centres of diversity (predominantly in the developing world), the pendulum has swung completely the other way such that now, farmers might be faced with lawsuits if they save seed from one year's crop to grow the next.

By contrast, biometric, or population based approaches, imply working with populations. They are less amenable to straightforward proprietary protection, and for this reason, it is also less easy to require farmers to purchase seed on an annual basis.

The attractions of Mendelian approaches, and the institutional forms supporting them has been given further impetus by the desires of many nations to reduce spending on public services. The institutions which have facilitated an increase in the range of appropriable products arising from agricultural research have facilitated a withdrawal of the state from 'near-market' research.

Why is this of interest from an environmental perspective? In traditional agricultural systems, epidemics are rare, unnoticed, undocumented, or all three. This is partly due to the genetic diversity, and hence, flexibility retained within the agricultural system. Genetically uniform systems lack this flexibility (Sydor, 1976; Perrin, 1977; Simmonds, 1979, p. 262; Thurston, 1992, p. 9). The more uniform the crop over space and time, and the less frequent are environmental conditions deleterious to particular pests and pathogens (they are most infrequent in the tropics), the more likely it becomes that an epidemic will occur, and occur over a large area. Modern agricultural systems are characterised by their uniformity. Ecologically, they are artificial in the extreme, and the level of inter- and intra-specific diversity is, in terms of the system's ecological vulnerability, worryingly low (Cox and Atkins, 1979, Ch. 6). The possibility that pest epidemics will emerge increases due to the strong selection pressure exerted in favour of pests that can overcome any resistance that the crop may have had.[24]

This vulnerability has had implications for the development of agricultural techniques. The trend towards increased uniformity in the field has:

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[24] Here I use the term 'pest' to imply all biological organisms which are deemed unwanted or undesirable in a given farming system (i.e. including insects, rodents, microbial organisms and 'weeds'). Insects resistant to pesticides have long been a problem, but herbicide resistant weeds are a relatively recent, though no less tractable phenomenon. There were 107 such weeds world-wide as of the late 1980s, 81 of which were resistant to more than one chemical formulation (LeBaron, 1991). Of course, the term 'pest' has a distinctly constructivist term. In some fields in India, there may be more than 100 useful plants grown in the field which might, from the perspective of another farmer, be considered 'weeds'. Indeed, in some cultures, there is no word equivalent in meaning to that of 'weed', merely 'useful' and 'not useful' plants (so whether something is a weed depends upon what it is, not where it is).

- made more likely the use of agrochemicals to compensate for the increased vulnerability of the plant;
- facilitated mechanisation of activities in the field;
- facilitated the standardisation of end products that is much sought after by retailers and food processors.

What one sees emerging, therefore, is not so much discrete technologies being developed in isolation from each other, but the development of a technique, a 'way of doing agriculture', in which different components become more or less well integrated as a system.

A Co-evolutionary View of Technological Development

It is possible to understand technologies and institutions as co-evolving over time. Co-evolution has been described as:

> 'an evolutionary process in which the establishment of a symbiotic relationship between organisms, increasing the fitness of all involved, brings about changes in the traits of organisms... Coevolutionary sequences frequently may be described as cooperation, but they do not depend on recognition by the organisms of the advantages involved.' (Rindos, 1984, pp. 99-100.)

In viewing the development of modern agricultural techniques as a primarily co-evolutionary phenomenon, one depicts the success or failure of a technology in the market place as being determined by its fit within existing 'ways of doing things'. Kauffman has sought to conceptualise technological changes through reference to fitness landscapes, a concept first used by Sewall Wright to explain adaptation of populations though appeal to Mendelian theory. In Kauffman's view, an economy is:

> 'a web of transformations of products and services among economic agents. Over time, "technological evolution" generates new products and services which must mesh together "coherently" to jointly fulfill a set of "needed" tasks.' (Kauffman, 1988, p. 126).

The mesh becomes finer and the web increases in complexity as economic interests grow and diversify, as institutions are transformed, and as industries mature, increasing the degree of specialisation in production.

This increasingly complex web effectively acts to filter out technologies as peaks on fitness landscapes. The degree to which technologies can be coupled with the existing way of doing things determines whether a given technology is 'selected' (i.e. is successful in the increasingly complex, and inter-related marketplace). Unsuccessful technologies lack close coupling and are 'deselected' (rejected).

The Role of Institutions

The influence of institutions on the shape of agriculture, and more specifically, the direction of agricultural research can usefully be understood through the development of institutions of intellectual property over time. More properly, one can consider this as a co-evolutionary process in which the tools provided by the new biotechnological revolution have made possible a change in the nature of intellectual property as it affects the results of plant breeding. These changes have, or so it is argued here, enabled the quest for 'the ideal plant' to follow paths which reflect both established trends in industrial agriculture and emerging trends which are influenced by other institutional changes.

Hambridge and Bressman (1936, p. 131) recognised long ago the tensions between free exchange in germplasm, and unfree exchange of the product derived from it:

> ‘From its rivals a nation may get the wheat germ plasm that enables it to supply its own needs or overwhelm those rivals in international trade... Will nations have the wisdom to deal with this situation, or will it lead to more bitter rivalries and more deadly conflicts, as the beneficent science of chemistry has enormously increased the deadliness of war? In his use of modern science, man has proved again and again that he is a bright child playing with fire.’

Metropolitan powers appreciated that control over commodity trade depended on restrictions on the movement of germplasm. Yet the metropolitan powers were those least well-endowed with genetic diversity. History is therefore replete with examples of the heroic efforts of plant explorers in overcoming embargoes on the movement of seeds, the breaking of which was in many cases punishable by death (Juma, 1989, Ch. 2; Raeburn, 1995, pp. 64-70).

The first claims for plant patents were made in 1885 (Kloppenburg, 1988, p. 132). But at the time, unless plants were crossed inbreds (a process which was not well understood until the 1930s), farmers could save seed for planting the following year without appreciable yield loss. In 1922, lawyers met in London to discuss patent protection for plant varieties but no action followed (Fowler *et al.,* 1988, p. 252).

The nursery industry was primarily responsible for the passage of the Plant Patent Act of 1930 in the U.S. For nurserymen, the obstacle to proprietary ownership of varieties lay in competition from other nurserymen, not farmers. The Plant Patent Act of 1930 (see Fowler, 1994, pp. 74-90) made it possible for asexually reproduced plants to be patented, with the exceptions of potatoes and Jerusalem artichokes. The rhetoric used in support of the act, that breeding had made such significant advances over the past decades, was actually completely irrelevant as far as asexually reproduced plants were concerned (Fowler, 1994, p. 74). Most of the work done by nurserymen lay in multiplying varieties that had been discovered by chance, and that were the product of insect or wind pollination, raising issues as to whether they should have been eligible for patents. Fowler concludes that:

> ‘The PPA did not recognise the individual inventor or the creative act as much as it recognised and rewarded the system that produced the new variety, whether by luck or by design.’ (Fowler, 1994, p. 89).

In France, ever since the turn of the century, rose breeders had been seeking the same recognition as inventors of machines. Early attempts were rejected by lawyers on grounds that even full disclosure would not make it possible for breeders to reproduce a variety. By 1928, however, there existed in the Ministry of Agriculture *de facto* protection of breeders’ rights through an ‘identity and purity service’ (Berlan and Lewontin, 1986, p. 785). The Italian High Court declared plant varieties patentable in 1948, but confusion led to calls for a special plant patent law. By 1957, with the view that plants and animals should not be patented in the ascendancy, the International Association of Plant Breeders for the Protection of Plant Varieties (ASSINSEL) accepted an invitation to host a conference in Paris on plant breeders' rights (PBR), leading to the establishment of the Union for the Protection of New Varieties of Plants (UPOV) in 1961 (Fowler *et al*., 1988, pp. 239-240), whose International Convention was revised in 1972, 1978, and 1991.

For the most part, PBR legislation has been true to the UPOV Convention, requiring that plants pass the tests for Distinctness (i.e. they had to be different from other plant varieties for which PBRs already existed), Utility (they had to be useful) and Stability (the trait had to express itself in a stable way) (the so-called DUS test). The 1960s and 1970s saw

several countries either joining UPOV or implementing a system of PBR of their own.[25] Key to the passage of these acts was the belief that sexually reproduced plants could breed true, which, for sexually reproducing plants, is only the case for pure-line varieties (those having undergone four to nine generations of selfing, or 'inbreeding').

Also critical was the definition (thought by many to be impossible) of the term 'variety'. The UPOV resorted to 'nothing other than a description of the steps of the method of breeding' (Berlan and Lewontin, 1986, p. 787), or more accurately, pure-line (Mendelian) breeding. Hence, the extension of intellectual property rights (IPR) to plants through PBR was an institutional innovation shaped, and made possible, by changes in breeding techniques and technology respectively. However, these were not institutional changes waiting to be implemented as soon as these techniques emerged. Just as there were technical options open to breeders, so the institutional changes made represented a choice from myriad possibilities.

As late as the 1960s, there were few multinational companies in the seed industry. A wave of acquisitions occurred in the 1970s as seed companies were bought up by transnational corporations, mainly food trading and petrochemical companies.[26] Food traders, seeking to open up new export markets in the era of US 'food power', sought to extend their activities upstream. The development of high-input seeds by international agricultural research centres had also led (agro-) chemical companies to seek new markets in the developing world, so these companies sought to market seeds through the same channels. With PBR legislation in place in many developed countries, seeds were no longer a weak link in the input supply industry. UPOV, by creating a degree of harmonisation in PBR legislation, fostered the emergence of a global seed industry, whilst the horizontal integration of agricultural input supply has deepened the inter-relatedness of inputs over time.

In 1976, the first of the new biotechnology companies, Genentech, was formed by Herbert Boyer and venture capitalist Robert Swanson. In 1980, Genentech placed a share offering on the New York Stock Exchange, the prices of which shot up from $35 to $89 per share in twenty minutes, a record rate of increase (Kloppenburg, 1988, pp. 195-6). This was due to the fact that three months earlier, General Electric had successfully challenged an earlier decision by the US Patent and Trademark Office (PTO) which had ruled that an oil-degrading micro-organism developed by their scientist, Ananda Chakrabarty, was not patentable subject matter. The new ruling held that whether or not 'an invention' was alive or dead was irrelevant to patent law (Fowler, 1994, p. 149).[27]

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[25] See Fowler (1994, pp. 106-118, 135-146) and Kloppenburg (1988, pp. 134-151) on the US's Plant Variety Protection ACT (PVPA). Both are of the opinion that the PVPA was very much a marketing tool for the seed industry wishing to conform to UPOV standards and offer reciprocal protection for other countries in an increasingly global industry. On the UK, see Bould and Kelly (1992). Clunies-Ross (1995, pp. 29-33) expresses the view that the UK's Plant Varieties and Seeds Act, replacing the 1920 Seeds Act, shifted the focus of its protection away from the consumer (the grower) and towards the breeder, the intention being, as a 1957 Committee reviewing legislation reported, to keep 'unsuitable varieties and strains off the market' (p. 31).

[26] See Table 6.3 in Kloppenburg (1988, p. 148) and Goodman *et al*. (1987, pp. 109-15). Fowler and Mooney's (1990, p. 123) research indicated that since 1970, more than 1000 independent seed companies had been acquired by, or were under the control of transnational corporations. However, Kloppenburg (1988, p. 136; also Barton, 1982, p. 1072) notes that industry concentration was already underway in the US by 1959 as seed companies increasingly began to make outlays for research, but also for marketing as a means of differentiating their products from those of public research organisations (though in some cases, they were probably the result of public research).

[27] There is continued exasperation at the application of patent law to living matter. Patents are granted on the basis that what is patented is new, involves an inventive step (the non-obviousness criterion), and is useful for something. Hobbelink (1991, p. 106) cites one plant breeder's response: 'Who will have the guts to declare a gene novel and non-obvious? Would anyone know enough of genetics and nature to claim such arrogance?'

In the PTO's ruling on Chakrabarty, the legal principle of 'pre-emption' disqualified materials protectable under the PPA or the PVPA from patent protection. But this ruling was also overturned in the 1985 *Ex parte Hibberd* case, in which Hibberd was granted patents on the tissue culture, seed, and whole plant of a corn line selected from tissue culture. Breeders could now choose the form of protection most suitable to them, including utility patents.

The developments occurring in the U.S. acquired an international dimension almost by accident in the context of the Uruguay Round negotiations of the General Agreement on Tariffs and Trade (GATT). Here, patents covering genetic material piggy-backed on already emerging debates concerning fake Rolex watches, music cassettes and other pirated material. The arguments used by metropolitan powers to support the notion of free exchange of germplasm had completed their about turn.

The final text of the agreement on TRIPs (Trade Related Intellectual Property Rights)[28] agreement established new multilateral rules on IPR based on uniform minimum standards for their protection and enforcement, including their availability, use and scope. As regards plant materials, the treaty allowed for exemptions on grounds of perceived environmental or public order impacts, yet at the same time, the treaty stated that plant varieties should be protected by patents 'or by an effective *sui generis* system or by any combination thereof' (Article 27.3 (b)). Although developing countries and least developed countries were allowed, respectively, five and ten years to implement the agreement, the '*sui generis*' clause is to be reviewed 4 years after the date of entry into force of the WTO agreement (Article 27.3b).

Paralleling the moves to enhance intellectual property protection under the auspices of the GATT were moves on the part of UPOV to bring the Convention into line with developments elsewhere, and particularly with respect to biotechnology. PBRs' research exemption made them inadequate for protecting biotechnically engineered plants since they offered protection at the level of the whole plant when what was required was protection at the level of the gene (Lesser, 1990, p. 67; Van Wijk *et al*., 1993, p. 7). But by 1987, it was clear that UPOV would be strengthened. According to Fowler *et al*. (1988, p. 241), UPOV's members had been divided between small seed houses and the integrated genetics supply industry, the former fearing gene patenting, the latter favouring new initiatives in this respect. UPOV was revised in March 1991.

There were some critical changes made to the Convention, outlined in Table 2. Note that the right of farmers to save seed from one harvest for planting the next, what the American Seed Trade Association had referred to as the 'farmers' right' in hearings on the PVPA had become known as the 'farmers' privilege' and was no longer secure (RAFI, 1993; Fowler, 1994, p. 153).[29] Section 15.2 of the new Convention allows, as an optional exception, seed saving 'subject to the safeguarding of the legitimate interests of the breeder', implying that royalties should be paid to breeders where seed is saved (UPOV, 1991, p. 14). On the other hand, there is a compulsory exemption for breeding other varieties (Article 15(1)(iii)). However, the right, in general, is strengthened since it applies to 'Essentially derived and certain other varieties' as defined under Article 14(5)(b) and (c). Lesser (1991, p. 129) expresses concern that, since the definition is unclear, this will lead to quasi-IPR being granted to a breeder over thousands of attributes of a variety which he/she did nothing to create. The 'essentially derived' clause would appear to apply to genetic insertion, giving the

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[28] The final agreement refers to Trade-Related Aspects of Intellectual Property Rights, Including Trade in Counterfeit Goods.

[29] See Knudson and Hansen (1990, p. 4) and RAFI (1994) on the Asgrow v Kunkle Seed Co. and Asgrow v Winterboer cases respectively.

owner of PBR the right to demand royalties from innovations based on insertion of one or two genes into a plant over which the right is held.

Table 2. Comparison of Main Provisions of PBR under the UPOV Convention and Patent Law

Provisions	UPOV 1978	UPOV 1991	Patent Law
Protection coverage	Plant varieties of nationally defined species	Plant varieties of all genera and species	Inventions
Requirements	Distinctness	Novelty	Novelty
	Uniformity	Distinctness	Inventiveness
	Stability	Uniformity	Nonobviousness
		Stability	Industrial application and usefulness
Protection term	Min 15 years	Min 20 years	17-20 years (OECD)
Protection scope	Commercial use of reproductive material of the variety	Commercial use of all material of the variety	Commercial use of protected matter
Research exemption	Yes	Not for essentially derived varieties	No
Farmers' privilege	In practice: yes	Up to national laws	No
Other	Species eligible for PBR cannot be patented		

Source: Adapted from van Wijk *et al.* (1993, p. 8).

New Biotechnologies

Recent developments in biotechnology can be understood in this context. A number of authors have commented on the paradigm-like shift that biotechnologies could achieve (Orsenigo, 1989; Otero, 1995; Roobeek, 1995; Freeman, 1995). Much of this discussion considers the issue at the macroeconomic level, and takes the view that it will not be biotechnology alone that leads to a new mode of accumulation, but biotechnology, new materials, and information technologies working synergistically to form a new *techno-economic paradigm*.

There is no doubting that there could well be some revolutionary changes in the way in which the agro-food system functions in coming decades. Most interesting of all are potential developments in the food processing industry, where authors have speculated for some time as to the possible emergence of a 'generic biomass inputs sector' as a result of technologies which allow biological materials to be fractionated into component parts for the final manufacture of food products (Goodman and Wilkinson, 1990, pp. 135, 134-9; also, Goodman *et al.*, 1987, pp. 123-44). The implications for commodity markets as they are currently understood could be far-reaching (see Ruivenkamp, 1992; Hobbelink, 1991, Ch. 6). Other potentially revolutionary techniques relate to so-called novel products, which will affect the ways in which agriculture interacts with other sectors of the economy.

Yet whilst certain techniques used to create new products are certainly emerging, 'there appears to be substantial continuity with the past with respect to:

1. increasing horizontal integration across agricultural inputs - breeding for responsiveness to inputs and to facilitate harvesting will give way to herbicide tolerant varieties;

2. deepening of vertical integration - breeding has facilitated mechanised harvesting and handling of the final product. Biotechniques are increasingly geared towards downstream aspects of food production, representing higher value-added, and greater opportunities for profit, in upstream sectors of the chain of value in food (Lacy and Busch, 1991, p. 160). Lamola (1995; also RAFI, 1997) speaks of end-use tailored, or identity-preserved varieties;
3. the actors involved are, in many cases, one and the same as those who prospered through the BCM paradigm (erstwhile agrochemical and seed companies);[30]
4. emerging products take their cue from their supposed ability either to replace, or alter the functioning of, elements of the previous paradigm which have been heavily criticised in the past (Buttel, 1995, pp. 32-5); and
5. a continuing lack of emphasis, in private sector breeding, on pest resistance - although biotechniques provide tools for reducing pesticide use, current trends seem as likely to increase, as to reduce their use. Where resistance breeding is undertaken, it is of the gene-for-gene vertical resistance type' (Hogg, 2000)

In many respects, therefore, the goals remain rather similar to those which have existed since the Second World War. As far back as then, scientists were discussing the possibility of breeding plants which would be resistant to DDT (something which eventually happened in the 1990s). In particular, the attractions of the new techniques are seen principally in terms of the increased control that can be exerted over the transformation of organisms through recombinant DNA techniques. Indeed, Richards (1994) speaks of biotechniques as heralding a 'second designer phase' for agriculture. Whereas the Green Revolution focused on ideotypes for monocropping in controlled *physical* environments, the second phase seeks to shape 'econotypes' to meet the need of future *economic* environments. The emphasis on control within the laboratory[31] has tended to obscure ecological issues concerning the functioning of biotechnically engineered products in the field. At the same time, innovation in agriculture seems to be designed less and less with the farmer and the field in mind, and more and more with a view to the higher value-added downstream processing and retailing possibilities.

The most obvious break with the past is the ability of biotechniques to extend the genepool available to breeders and biotechnicians beyond the primary and secondary genepools into the hitherto unexplored (because of species incompatibility) tertiary genepool (Plucknett, 1994, p. 357). Less immediately obvious are the changes which have already been wrought by biotechniques on our perception of the nature of life itself, and the significance of these for our perception of the nature of food and agriculture in the longer-term. To sum up:

> 'Paradoxically, therefore, we are witnessing changes which are simultaneously profound, and incremental. The mode of agricultural research is changing through use of powerful new techniques, but its roots remain in the [pre-existing] … mode. This is to be expected if one accepts that agriculture had become locked in to [a particular] … way of doing things. As Teece (1988, p. 264) points out, one aspect of the locking in process is that firms tend to do best what they have done in the past. If the emergence of biotechnology constituted a radically new paradigm, learning advantages accumulated over time by established FAROs [formal agricultural research

[30] Takeovers have been facilitated by what some see as the industry's premature commercialisation on the basis of hype and speculation (Buttel, 1995, pp. 38-9; see also Maitland, 1996). Even 'established boutiques', such as Genentech, were being taken over (Junne, 1990). Eight years after the flotation of Genentech in 1988, no biotechnology company in the US was reporting a profit (OTA, 1988, p. 81).

[31] This degree of control is, in any case, illusory (see, e.g., Mellon, 1991).

> organisations, both public and private] would have lost much of their significance. However, the fact that biotechnology is very much a process technology has meant that much of the significance of learning, particularly in the downstream operations of private multinational corporations, has been retained. Furthermore … the techniques are deployed in pursuit of a familiar goal, the genetically uniform ideal plant.' (Hogg, 2000)

Speculations Concerning the Role of Economic Instruments

If agriculture techniques really are 'systems', as the above suggests, how does one change them? How does one set about changing 'a way of doing things' in which elements of a system interact? Here, we concentrate on one example, that of pesticide use.

The concept of a pesticide tax, working in isolation, is that through changing the price of pesticides, one alters, at the margin, the use of pesticides. But the systemic nature of the technical system is such that the inputs which combine constitute a particular 'way of doing agriculture'. Marginal changes in use may be possible in this context, as may be the switching from one product to another (if the tax was structured to reflect some measure of potential environmental damage) but the likelihood of bringing about more significant changes in behaviour seems less likely. The following considerations seem important:

1. The downstream requirements of major food processors tend to mitigate against a significant shift to *in-situ* diversity in agriculture. The same can be said for the requirements of consumers and retailers in respect of the cosmetic appearance of unprocessed foods. The institutions governing the availability of seed varieties which can enter into commerce also mitigate against any broadening of the genetic base of agriculture in situ;
2. The uniformity of the crop in the field places some demands on the use of pesticides. Some new biotechnologically engineered crops are designed with the tolerance to herbicides in mind. In this context, marginal changes may be possible, but for a given seed, switching herbicides is not an option. The integration of seed and chemical is specifically engineered in the genetic make-up of the seed;
3. Trying to reduce the use of pesticides in a more fundamental way requires a new approach to 'doing agriculture' which places different demands upon the cultivator in terms of the required knowledge and skills. The increasing resort to 'off-farm' inputs has led, to some degree, to a transfer of expertise and knowledge from the farm to the input supply industries. Changing one's practices requires the agronomic equivalent of re-training;
4. This in turn requires that the human capital exists to facilitate this 're-training'. To the extent that accompanying measures are absent, or poorly developed, the pool of human capital resources required to facilitate such changes may be limited;
5. The limitations of human capital availability are likely to reflect the increasing privatisation of agricultural research. It can be expected that the perspective of private agricultural research stations might be somewhat different to that of public ones. The transfer of agricultural research capabilities from public to private has been occurring at exactly the time when the public good nature of agriculture has come to be perceived as increasingly important, and as concern regarding the negative externalities associated with modern agriculture have become better understood.

None of the above is intended to deny that instruments such as pesticides taxes may have a role to play in an overall policy package designed to move agriculture away from the 'high external input' model which it has followed for thirty years and more. But there are reasons to suspect that the changes which flow from such a tax implemented in isolation, will not be especially profound (unless implemented at a 'deliberately punitive' level).

There are other factors at work. Several factors incline the agricultural system towards greater genetic uniformity. These include the demands of retailers (products which can be handled easily because of their standardised nature); the demands of processors (for specific physical and chemical properties of products, products with a specific taste); the demands of consumers (unblemished, 'cosmetically pure' products); and the exigencies of 'mechanical control' in the field. These factors, when set alongside the pattern of integration of inputs in agriculture, make profound change rather more difficult to realise.

The changes which have occurred in agriculture over the decades reflect a co-evolution in tastes, technologies, and institutions. They both reflect, and have enabled, wider cultural changes (within and outside rural areas). We are, to a degree, locked in to a system founded on genetic uniformity. It is this uniformity, and the implied ecological vulnerability, which partly determines the requirement for chemical inputs.

For these reasons, the potential for changing farmers' practices (in ways occasioning reduced use of chemical inputs) seems as likely to lie in helping farmers 'escape' the demands for uniformity which they experience, as it does in changing the price of pesticides. The proliferation of farmers' markets is one mechanism through which this can occur, since direct marketing of fresh (or processed) produce enables farmers to produce for more specialised markets, and ones in which they themselves can play a role in shaping tastes and preferences. Indeed, the tastes and preferences of consumers can also influence more directly the practices of farmers rather than being 'mediated' by the wishes of processors and retailers. Tastes and preferences are amenable to change over time.

5.2 Energy saving and waste minimisation technologies

Empirical experience suggests that there may well be five pound notes waiting to be picked up from the floor where issues of waste generation and energy consumption are concerned (probably water use also). The case of the Landfill Tax provides some interesting examples. In the case of firms, the possible responses to an environmental tax might be categorised, broadly, as follows:

i. Reduce exposure to the tax by acting illegally (illegal dumping);

ii. Reduce exposure to the tax by exploiting loopholes which it becomes financially profitable to exploit once the incentive structure it is faced with has been altered by the tax;

iii. No response, other than simply paying the tax;

iv. Reduce waste landfilled slightly, with no significant change in technology or technique (through, for example, marginal increases in recycling);

v. Revert to alternatives to disposal to landfill, hence reducing exposure to the tax, though without major changes in the production technique;

vi. Make use of existing cleaner production techniques employing different technologies and reducing exposure to the tax by reducing generation of waste in the production process; and

vii. Having made use of existing technology, investing in new research and development aimed at uncovering innovative technologies and techniques for use in production.

These responses indicate progressively more sustainable approaches to the problem posed by the environmental tax. Which of these responses any one firm makes will depend on the range of institutional factors discussed above. In particular, it needs to be stressed that:

> '…many prevailing industrial techniques that operate effectively in a given establishment can be transferred to another only with considerable cost, even if the original operator is open and helpful. Partly that is because of the complexities involved and the high cost of teaching and learning. Partly it is because significant modifications may need to be made if the technology is to be effective in a somewhat different context.' (Nelson, 1992, pp. 61-62)

The 'micro' factors that appear to influence the way in which firms respond differently include the following:

i. Size of company (management time available to examine the issue);

ii. Nature of the examination of the issue undertaken (if at all) – how long is spent? What is the level of knowledge of the alternatives? Are costs well known? How well is the financial appraisal carried out?

iii. Nature of the company (does the company encourage continuous innovation throughout the organisation?)

iv. Degree of significance (real and perceived) of waste as a 'key cost issue', which in turn may be related to both waste intensity and the method of accounting for waste expenditure.

The more 'macro' influences on behaviour appear to include:

i. Institutional inertia;

ii. Policy uncertainty (which relates to actors' expectations);

iii. Availability and knowledge of alternatives;

iv. Culture – although again, this is changing (steadily rather than quickly).

An important lesson from environmental practice is that the response of firms to price signals varies from firm to firm – even when all firms face the same change in price signals. The explanation for these different behaviours must therefore include factors other than price incentives.

At one level, the different possible responses to an environmental tax are easily explained. We simply resort to the language of market failure. We can explain sub-optimal changes by a lack of internalisation of externalities (which a landfill tax seeks to address), a lack of information available in the marketplace, 'government' failure, 'institutional failure'. But whilst one explanation may explain the case of a given enterprise, enterprises respond quite differently even when they operate in the same market. It seems inadequate to simply point to failures of markets when some companies make a vastly better job than others of responding to the challenges they face in *the same* market place. It is not an issue of *markets failing*, but one of companies within markets behaving differently.

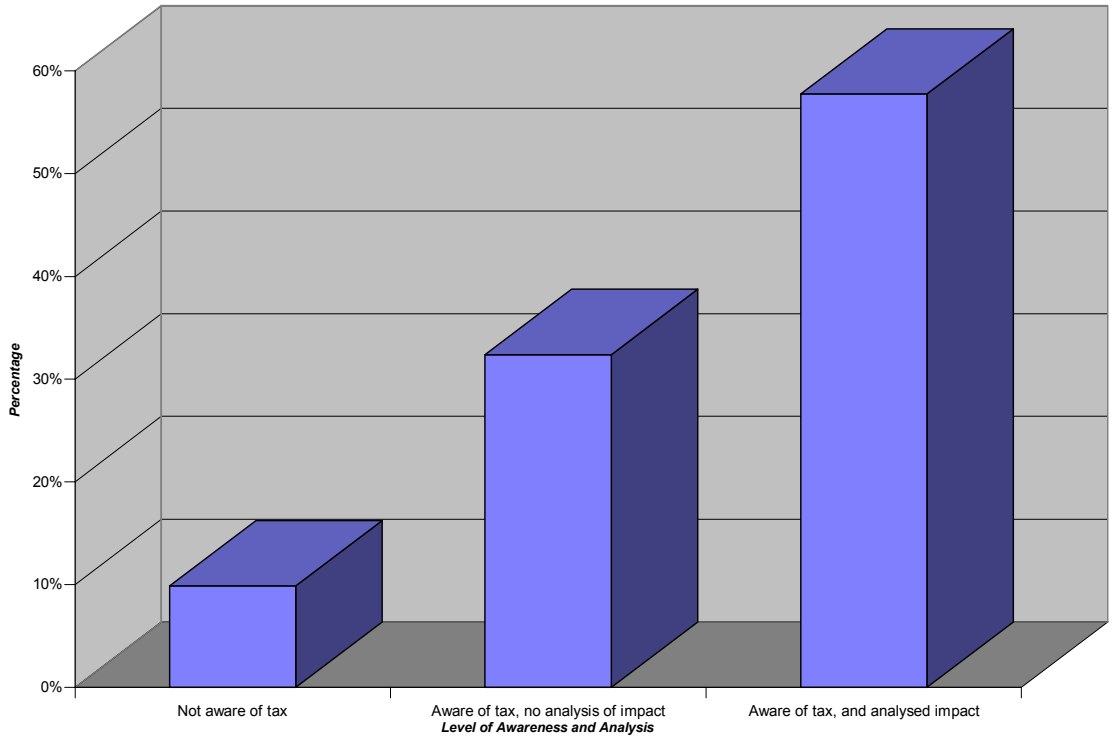
Whilst price incentives act to generate signals to move matters in the right direction, without measures to understand, and overcome, the differentials in performance which exist, the effects of price alone can be expected to be muted since, *a priori*, some firms are less likely to respond than others. In what follows, we look at the response of actors producing different waste streams.

General Issues

One of the pre-requisites for considering a response to a tax is 'knowledge of it.' In a 1997 study by ECOTEC (EFILWC 1998), an attempt was made to understand the level of knowledge of the tax amongst commercial and industrial companies shortly after it was first introduced. Figure 1 illustrates the percentage of those sampled who were aware of the tax in advance, and of those who were aware, those who made some attempt to analyse its impact in advance. Seven companies, or 10 per cent of the sample, stated that they were unaware of the tax in advance. None of these respondents analysed the tax's impact. Of those who showed awareness of the tax in advance (90 per cent of sample), approximately a third (32 per cent) carried out no analysis of the tax's impact.

From the few accurate responses obtained (concerning details of the tax), there was clearly substantial variation in the advanced knowledge of the tax which companies had. Some companies were aware as much as two years in advance, whereas others became aware only a month in advance. It is clear from the responses that at least three waste management companies ran seminars in advance of the tax to inform customers of the tax and how to cope with it. Apart from this source, trade journals and associations were mentioned as sources of information. There does not appear to be any correlation, from the limited evidence gained, of a link between the time for which companies were aware, and their response to the tax.

Figure 1: Awareness of Landfill Tax prior to its introduction

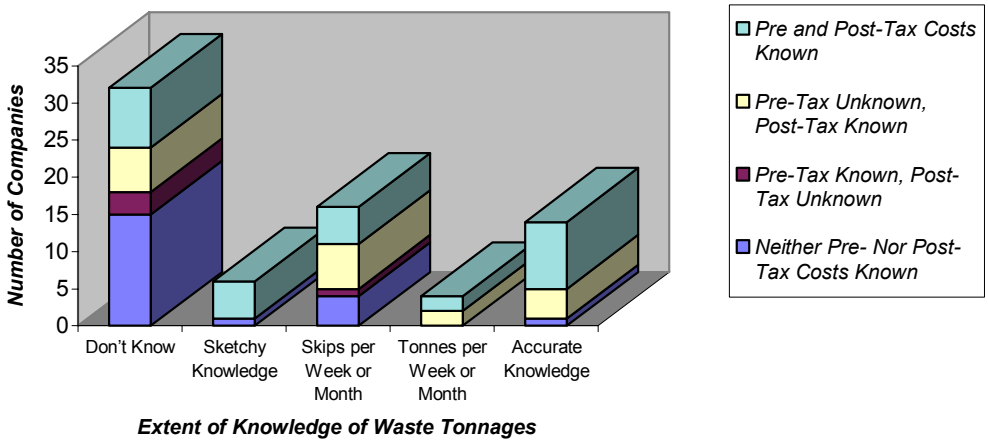


Source: EFILWC (1998)

To understand the extent to which awareness of waste issues had changed as a consequence of the tax, we asked the same companies about the amount of waste they produced before and after. A large number (44 per cent) of companies did not know the quantity of waste they produce. Coincidentally, this was the same figure as in an earlier survey conducted for Biffa in advance of the landfill tax. This estimated that although waste was costing UK industry £2.6 billion, some 44 per cent of UK firms did not keep track of

waste costs, and over half had no plans for waste minimisation (Biffa Waste Services, 1994). In our survey, of the 44 per cent who did not know the quantity of waste produced, around half (21 per cent of the total) did not know anything about the costs of waste management either.

Figure 2: Extent of Knowledge of the Tax Pre- and Post-introduction



Source: EFILWC (1998)

With the exception of some inert construction and demolition wastes, the tax appears to have been passed through completely by most landfill operators, so that the tax is more or less fully incident upon 'the disposers'.[32] Even where it was passed through in full, some companies would not have made it clear to their customers what the reason for the increase in gate fee was. The regulations surrounding the tax suggested that if landfill operators wanted to be able to recover unpaid landfill tax as a bad debt, they had to declare the tax *as* landfill tax on customer invoices. If they did not, however, they were allowed to reduce their liability for the tax through sorting of waste prior to its disposal to landfill. In other words, if the tax was not declared as such on invoices, the landfill owners could use the amount charged, but not stated, as tax to support sorting of waste (for recycling, or separation into lower rate and standard rate materials) prior to its being landfilled. Where landfill operators adopted this approach (and many did), customers would not be able to tell from their invoices that the increase in payment for disposal was due to a *landfill tax*.

Effects on Commercial and Industrial Wastes

There is no data from which one can really elicit the change in quantities of commercial and industrial waste landfilled since the tax was introduced. An ECOTEC survey just after the Landfill Tax was introduced suggested that many commercial and industrial waste producers were responding to the tax, but that the responses exhibited enormous variation (even within sectors and across what seemed otherwise similar companies). It was generally believed that the elasticity of response to the tax from commerce and industry would be greater than that for municipal waste, but lower than that for construction and demolition waste. Figure 3 reports the response to the tax of companies surveyed.

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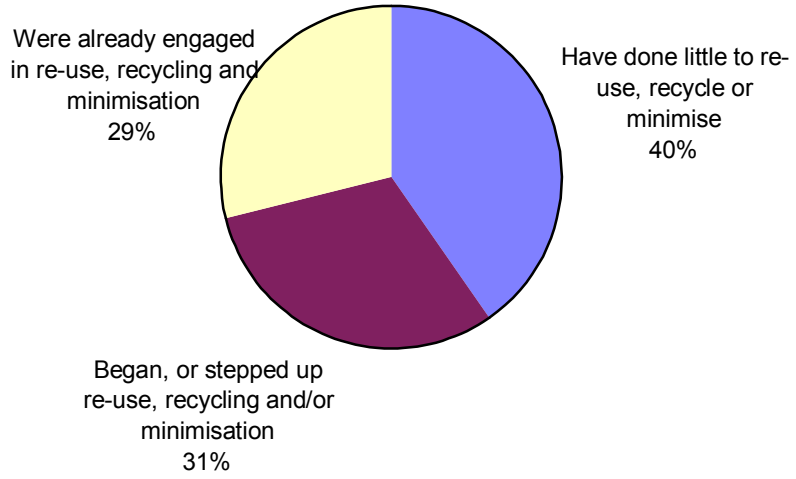
[32] One could probably discern a declining trend in pre-tax landfill gate fees in real terms in recent years. But the explanation for this would appear to lie not in competition across disposal options (though construction and demolition wastes would provide an exception), but in competition within the landfill disposal companies arising from a desire to maximise the fill of void space prior to the introduction of new regulations arising from the Landfill Directive.

Figure 3: Responses to Landfill Tax of Companies Interviewed



Note: Total responses in this chart was 72 (one response for each company)

Source: EFILWC (1998)

The range of responses prompted by the tax was considerable: 31 per cent began, or stepped up, efforts in waste minimisation, re-use and recycling, whilst 40 per cent did nothing. Five companies implemented waste minimisation schemes as a result of the tax. Fifteen companies in the survey mentioned the Packaging Directive when asked about other issues concerning waste that were affecting their outlook. The Directive led to a heightened awareness of the need to recycle packaging wastes. Thus, it seems that some of the increased recycling activity recorded was probably not due to the landfill tax *per se*, but to the combination of the tax and the Packaging Regulations.

Picking up the Fivers on the Floor – Some They Will and Some They Won't

Despite the influence of other instruments, many companies seemed to be largely unmoved by the tax, raising questions as to how one could best explain the differential responses of companies in the wake of the landfill tax. Five companies in the ECOTEC survey undertook waste minimisation as a result of the tax. All four who were able to quantify the reduction in wastes generated reported reductions in waste quantities of a third or more, whilst three reported reductions of more than two-thirds in the quantity of waste produced. The companies engaging in waste minimisation made investments that had payback periods of between a year and a half and two years.

Foundries

The response of different foundries was particularly noteworthy. Waste sand is an intrinsic element in manufacturing castings. All the foundries consulted in ECOTEC's survey had examined the impact of the tax, although several firms had already made an effort to recycle or reduce their waste well before the tax. Three companies had invested in a waste sand reclamation unit before the tax was enforced. Another three foundries, however, thought that the size of their site precluded segregation or the installation of reclamation equipment. Since these companies appeared to be no smaller than those who had invested in such equipment, it seems unlikely that this was the case. The different types of response are outlined below.

A Bristol foundry, having examined the costs of waste disposal, switched contractors, from a large company to a local firm. The foundry was paying less after the tax than it did before without. Another Bristol foundry convinced their waste management company that if they segregated their wastes into inert and active they could reduce their waste disposal bill. The waste management company was less forthcoming on waste minimisation advice which the foundry requested. A Midlands foundry reported that the landfill tax 'was a spur to finding new waste minimisation schemes.' Another foundry in the Midlands, after the tax was introduced, found a secondary user for half of their waste sand, diverting almost 8000 tonnes per annum from landfill. This foundry has also investigated thermal reclamation but found it to be incompatible with their binder resins. However, this same problem was overcome by a Staffordshire foundry who changed their binder system.

A Manchester foundry started recycling schemes for some of their wastes but not sand. The tax made them look once again at thermal reclamation but they still believe it to be uneconomical. The firm has said that it might link up with other foundries to benefit from the economies of scale associated with thermal reclamation.

The gap between best and worst practice is large in the foundry sector. ECOTEC's survey found what might be described as 'best practice' in three smaller foundries, suggesting that scale was probably not the obstacle others perceived it to be.

Food Companies

All of the food companies interviewed were aware of the tax in advance though once again, there was considerable variation in exactly when they became aware. Only one did not examine the impact of the tax in advance, and this company has not changed its practices in any way. All other companies expressed the view that they would be able to offset the increased costs of the tax through waste reduction.

One company claimed to have examined the impact of the tax 'to a certain extent' but had taken no action thus far. It expected to be changing its waste management company in the near future. Two companies mentioned the fact that the tax had led to a more rigorous examination of the costs of disposal and of waste more generally. One of these began to implement waste minimisation policies, and had employed a part-time waste reduction officer for the purpose. The same firm asked its contractor to weigh all waste arisings having previously been charged on a volume basis. The other was already engaged in waste reduction activity. For another company, a major waste minimisation programme was introduced just before the tax, and it changed its waste disposal company to one that employed a MRF. In one other firm, a waste reduction strategy was introduced, and it was looking to comply with BS7750/EMAS. The last company in the survey stated that they had been recycling for 20 years, but that recently, owing to contract complications, they had to cease recycling of polythene. The landfill tax had not increased product prices.

All in all, five of the eight companies interviewed were either considering or actively involved in waste minimisation practices. In this respect, the food sector shows a high degree of responsibility as regards waste issues. This may be due to the fact that generally, the sector experiences strong competition on price, and may already have taken measures to reduce costs as far as possible.

Effects on Construction and Demolition Wastes

The waste stream which has, almost without doubt, been most affected by the tax has been construction and demolition (C&D) wastes. A detailed exploration of the change in fate of these wastes can be found in ECOTEC (1999). In this section, we explore some of the key issues.

First of all, as with other wastes, pre tax data was not good. There are problems with trying to quantify the C&D stream, not least because a significant fraction may be used on site for 'useful purposes' or simply for burial within a given development. The 'official' estimate of C&D waste arisings was, for many years, that produced by Howard Humphreys (1994). Their estimate of 70 million tonnes was believed to be out of date. However, England and Wales data from a more recent survey suggests this may be a reasonable estimate (total estimated is around 72.5 million tonnes – see below). On the other hand, an estimated 'error' figure of the order 35 per cent is believed to be applicable. Other recent estimates include that of BDS Marketing (1997) who placed the figure at 88 million tonnes. Industry operators with whom we have spoken believe the figure may be closer to 100 million tonnes. The margin of error is clearly large (equivalent to the annual weight of municipal waste arisings in the UK).

What is known about C&D wastes is that landfill operators were inclined to accept materials such as uncontaminated soils, clays, concrete, brick and other hardcore materials at low or zero charge (as discussed earlier). This is because the materials could be used in the construction of access roads, for cover material, and for site remediation at the end of the landfill's life. For sites accepting inert wastes only (for example, quarries whose planning permission requires them to backfill the quarry as material is excavated) these bulk materials were essential in order for quarry companies to meet the requirements of their planning consents (which might require them to backfill as excavation proceeds).

Because the gate fees for these wastes had been so low, and because they are typically quite dense, the tax implied a significant increase in the disposal costs. The other significant cost element associated with C&D wastes is transport costs, and these have also been rising recently as a consequence of the fuel duty escalator in place in the UK. Hence, both transport costs and disposal costs have been increasing in the post-tax period.[33]

Historically, because of the lack of landfill in the area, and because of the costs incurred in importing raw materials and exporting wastes from and to appropriate destinations, the South-east of England has seen the development of an industry engaged in recycling materials suitable for (re)use in construction. The arrival of the tax has seen this approach being adopted more widely, so that there is now increasing competition between, for example, low grade primary materials, and the products produced by mobile and static crushing plant operated by various actors who are now entering this field of activity. Indeed, those traditionally in this industry appear to have witnessed a surge in competition as a consequence of the behavioural changes initiated by the tax.

Alongside the tax, one can point to other initiatives that may have assisted in this development. These are:

i. The increase in transport costs (fuel duty escalator);

ii. The desire of the primary aggregates industry to be seen to be 'doing something' under the threat of an aggregates tax (now a reality, merely substituting a 'PR imperative' to act with a financial incentive); and

iii. The combined effect of a number of initiatives started in DTI and by the industry to promote changes in building practices.

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[33] It is interesting to note, in this context, that in the CSERGE (1993) study of externalities of landfill which was used to inform the tax level, landfilling was linked to a 'typical journey' length. The associated transport externalities form a significant portion of the total external costs estimated.

Table 2: Construction and Demolition Waste Production in England & Wales 1999

	Uses/ destinations	Specific component parts	'000 tonnes Arisings
Recycled Materials 25.1 million tonnes (34.7%)	Aggregates: 22.7 million tonnes (31.3%)	C& DW crushed for use as aggregates	20,467
		Mixed C& DW/ soil screened for use as aggregates	2,231
	Soil: 2.4 million tonnes (3.4%)	Mixed C& DW/ soil screened for use as soil	1,643
Other Beneficially Re-used Materials 29.8 million tonnes (41.2%)	At licensed landfills (both clean and/ or contaminated materials): 9.5 million tonnes (13.2%)	Useable crusher fines/ soil from crushing C& DW	790
		C& DW used for restoration	111
		C& DW used for engineering	1,229
		Soil used for restoration	2,663
		Soil used for engineering	2,335
		Mixed C& DW/ soil used for restoration	2,692
		Mixed C& DW/ soil used for engineering	505
	At registered exempt sites (inert only): 20.3 million tonnes (28.0%)	C& DW and recycled aggregates	8,552
		Soil and rock	11,132
		Other inert materials	630
	Materials landfilled as waste at licensed landfills 17.5 million tonnes (24.1%)	Clean, unmixed C& DW	66
		Mixed and/ or contaminated C& DW	2,569
		Clean soil and/ or rock	3,042
		Mixed and/ or contaminated soil	4,506
		Mixed/ unspecified C& DW/ soil	7,319

Though these other aspects may be of some significance, our own work suggests that the tax is the most important driver. One can say this with reasonable confidence on the basis of the timing of the changes which occurred (they occurred at the tax's implementation or soon after), and on the basis of the responses of companies that the author interviewed from construction and demolition, waste management, and primary and secondary aggregates industries.[34]

As a consequence of changes in the way in which C&D wastes are managed, the fate of these wastes is changing. Obviously, the initiatives mentioned above would be expected to make themselves manifest through reductions in disposal to landfill. However, the magnitude of the reduction that has been experienced cannot be accounted for by increased recycling and re-use alone. There has been significant concern over the developments in respect of disposal to sites exempt from waste management licensing, and therefore, not liable to pay landfill tax.

Exemptions from waste management licensing follow from the UK interpretation of the Waste Framework Directive, and are set out in Schedule 3 of the UK's Waste Management Licensing Regulations (by which the Framework Directive on Waste was transposed into UK law) (HMSO 1994). The two exemptions of most significance in the context of C&D wastes are those under Paragraphs 9 and 19 of Schedule 3 of the WMLR. Paragraph 9 relates to:

> 'the spreading of waste soil, rock, ash or sludge, or waste from dredging any inland waters or arising from construction or demolition work, or any land in connection with the reclamation or improvement of that land if –
>
> by reason of industrial or other development the land is incapable of beneficial use without treatment;
>
> the spreading is carried out in accordance with a planning permission for reclamation or improvement of land and results in benefit to agriculture or ecological improvement; and
>
> no more than 20,000 cubic metres per hectare of such waste is spread on the land.' (HMSO 1994)

The last clause can be converted, roughly, into a tonnage requirement. A number of different factors are proposed for different types of waste. Taking the figure recommended by Customs and Excise for converting volumes of inert wastes to weights, the factor would be 1.5 tonnes per cubic metre, giving a maximum per hectare weight of material recovered of 30,000 tonnes.

Paragraph 19 refers to the use of waste materials from demolition and construction and other activities for '*relevant work if the waste is suitable for those purposes.*' These relevant works include '*provision of recreational facilities'* or '*the construction, maintenance or improvement of a building, highway, railway, airport, dock or other transport facility on that land but not including any deposit of waste in any other circumstances or any work involving land reclamation*'. There is no limit placed upon the quantities which can be used for 'relevant work' although Para. 19 does also refer to storage of waste, and there is a limitation on the weight of waste that can be stored where road plannings are concerned.

Since any site which is exempt from licensing does not fall under the scope of the Landfill Tax, it becomes clear that whilst (depending upon the fee structures) prior to the tax those responsible for managing inert wastes might have been indifferent as to the status (licensed or unlicensed) of the site (at both types of site material would have been accepted at

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[34] Further details can be found in ECOTEC (2000).

zero, or close to zero gate fee), in the wake of the tax, the incentive structure has shifted in favour of sending waste to sites exempt from licensing, and hence exempt from the tax. To the extent that the letter of the law (laid down in the WMLR) is adhered to, this is in complete accord with Government policy, and indeed, is seen as desirable where the exempt site is operating within the terms of exemptions as specified. Through this process, waste is moved up the so-called 'waste management hierarchy', away from landfill and toward recovery (and recycling) activities.

The advantages, in terms of the costs of inert waste disposal/recovery, of being close to an appropriate exempt activity can be significant. Consultations undertaken for the ECOTEC (1999) report suggested also that owner operated exempt activities are a prevalent phenomenon, just as is the case with licensed landfill sites. The low or non-existent gate fee at sites exempt from licensing also makes it financially worthwhile to transport inert materials a greater distance to the site than would be the case if disposal was to a licensed landfill. Indeed, the fact that gate fees can be set on the basis of transport costs to maximise revenue for a given load has been used to good effect by some exempt site operators who may vary gate fees depending upon the distance a load has travelled. Wastes travelling further can be accepted at lower gate fees if they have 'passed' existing licensed sites. Consultees gave varied responses when asked how far wastes could be transported to their sites. The longest distance was 50 miles, though some operators who had contracts with those generating waste nearby mentioned that typical distances were much shorter.

Conversely, those operating licensed inert waste landfills comment that running such sites is no longer profitable. Some of these landfills are quarries which are having problems meeting the terms of their planning consents. The period taken to restore such sites has, in the view of planning officers, doubled.

The Changing Fate of 'Inert' Wastes

Shortly after the tax was introduced, the Environmental Services Association (ESA), on the basis of a survey of its members, estimated that there had been a reduction in inert wastes being landfilled from 42 million tonnes to 24 million tonnes, a reduction of 18 million tonnes from the pre-tax situation. They argued that this was leading to a lack of daily cover and engineering material and was leading to an increase in demand for primary materials. Indeed, ECOTEC (1999) surveyed a small number of companies selling alternative cover materials and some had clearly benefited from the tax's introduction.

That work suggested that as much as 36 million tonnes per annum of inert wastes might have been diverted away from landfill in the wake of the tax. If one accepts the Quarry Products Association's estimates that there has been an increase in recycling and re-use of C&D wastes of 12 million tonnes in the last decade, then the increases in recovery of inert wastes through exempt activities is likely to have been of the order of 24 million tonnes per annum. This waste is being used in the construction of bunds, hardstanding on farms, 'landscaping' (including golf courses and sports fields), levelling of fields, and other such purposes.

This would be of less concern were it not for the fact that because the sites are unlicensed, and because license fees are intended to cover costs of inspection, the only resources available to recover the costs of the inspection of exempt sites are those resource made available to the Environment Agency and the Scottish Environmental Protection Agency under Government grant-in-aid. This leads to a frequency of inspection which is most probably inadequate to ensure the exemptions are not being abused, especially since the activities have increased significantly in the wake of the tax. ECOTEC (1999) listed a number of sites identified by planning officers and Environment Agency staff as being 'of concern'.

Many actors, from area Environment Agency officers, to County Planning Officers, through to landfill operators themselves, as well as waste management consultants, raised concerns regarding these exempt activities. It is believed that many accept wastes that should not be, including large quantities of (methanogenic) wood, and hazardous wastes such as asbestos and contaminated soils. Furthermore, in England, waste disposal matters are dealt with (for the most part) by a separate tier of local government from that which deals with planning applications (which are a free-standing requirement for most exempt sites other than those counted as permitted development). Waste planners feel that those granting planning permissions are not fully aware of the issues surrounding waste disposal and grant permissions that are too lax. They find that it is close to impossible to prosecute those who abuse their exemptions by constructing vast 'landscaping' projects (for which no physical limits appear to have been established in many cases).

Exempt Sites

In the ECOTEC report, 32 exempt site operators were consulted. Of these, only one had not commenced activity (they had merely registered the site), another claimed to have no recollection of the activity (it may have been a 'dead' activity – the selection of interviewees was random from the Public Registers), and two *probably* should not have been exempt in the first place.[35] Of the remaining 28, 20 began operations after the tax was introduced and four were operating before. Four were unable to say when the operation started (see Figure 4).

The fact that such a large percentage of the exempt activities sampled (randomly) came into operation after the tax came into effect, though potentially significant (even allowing for the small sample), should be seen in the context of:

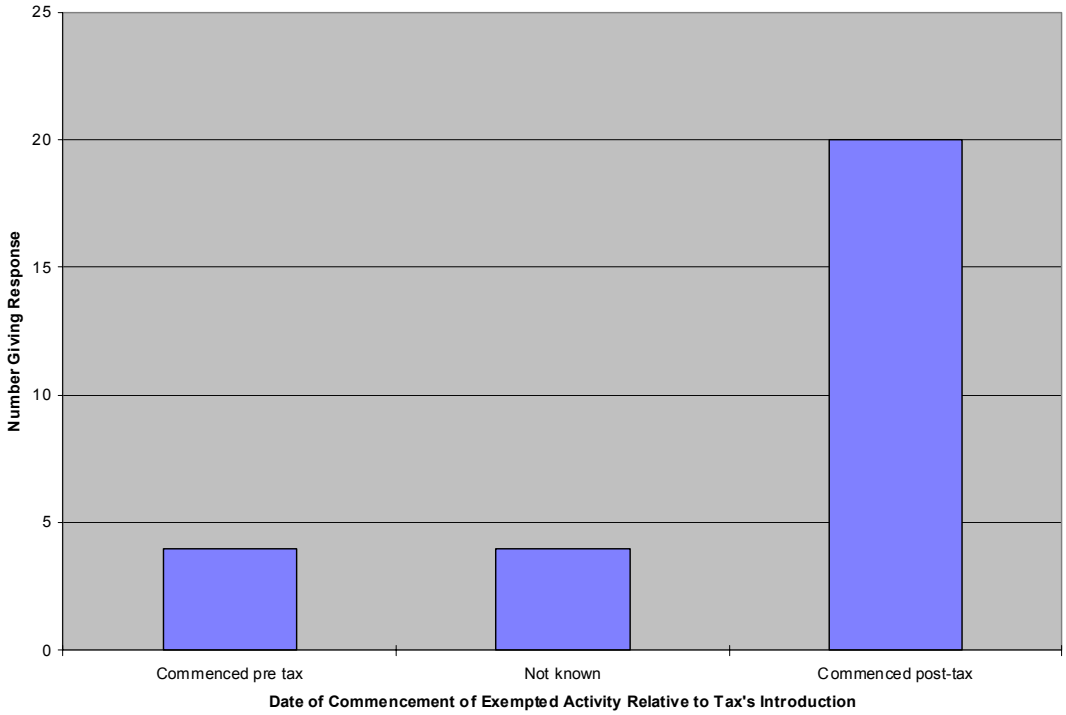
i. the fact that the WMLR were only introduced in 1994, so that there have been more 'post-tax years' than pre-tax ones as far as the WMLR are concerned; and

ii. the fact that exempt activities may have, on average, a relatively short lifetime (although equally, the supposition is that Environment Agency lists of exempt activities are not restricted in all cases to 'live activities' only).

Both these factors could incline one to the view that the apparent skewing of the activities towards the post-tax period is explicable, at least partially, through appeal to the timing of the introduction of the WMLR and the (possibly) short lifetime of exempt activities. As such, in and of itself, it may not be evidence of increased exempt activity.

[35] This is a diplomatic way of saying they were almost certainly breaking the law.

Figure 4: **Date of Commencement of Exempt Activities**



Note to Figure 4: 28 responses.

In our survey of construction and demolition companies, we asked them where they sent wastes which were not recycled or re-used. All twelve responded that they sent some waste to landfill, whilst eight sent some waste to exempt sites. These eight respondents now *actively* seek out exempt sites for recovery. One actually advertises in newspapers, another simply commented that they 'keep an ear to the ground' in what is a small community, whilst a third respondent mentioned that farmers were frequently happy to use hardcore for roads and hardstanding. Only one respondent seemed to have sought out an exempt site without finding one.

Of those that did not actively seek out exempt sites, one simply commented that it was easier to landfill wastes, though they themselves had registered for exemptions in the past. They added that clients were happier with licensed landfill since there were unlikely to be issues arising in respect of the legality of any operation. Another implied that they might have done so were they more certain of the legal issues arising. Indeed, the head of the company was considering applying for an exemption on his own farmland which repeatedly flooded in wet weather.

Box 1 captures some, but by no means all of the rationale for re-routing inert wastes away from licensed sites and towards exempt sites. Other slightly more subtle effects are at work, owing to the way in which the Landfill Tax is levied. By common consent, few 'inert' wastes are strictly inert. If construction and demolition materials were to be presented to a licensed landfill site, the load could be assessed as being 'not inert', and hence liable for the standard rate of tax of £10 per tonne. Clearly, to the extent that such a possibility exists at licensed sites but not exempt ones, a carrier with a mixed load is (notwithstanding Duty of Care legislation) less likely to present waste at the licensed site.

BOX 1: ECONOMIC EFFECTS OF THE TAX

Suppose, in the pre-tax situation, landfill of inert wastes costs £X per tonne. Suppose also that there are some exempt sites in existence, and these charge £Y per tonne. Suppose that the cost of aggregates is £Z per tonne.

When the tax is put in place, the landfilling of inert wastes costs £(X+2) per tonne. Under these conditions, the gate-fee which exempt sites can charge could increase to the same level, or if they wish to accept more material, they may choose to charge less. This may be a strategic decision affected by the purposes of the exempt activity (is it the speed of the operation, or the revenue generation which is most important?), the options available to those who could send wastes to the exempt activity (to what extent are there other exempt sites/licensed sites nearby, or to what extent are crushers looking to obtain material and on what terms) and the responsiveness of waste producers to changes in price (which may be related, for example, to the costs of transporting materials since the market is significantly affected by spatial issues).

If the exempt site charges only £2 to accept wastes (the level of the tax), competing sites nearby would have to reduce gate fees to zero in order to remain competitive. If they do not do this (and they may not if there are no exempt sites nearby), an incentive is given to aggregates recycling to the extent that disposal costs to licensed landfill sites have now increased and may make it worthwhile to engage in crushing secondary aggregates or sending aggregates to those already undertaking such activity.

Some aggregates crushers have commented that materials have been more scarce than they expected as a consequence of the establishment of exempt activities. These limit the extent to which they can increase gate fees. This alone would tend to support the view that inert wastes recovered through exempt activities have increased following the tax, although it should not be forgotten that competition for materials amongst those looking to recycle materials has also become more fierce (and some of the exempt sites are themselves involved in crushing activity).

In addition, where fly tipping occurs, the lower costs of sending waste to exempt sites makes it possible that those who are subjected to fly-tipping (who are also those liable for clean-up, and they are subject to Duty of Care obligations) are more likely to seek recovery through exempt activities than disposal to licensed sites. One Environment Agency area office mentioned to us that where waste is fly-tipped on private land, the owners of the land have occasionally done this without much consideration for the nature of the waste. This is not in keeping with Duty of Care obligations and it raises questions concerning the environmental effects of the recovery activity at exempt sites (the Agency has persuaded one private land owner to carry out sampling to determine where the waste should be sent).

Exempt sites often operate for short periods of time, else they may be part of a large development. Consequently exempt sites will either not require any site engineering as such, or any engineering requirements beyond those implicit in the development being undertaken, and so the costs incurred for site management are minimal. Since there is no licence fee, and no regulatory monitoring, it becomes easier to understand why exempt sites can charge gate fees below those at licensed active landfill sites (whether inert or active).

Policy Response

In the March 1998 Budget, the Chancellor announced that a new exemption from Landfill Tax would enter into force in October 1999. The exemption was to affect restoration of licensed landfills as well as progressive backfilling of active mineral workings.

The rationale behind the exemption was to reduce the extent of the problem associated with the lack of materials at licensed inert sites. The exemption recognises that there are environmental costs associated with the slowing down of restoration of completed landfill

sites and of the backfilling of quarries (to the extent that it is a condition of their planning permission that they be backfilled). Implicitly, disposal of waste to such sites is assumed to be at least of equal value to those currently exempt from the tax by virtue of being unlicensed. The exemption from tax is intended to enable licensed operators to compete on a level playing field with exempt site operators as they seek to attract waste for the operations exempted from tax.

The new exemptions from tax suggests that there is an assumption that the effects of the tax are, to some extent, reversible where the fate of inert materials is concerned. There may be reasons to doubt this assumption. That is to say, there may still be problems for licensed sites seeking to attract materials for completion or backfilling. These reasons are outlined below:

i. the nature of the markets which these materials now enter are substantially different from their pre-tax form. It is debatable that, with investments already made in crushing plant, and with exempt site operators seeking to attract materials for different purposes, that once the tax exemption is in place, the materials will begin to flow back to licensed landfill sites. Certainly, the exemption helps in that it makes it possible to drop gate fees to zero on materials for restoration and infilling, thereby levelling the playing field between licensed and exempt sites; and

ii. the fact that some exempt sites are 'in house' activities or are closely tied in with the activities of local enterprises is a reflection of the fact that such enterprises seek to minimise the costs of dealing with waste materials. It may be the case that, in the case of restoration of landfills, ongoing concerns will be disinclined to resort to disposal at licensed sites in the general case. They are likely to seek permanent solutions to problems, and they are likely also (in the case of owner-operated exempt sites) to seek to minimise transportation costs. As such, they might be inclined to avail themselves of the licensed site's tax exempt status only where the financial considerations make such a decision worthwhile. It may be that this still requires licensed sites to subsidise disposal of materials and/or transportation.

Note that the situation is further complicated by the increased prevalence of aggregates recycling operations. Where exempt sites carry out recycling, such operations could be used to enhance the value of waste materials delivered to their site. The same may be true of some licensed landfill sites, but the presence or otherwise of aggregates recycling facilities may give a competitive edge to sites where these are found.

It is also to be expected that loads which might be liable to standard rate tax if delivered to licensed sites are being taken to exempt sites (hence, some exempt operators say that they are accepting 'construction and demolition' wastes, as opposed to wastes where inert fractions have been separated). These are likely to continue to be delivered to such sites as they are ways of avoiding the possibility of having to pay standard rate tax on mixed loads (of inert and 'active' waste).

Analysis

The range of responses lends to the tax a paradoxical character. On the one hand, one could argue that the tax has had a more limited effect than might have been expected, perhaps owing to the fact that its impact on overall costs (and pricing and competitiveness) has meant that its impact in terms of encouraging waste minimisation has been minimal. On the other hand, one could argue (see below) that it is quite odd that in the case of commercial and industrial wastes, such a low tax should have had as significant an impact as it has on

industry. In the survey by ECOTEC (EFILWC 1998), estimates of costs relative to turnover were made. These are shown in Table 3.

Table 3: Survey Results Concerning Waste Disposal Costs as a Percentage of Turnover
Figures are: AVERAGE (RANGE) (PRE- OR POST-TAX) (NUMBER OF DATA POINTS)

Sector	Disposal Costs as % of Turnover
Food	0.00029 (0.00027-0.0003) (pre-tax) (2) 0.0005 (0.0001-0.0009) (post-tax) (4)
Metal goods	0.0035 (0.0007-0.009) (pre-tax) (4) 0.0038 (0.0002-0.01) (post-tax) (7)
Construction	0.0038 (pre-tax) (1) 0.004 (0.0009-0.0075) (post-tax) (4)
Education	0.0011 (0.0005-0.0018) (pre-tax as % salaries) (5) Two increases reported were 17% and 70%
Clothing and leather	0.0004 (0.0001-0.0006) (pre-tax) (2)
Manufacturing	0.00017 (0.00004-0.0003) (pre-tax) (2)
Mechanical Engineering	0.0002 (pre-tax) (1) 0.0003 (post-tax) (1)
Non-metallic Mineral Products	0.0007 (pre-tax) (1) 0.006 (0.00075-0.015) (post-tax) (3)
Retailing	0.025 (0.0072-0.033) (post-tax) (3)

Source: EFILWC 1998

Note: Does not include small construction companies where percentages are of the order 5%.

In the absence of data concerning the effect of the landfill tax on industry, we have calculated the strength of the exposure of different sectors to the tax through combining data sources:

i. The Environment Agency for England and Wales has recently published preliminary data on industrial and commercial waste arisings. This is the result of a survey of around 20,000 companies undertaken in 1998 and 1999; and

ii. Data on turnover and employment of each sector.

The calculated figures will slightly underestimate the burden, as the turnover and employment figures relate to the UK as a whole rather than just England and Wales. However, England and Wales account for some 85-90 per cent of all UK wastes and a similar proportion of industry.

A number of different figures for the burden on industry have been made. This is because no data have been found on the relative amount of industrial and commercial waste that is classified as active or inert waste and hence attracts a differential rate of tax. In the high estimate, all the waste generated in 1998 was assumed to be active waste, so attracted a tax rate of £7 per tonne in that year. The low estimate assumes that all waste was inert, thus attracting a tax rate of £2 per tonne. Evidently, for some industries, the majority of wastes can be 'guessed' to be active, and for others, inert. However, the range gives the complete boundary to all estimates in the absence of more detailed knowledge.

The tax's impact, expressed as a percentage of turnover, is clearly miniscule. The education sector accounts for the highest burden. This is consistent with the fact that the wastes generated arise from the presence of large numbers of students in a relatively low turnover sector.

In advance of the survey, it was hypothesised that the tax might encourage firms to look not just at the costs of waste disposal, but also at the costs of waste materials. In a sense, the tax would act as a lever to persuade companies to look at waste costs as they began to track the costs of waste disposal. The likelihood of this happening in the commercial and industrial

waste sector might, a priori, have been considered low given the small additional financial burden of the tax. Indeed , many companies appear to have changed their attitude to waste in incremental ways or not at all, some doing nothing, others simply seeking a cheaper contractor, or a separation of inert and active wastes so as to reduce their exposure to the tax without altering the amount of waste they produce.

Table 4

	Turnover	**Tax as % Turnover**	**Tax as % Turnover**	**Tax as % Turnover**
	(£m ex VAT)	**High Estimate 2000**	**High Estimate 1996**	**Low Estimate**
Tax Rate Used for Estimate		£11.00	£7.00	£2.00
Industrial Companies				
Food, drink and tobacco	73,246	0.008%	0.005%	0.001%
Textiles, wood, paper	71,185	0.023%	0.015%	0.004%
Chemicals, rubber, mineral products	81,963	0.052%	0.033%	0.010%
Metals, metal products	47,075	0.018%	0.011%	0.003%
Other manufacturing	170,240	0.038%	0.024%	0.007%
Coke, oil, gas, electricity, water	63,314	0.043%	0.028%	0.008%
Transport, storage, communications	131,724	0.028%	0.018%	0.005%
Miscellaneous	-	0.000%	0.000%	0.000%
Total Industrial	**638,747**	**0.034%**	**0.022%**	**0.006%**
Commercial companies				
Wholesale	488,178	0.007%	0.004%	0.001%
Retail	217,710	0.027%	0.017%	0.005%
Hotels and Catering	48,451	0.068%	0.043%	0.012%
Education	5,349	0.309%	0.197%	0.056%
Other business and public administration	2,430,626	0.004%	0.003%	0.001%
Total commercial	**3,190,314**	**0.008%**	**0.005%**	**0.001%**
Total industrial and commercial	**3,829,061**	**0.012%**	**0.008%**	**0.002%**

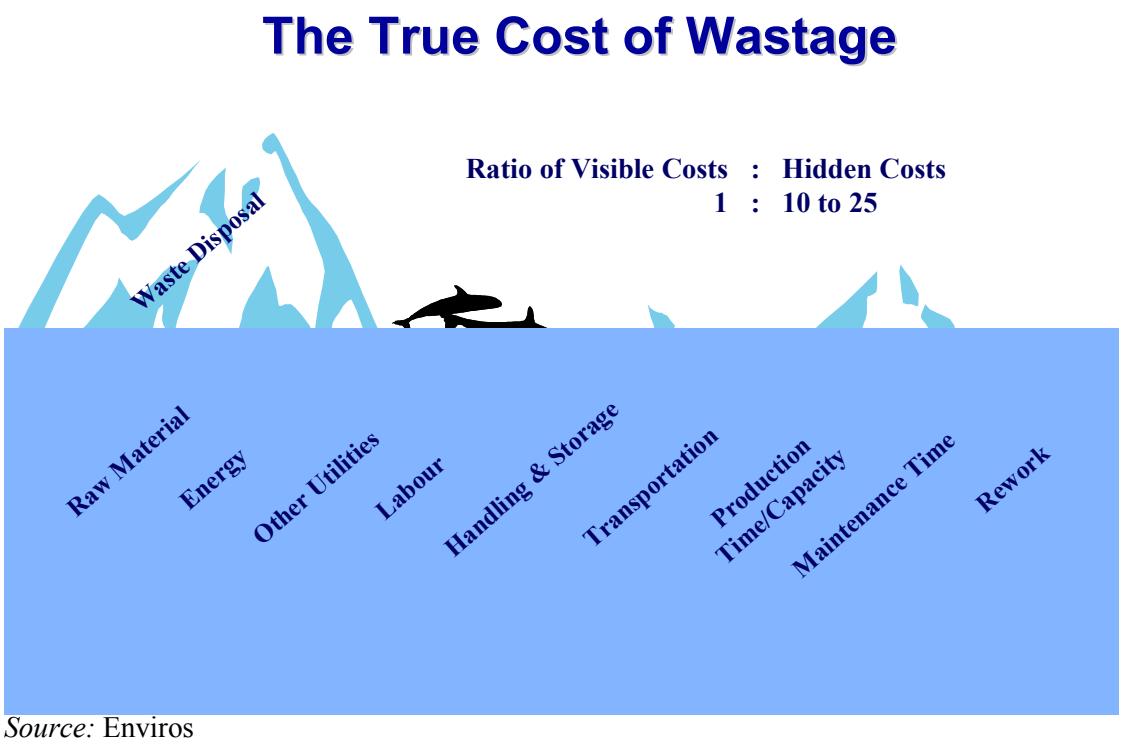
Source: ECOTEC 2001

Yet some companies make fairly profound adjustments to existing practices. Indeed, they adopt practices which, or so the outcomes suggest, they should have adopted earlier. The interesting point here is that some of the 'less marginal' changes appear to deliver the most beneficial outcomes.

To characterise the potential responses, for many, the choice is one of 'marginalist adjustment', or 'Schumpeterian innovation'. In the marginalist adaptations, the same amount of waste is produced, but different ways of dealing with the waste are considered. In the Schumpeterian adaptation, the more radical approach entails not just reducing costs 'at the margin', but reducing waste production. The most significant features of the response cost curve, far from being a smoothly increasing marginal cost, is a) the presence of discontinuities and b) the fact that marginal abatement costs depend on where you start, and where you want to go. Of course, it may well be that for the nation as a whole, an abatement cost curve exhibits fewer discontinuities, but the Schumpeterian 'tunnels through' the cost barrier by making more radical adjustments, improving company performance despite, perhaps even because of, a tax!

Yet the fact remains that to many companies, the benefits of waste minimisation remain hidden. The Schumpeterians are out there, but they may not be the majority, and this applies especially to SMEs. The benefits of looking beyond the 'tip of the waste iceberg' are estimated to be of the order 10-25:1 (see Figure 5). The further along the manufacturing process the waste arises the more significant these losses are, more and more 'value' having being added at each stage of production.

Figure 5: Savings Related to Waste Minimisation



Source: Enviros

Ten companies in the ECOTEC survey were able to give some response when questioned as to the percentage of total costs accounted for by wasted materials. Of these, seven were able to place a figure on their response. Typically, companies who can estimate a figure estimate the percentage of costs to be of the order of a few percent of total costs. This is much greater than the proportion of total costs accounted for by waste disposal, which is typically of the order of a thousandth of a percent (see above).

In some ways, it is noteworthy that what for commerce and industry is a small tax has promoted *any* effect on waste at all. It suggests the significance of signalling mechanisms, prompting companies to re-examine their position in respect of waste. Our view is that this signalling effect is magnified in situations where one member of staff has responsibility for waste as a specific 'budget line' rather than for 'all costs'. Hence, even though waste may be a fraction of any company's total costs, when the landfill tax came in, it implied a significant percentage increase in the costs of waste disposal. Those who 'saw' the tax not in terms of the implied percentage increase in the company's total costs, but as a (much higher) percentage change in the company's disposal costs will have experienced a much greater change (and hence, driver *to* change). This suggests that how companies account for their costs can influence their propensity to change behaviour when a given item in the budget experiences a cost increase.

Reasons typically offered for 'not doing the right thing' as regards waste minimisation include:[36]

- initiative fatigue – companies tire of naïve do-gooders;
- lack of strategic thinking, goals and targets;
- inadequate cost accounting systems;
- poor attitudes to investment - short termism;[37]
- inadequate internal communications;
- inadequate external communications;
- inflexible culture - resistance to change;
- lack of time - for investigation and implementation;
- lack of money – for investigation and implementation;
- lack of required technical skills and knowledge;
- lack of 'risk/investment appraisal' skills.

Typical 'excuses' (and responses) identified by those engaged in the Envirowise programme are:

- *I'm too busy* (let's get you some help);
- *I don't have the skills* (let's train/support you);
- *We tried that and it didn't work* (when, how, why not?);
- *Our process is different* (really true? minor or major changes required?);
- *Its not financially viable* (have you really included all the benefits? Could things have changed?);
- *I can't get management support* (have you really tried to make a *business* case?).

Given these points, one can speculate as to the shape of the abatement cost curve (or more meaningfully, the 'response cost curve' – some of what happens isn't so much abatement as displacement) in this respect. It is less than clear that marginal abatement costs should always be increasing where waste is concerned. This is especially true where industrial wastes are concerned, partly for the reasons outlined above – the costs saved through minimising waste may be far greater than those costs related only to initiatives undertaken in respect of waste.

One can speculate that more radical 'Schumpeterian' changes (for example, the pursuit of Zero Waste strategies) can actually be more profitable than approaches based upon incremental, marginal changes in response to a price signal conveyed by a landfill tax. Equally, it seems there are also barriers to the adoption of new investments which generate significant savings. It seems reasonable to try to represent these in any attempt to portray the potential abatement costs as perceived by enterprises. Hence, we may have to become more

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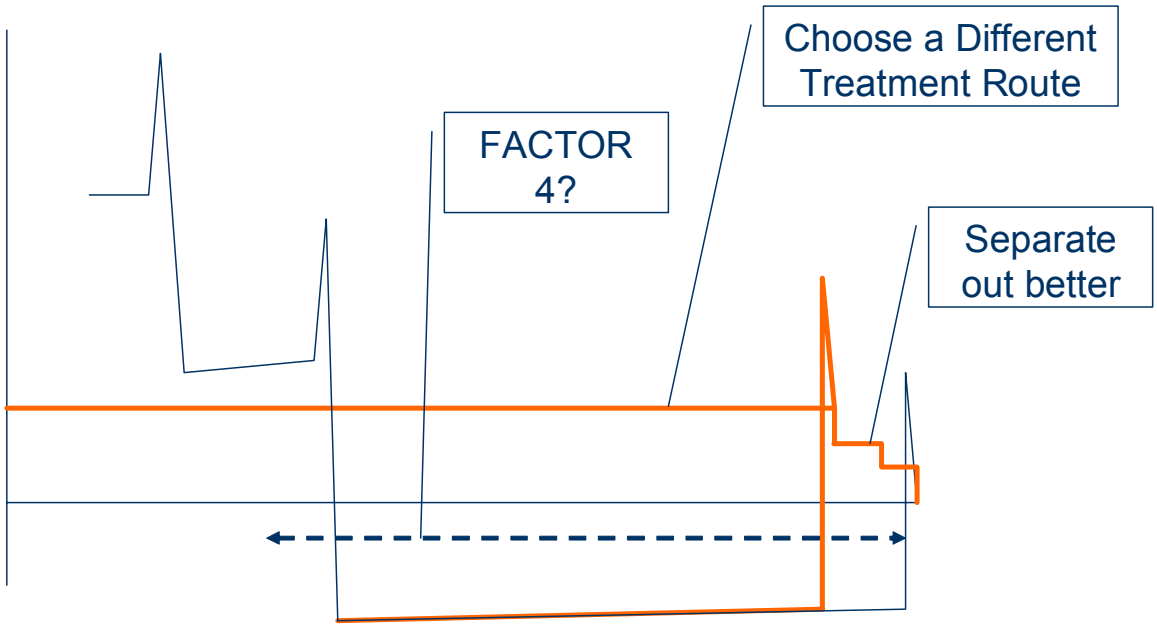
[36] I am grateful to my former colleague, Mark Hilton, now at Enviros, for pointing out some of these reasons, which include those commonly encountered by him and his colleagues in work for Envirowise (formerly Environmental Technology Best Practice Programme, or ETBPP).

[37] This item has, of course, its institutional dimension. Some specialists working in this area suggest the maximum payback period deemed acceptable has shrunk from 3 to 2 years over the last decade or so.

accustomed to abatement cost curves which look rather like that shown below. The situation is likely to be quite different for different environmental issues (and the assumptions of orthodoxy seem likely to hold more or less well where different issues / situations are concerned).

Figure 6: Hypothetical Landfill Abatement Cost Curve



In the case of inert construction and demolition wastes, the effect of the tax has almost certainly been somewhat more dramatic. Two factors have been of major significance (Hogg 1999):

i. The magnitude of the tax in respect of its impact relative to pre-tax disposal costs; and

ii. The existence of a 'response option' which implied very little change in practice, but significant cost savings.

The fact that existing regulations gave producers of these wastes 'an easy adaptive response', allied to the relatively strong price signal, has led to a response more in line with what was expected. Unfortunately, however, it is less than clear that all the outcomes are entirely desirable.

The case with inert wastes shows why it is extremely important, when implementing new policy instruments, to understand how the existing institutions shape not so much preferences themselves, but the available menu of choices over which those preferences can be expressed. In seeking to adapt to what were significant price changes for disposal, some waste producers (and waste hauliers) have simply shifted material from licensed to unlicensed sites.

To the extent that these responses were legitimate, yet not entirely desirable, they suggest that the prevailing institutions do not adequately reflect a view of what is socially desirable. In other words, the prevailing institutions are an inadequate reflection of a nominal social welfare function, since they legitimise responses which are not necessarily socially

desirable.[38] This is interesting since the response, from an orthodox perspective, may be 'efficient'. But this merely highlights the fact that 'efficiency' has meaning only within specific institutional contexts. Here, efficient responses may be at odds with what is perceived as socially desirable. The failure is not so much one of 'markets' (the market 'did' what it was structured to do), but a human one, and one which reflects a mis-specificaton of the institutions which define the choice set over which preferences are expressed.

It is interesting to note that the Environment Agency has been seeking changes to the Waste Management Licensing Regulations to reduce the extent to which negative repercussions flow from the 'recovery' of waste at sites exempt from licensing. These are still 'being considered' four years after they were proposed by the Agency. One would expect such changes to re-define the choices over which preferences are expressed.

6. Implications for the design of policy measures

The key implications from the discussion in this paper for the design of policy measures are as follows:

6.1 Corporate behaviour and managerial discretion

Since firms price according to a mark-up over normal operating costs, policy aimed at altering decisions at the margin may fail to have the desired effect. With oligopolistic industrial structures, tax rises may squeeze profits rather than, as intended, leading to increased prices and reduced consumption and production of the good with the negative externality. Policy designed to alter consumer and producer decisions at the margin may prove to have much more 'lumpy' effects. In addition, the speed at which such processes work through will depend on a range of factors, one of which is the remaining lifetime of assets. Risk and uncertainty play a key role. For example, what matters is not just the effect of a tax change on relative prices, but what the *expectations* will be of price and tax changes in the future.

More generally, firms' decisions to invest are shaped by factors other than short-run financial criteria. Institutional and regulatory changes – laws and codes on corporate governance, policies on corporate social responsibility and so on – will all play a role.

6.2 The nature of rationality

The specifically policy proposals outlined above are to:

> **1:** Internalise the free-rider problem that characterises business investment in training, either by subsidising education and training in environmental technologies and management or by encouraging firms to make joint investments in training programmes.
>
> **2:** Change the corporate governance structure of firms to increase the influence of stakeholders taking a long-term perspective, such as employees and local communities vis-à-vis shareholders that favour short-run profits. This could be promoted by:
>
> i. making environmental reporting for large organisations mandatory; and
>
> ii. giving independent directors responsibility for company policy on environmental matters and sustainable development.

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[38] This interpretation broadly follows that of Bromley (1989)

3: Create a cluster of firms in the industry pursuing environmentally friendly production strategies to kick-start diffusion throughout the industry, via:

i targeting existing firms in the industry to encourage them to switch to environmentally friendly production strategies; and/or

ii introducing new firms, perhaps with mutual or community ownership, with environmental sustainability in their Memorandum & Articles of Association.

4: Establish a training programme in strategic environmental management.

5: Engender cultural change and set new norms and standards in environmental management and corporate social responsibility.

6.3 A systems approach

A systems approach is quite different from the approach often adopted in the literature on environmental issues, of looking for market failure, and then attempting to calculate what tax or regulatory changes would be needed to overcome such failure. The differences between countries in technological progress over time cannot be explained simply by different incentives derived from their firms facing different relative prices, but rather are influenced by a range of systemic factors including the countries' education and training policies, public and corporate research and development arrangements, availability of finance, and so on. In seeking to move firms towards more environmentally sustainable technologies, policy needs to act on all aspects of the innovation system.

A systems approach points to the need to act on other (non-price) factors to influence decision making. As the Nobel-prize winning economist Douglas North argues:

> 'That institutions affect the performance of economies is hardly controversial. That the differential performance of economies over time is fundamentally influenced by the way the institutions evolve is also not controversial… the institutional framework (of rules, norms, and enforcement characteristics) together with the traditional constraints (budget, technology) of economic theory determine the opportunities available at any moment in time.' (North, 1993, pp. 242-243).

It is important to appreciate the power of cultural, informational and 'learning' policies. It may be that *packages* of policies will be more effective than a series of individual policy initiatives.

6.4 Conclusion on policy

In summary, the variety of policy instruments that could usefully be developed is far wider than much of the standard literature suggests. At the same time, it is evident that packages of policies may be more effective than individual policies operating in a single dimension. There is therefore a need to explore both theoretically and empirically, how, and to what extent, different policies work, both individually and in combination. In particular, there is a need for more analysis of detailed case studies to uncover the complexity of effects.

7. Further work

The Sustainable Technologies Initiative (STI) is funding a number of diverse projects.[39] The individual projects are pursuing a range of different research methods and methodologies, with varying degrees of reference to economic theory. It would be useful to reflect on how useful or otherwise these various projects had found the theory that they had drawn upon, and to consider whether other theoretical approaches might help shed light on their findings.

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[39] See http://www.sustainabletechnologies.ac.uk

A 'meta project' might review the projects undertaken within the STI and also elsewhere, to see what common ground there either is or may be emerging around the most useful theoretical apparatus to analyse such issues, such as systems theory, the behavioural responses to incentives, the role of corporate and social culture, and so on. More ambitiously, such a 'meta project' might revisit some of the research questions within one or more of the STI projects to consider what further light such concepts might shed on any given project's findings, and conversely, whether those concepts could be further developed when tested in this way.

On the specific case of waste management, there are a host of possible avenues for exploring the reasons why firms have responded differently to the changed relative prices brought about by the Landfill Tax. In previous work, the effects of the Landfill Tax was examined through detailed surveys. This work could be taken further by segmenting the population for firms as 'non-responders', 'might responds' and 'already doing things, but could do a little mores', and investigate what caused the firms to fall into one category rather than another. This might indicate what combination of policy measures is required to bring about the required change in firms' behaviour.

8. Conclusion

Theorising requires abstraction and must make simplifying assumptions. Using equilibrium concepts may be a useful analytical tool to conceptualise the interactions between various elements in a system. But when it comes to policy design, it is vital that any unrealistic assumptions that have been made for conceptual purposes are replaced with ones that accurately describe how actors will actually respond to changes in prices, incentives, regulation and other factors. In trying to uncover how agents actually respond, it is important to understand the complex relation between a whole range of economic and non-economic factors. These include the role of corporate and consumer culture. They also require an understanding of how systems operate – and hence change – over time.

History matters in economic processes. Firms and industries can get 'locked in' to particular technologies.[40] Routines and corporate culture are important factors in the way firms behave, and are not easily altered. When analysing the dynamics of economic development and the design of packages of measures, including economic instruments, to achieve environmental outcomes, it is therefore important to draw on those traditions within economics that have developed these concepts and have analysed the various issues involved.

APPENDIX

The environment game illustrated in Table 1 can be re-expressed in general terms as shown in Table A.1 below.

TABLE A.1 ENVIRONMENT GAME EXPRESSED IN GENERIC TERMS

		Firm 2	
		Production Strategy creating negative externalities	Production Strategy without externalities
Firm 1	Production Strategy creating negative externalities	(π_3, π_3)	(π_1, π_4)
	Production		

[40] For a discussion of which, see for example David (1985).

Strategy without externalities	(π_4, π_1)	(π_2, π_2)

where $\pi_1 > \pi_2 > \pi_3 > \pi_4$

The tit-for-tat (TFT) strategy is collectively stable provided the w – the discount factor, $w = 1/(1 + r)$ – is greater than:

$$\text{Max } [(\pi_1 - \pi_2)/(\pi_1 - \pi_3), (\pi_4 - \pi_2)/(\pi_2 - \pi_4)]$$

For the values of the payoffs shown in Table 1 it can be sent that the TFT strategy is collectively stable if $w > 2/3$. Hence, as Axelrod notes,

> 'The significance of this theorem is that it demonstrates that if everyone in a population is cooperating with everyone else [not producing externalities] because each is using the TFT strategy, no one can do better using any other strategy provided the discount parameter is high enough.' (Axelrod, 1981, p. 312).

As discussed above, TFT is not the only collectively (or evolutionary) stable strategy. The free-riding, environmentally unfriendly strategy is also collectively stable. Axelrod has shown that the number of collectively stable strategies is less than the number of Nash strategies and that some collectively stable strategies can be invaded by groups of players adopting other collectively stable strategies. More precisely, consider the situation where an industry is characterised by firms playing the free-riding, environmentally unfriendly strategy that produces externalities. This strategy is collectively stable and cannot be invaded by a single player arriving and trying to play the cooperative, environmentally friendly strategy (with no externalities). However, if a small cluster of environmentally friendly firms adopt the environmentally friendly strategy then TFT can evolve as a stable strategy provided that for the proportion of environmentally friendly firms, p, the following holds:

$$p > [(\pi_3/\delta) - (\pi_4 + (1 - \delta)\pi_3/\delta)]/[\pi_2/2\delta - (\pi_4 + (1 - \delta)\pi_3/\delta)]$$

Given the values of the payoffs shown in Table 1 and setting $\delta = 0.1$ (which implies that two interacting players have a 90 per cent chance of meeting again) then environmentally friendly strategies can evolve as collectively stable in an industry of 21 firms provided at least 2 firms adopt the environmentally friendly production technique. Clearly this is a very powerful result. The intuition behind this result is that TFT does as well against free-riders as the free-riding strategy, but better than free-riders against a like minded TFT player. It follows that the widespread adoption of environmentally friendly production strategies can emerge via the establishment of a small cluster of firms in the industry that adopt environmentally friendly techniques. This suggests that policy efforts that are targeted and that might appear expensive if the cost-per-firm were aggregated across all firms, may in fact prove to be both successful and cost effective, since only a small number of firms need to have that targeted effort, with the effect being subsequently diffused through the population of firms with no further policy effort required.

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