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Introduction

Lawrence Summers' World Bank memorandum[1] — urging that the rich countries export their hazardous wastes to the poor countries — is based on impeccable economic reasoning: If the winners (the rich countries) can fully compensate the losers (the poor countries) and still be better off than they were then that is preferable to the status quo. This is the principle of Pareto optimality, and it is important to note that what is crucial is that the winners *can* compensate the losers, not that they *do*. In Summers' proposal, however, the compensations do happen, because they are part and parcel of the market transactions between the various nation states. "What," economists like Summers will ask, "could be fairer than that?"

Well, we should note that this is a *market solution*, and that what is seen as fair by market actors may not be seen as fair by those who favour other solutions — the *hierarchical*, for instance, in which (as has recently happened in a number of countries) governments enact and enforce regulations to control transboundary shipments of hazardous wastes. And those who favour what I will call the *egalitarian* solution, and who wish to radically transform the production and consumption system that is all the time generating these hazardous wastes, will see both markets and hierarchies as inevitably perpetuating rich-poor divides, on the one hand, and exploitative and unsustainable technologies, on the other.

In very general terms, market actors are disposed to see as fair an outcome in which those who have put most in get most out — a

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1 Lawrence Summers, *Why the Rich Should Pollute the Poor,* The Guardian, Feb. 2, 1992, at 8.

principle that is not consistent with the hierarchist's idea that distribution should be by rank and station (that brahmins, for instance, should have more water because they are more easily polluted than those who are of lower caste). Nor are either of these fairness principles compatible with the egalitarian's insistence that people should all get exactly the same, regardless of their contribution and regardless of any claim they may advance to priority. If policies are being designed and implemented on the assumption that just one of these three solutions is the right one (or even on some compromise between just two of them) then we should not be too surprised if those who favour the excluded solutions (or solution) scream "Unfair!" Nor should we be too surprised if they then set about a course of action that ends up putting such obstacles in the way of that policy that the proposed facilities become unsiteable.

What may be surprising though is the suggestion that, in causing all this trouble, they are actually doing those who have excluded them a favour. The argument for this seemingly paradoxical state of affairs, coming back to the hazardous wastes example, has to do with the harm that rich countries may do to themselves in going along with Summers' proposal for an international trade in "bads." The argument, at its simplest, is that if rich countries can fairly effortlessly get rid of noxious waste streams from their technologies, then they will never receive any signals that would encourage them onto different and cleaner lines of development: Lines that are better by the market criteria and by the hierarchical and egalitarian criteria.

So what I am suggesting is that serious problems over siting some facility should make positive contributions to the process of *technology assessment.* Specifically, unsiteability should be seen as a valuable *indicator of technological inflexibility.* Yet, it is not quite as straightforward as this, because such assessment, as currently instituted, does not address itself to the task of ensuring technological flexibility.

Another obstacle, it might be objected, is that unsiteability may result not from the inherent properties of the technology in question but from the institutional aspects of the siting process — serious losses of trust by the public, for instance, that could perhaps have been avoided (by, for instance, following the Wharton School's Facility Siting Credo).[2] In cases such as this, it might be argued, it is only a matter of sorting out the institutional arrangements, and there is no need to question the line of technological development that happens to be embodied in the unsiteable facility. However, this argument would be valid only if the technical and the institutional were clearly separable, and this is never the case. Technology is always a social and cultural process, and disentangling its technical and institutional factors, in a way that is unanimously agreed upon by all the policy actors, is never possible.[3] I will therefore stick to my guns and insist that unsiteability, regardless of the reasons that may be advanced for it, should always be treated as an indicator of technological inflexibility.

This, I hasten to add, is not to say that we should not try to improve the siting process. Rather, it is an argument for constructively relating two lines of improvement — of technology and of how to share environmental burdens and benefits — that at present both suffer from being carried out in isolation from one another.

Redefining Technology Assessment

Technology assessment is largely the creation of one person — U.S. Congressman Emilio Dadario — and its aim, from the outset, has been to anticipate the consequences of technology. Over the years, this rather grandiose aim has been modified somewhat. The U.S. Office of Technology Assessment, for instance, before being abolished, saw its task more in terms of the comparative assessment of technological *options* — a process that can be deemed successful even if it does not anticipate all consequences of the technologies it compares. And more recent institutions actually incorporate this more modest aim in their titles. The European Parliament, for instance, is advised by an office of Scientific and Technological Options Assessment. However, backing off from an over-ambitious goal is not the same thing as seriously questioning that goal and replacing it with a different one. And that, I am arguing, is what is needed.

The trouble with the anticipation goal is that technology assessors, at best, can only anticipate those consequences that are anticipable —

2 Howard Kunreuther, Kevin Fitzgerald & Thomas D. Aarts, *Siting Noxious Facilities: A Test of the Facility Siting Credo*, 13 Risk Anal. 301 (1993).

3 *See* Michiel Schwarz & Michael Thompson, **Divided We Stand: Redefining Politics, Technology and Social Choice** (1990).

capable, that is, of being anticipated. No one, for instance, could have foreseen what CFCs would do to the ozone layer, nor could the inventors of the vacuum cleaner have anticipated that it would pretty well rid the developed world of the human flea and its associated diseases. It is this ineradicable shortfall between what technology assessment aspires to and what it is capable of that is the source of what David Collingridge calls the "control dilemma."[4] Initially, you don't know enough about a technology, and by the time you do know enough it's too late! At the early stages, when we still have the chance of abandoning or profoundly altering the technology, we simply cannot anticipate enough about it, and by the time that that information *is* becoming available to us we have become irrevocably committed to the technology and can no longer effect the required changes. Collingridge calls this *entrenchment,* and it is very similar to what Brian Arthur calls *lock-in*[5] — Finding ourselves stuck with a particular way of doing things (the QWERTY keyboard is a nice example) even when we are aware of more efficient alternatives.

If you put these two notions together, and take them seriously, then the aim of technology assessment changes from anticipation to the avoidance of avoidable entrenchments and lock-ins. In other words, we should stop bothering about what the consequences of individual technologies might be and concentrate instead on ways of ensuring that our technologies are kept as flexible as possible. To do that we need to focus on the very early stage in a technology's life — a stage when hardly any of its consequences are anticipable. The question Collingridge asks is: "Is there anything that you *could* know at this early stage that might tell you you are headed for serious inflexibility?" He argues that there is, and he has developed a set of four *technical indicators of inflexibility:*

- Large scale (of the production unit)
- Long lead time
- Capital intensity
- Major infrastructure needs.

4 David Collingridge, The Social Control of Technology (1980).

5 W. Brian Arthur, *Competing Technologies, Increasing Returns and Lock-in by Historical Events: The Dynamics of Allocation Under Increasing Returns,* 99 Economic J. 116 (1989).

These have now been augmented by four *organisational indicators of inflexibility:*

- "Single mission" outfits
- Closure to criticism
- Hype (as in "If we don't muster the political will and invest X billion ECUs in the European Broad Band Fibre Optic Network the Japanese will take over.")
- Hubris (as in, after Chernobyl, "It couldn't happen here.")

I will not go into the reasoning behind these eight indicators[6] — the only requirement for an indicator is that it works — nor do I want to argue that these indicators are perfect (they represent only the very first steps in the effort to re-focus technology assessment). Yet, they do work rather well when we try them out against technologies, like high-rise systems building,[7] that we have abandoned and now wish we had never embarked on. It is to these sorts of indicators, therefore, that I want to add the now quite common phenomenon of unsiteability.

Some Precedents

In the 1960's a large building in London — Bowater House, in Knightsbridge — was quickly erected, thanks to some revolutionary constructional techniques. The concrete beams at each level were *post-tensioned,* i.e., they had holes through them into which were fitted steel cables which were then tightened, ratchet-wise, so as to provide a level of strength that could never be achieved with the conventional steel-reinforced beam. As each floor was added, the tension of the beams on the lower floors was increased so that they were able to bear the progressively increasing weight of the building.

Only some months after the building was completed did it occur to anyone to ask how it might be demolished at the end of its useful life. There was, it turned out, no way of progressively slackening the tension of the cables and, since no one has yet come up with a way of demolishing a building from the ground-floor upwards, this meant that any attempt to take it down would result in a whole series of explosions as each floor was propelled violently upwards once the weight above it had been removed. The building, quite simply, was *undemolishable.*

6 But Collingridge, *supra* note 4, supplies much of that reasoning, and more is to be found in Schwarz & Thompson, *supra* note 3.

7 Barry Russell, Building Systems, Industrialization and Architecture (1981).

The authorities responded quickly to this discovery, and legislation was soon in place requiring the designers of complex buildings to lodge precise details of how their masterpieces were to be demolished at the time that they submitted their applications to construct them. Thanks to that response, the entire line of technological development, of which Bowater House represented the first step, came to an abrupt halt, and we have now had 30 or so years of development along a variety of other lines, all of which provide us with buildings that can be demolished without destroying everything else around them. My argument is that unsiteability is like undemolishability. Once it is seen as a clear indication that there is something seriously incomplete about the design of the technology concerned, it becomes a valuable and positive contribution towards long-term sustainability.

There is, for instance, a close parallel between the design of Bowater House and the design of Britain's nuclear technology. Both are seriously incomplete: There is no satisfactory way of demolishing the former, and there is no satisfactory way of dealing with the unwanted and unpleasant products of the latter. Deep, underground disposal, of course, was supposed to be a satisfactory solution, and Britain's nuclear establishment (itself a "single mission" outfit) set up a subsidiary "single mission" outfit, Nirex, to carry out the job. Nirex, having identified those areas of Britain with the ideal geological characteristics, began exploratory drillings. Or, at least, it *tried* to begin exploratory drillings.

Local resistance (including local government resistance) was so strong that Nirex was unable to gain access, legally or physically, to the technically suitable sites. The repository was unsiteable[8]. Nirex withdrew and, after due deliberation, announced that the ideal geological formation was, in fact, directly below Windscale — the site

8 Something very similar happened with a bilateral forestry aid project in Nepal: the team found itself denied access, by the local villagers, to the forest they had come to re-plant. However, instead of going away, or calling in the army to protect them, the team sat down with the villagers for a lengthy discussion in which each side was able to learn about the other's idea of what a healthy forest should look like. In this way the two visions - top-down and bottom-up - were negotiated into a socially viable and physically possible solution that is now becoming the template for village-level forestry throughout the region. *See* Michael Thompson, Michael Warburton & Tom Hatley, Uncertainty on a Himalayan Scale (1986); and Jack D. Ives & Bruno Messerli, The Himalayan Dilemma: Reconciling Development and Conservation (1989).

on which stand many of Britain's nuclear installations (including the plutonium breeding pile that has been sealed since it caught fire in the 1950's, and the Thermal Oxide Reprocessing Plant that is about to start operation). This site, of course, already belongs to the organisation that wants to dispose of the nuclear waste. Even so, it does have to obtain planning permission for the repository. And, in view of the high level of disbelief, not to say derision, over Nirex's claim that this is technically the best place for the repository (it was not even on their original list), it would be unwise to assume that the approval of their application is a foregone conclusion[9]. Indeed the whole thing is a ghastly mess — exactly the same sort of ghastly mess as the undemolishable Bowater House[10].

Actually, it is an even ghastlier mess, because the technology of nuclear power is much, much more deeply entrenched than was the post-tensioned building technology of Bowater House. But the message is exactly the same: Abandon that line of technological development. Such a prescription, of course, is always met with a flurry of objections from those whose interests lie in perpetuating and deepening the entrenchment they have already put in place: "We can't afford to change;" "There is no alternative to change to;" "The alternatives have incompletenesses in their designs that will turn out to be even more intractable." This, of course, is the hierarchical line of reasoning that was so nicely satirised by Hilaire Belloc: "Never, ever let go of nurse — For fear of meeting something worse." And, beyond all those paternalistic objections, there is the neoclassical economist's trump card: "If there is a better alternative we would have found our way to it by now."

This objection, I should point out, is in a different league from the others, because it totally dismisses my entire line of argument about technological inflexibility and the desirability (when the signs are that we are becoming entrenched) of switching to a different line of technological development. In the neoclassical account of how technology develops lock-in and entrenchment are simply not possible.

9 At the time of writing, the decision has not been made and the dispute rumbles on over the terms of reference of the inquiry (the application having been "called in" by The Secretary of State for the Environment).

10 Institutions and technical claims, we can see here, are so snarled up with one another that there is no possibility of separating them in a way that will be agreed on by all the actors in this long-running nuclear debate.

The market encourages new technological developments and then puts them in competition with one another. In doing that, it quickly reveals which of the competing technologies is the most efficient and, once that has happened, changes at the margin ensure that the most efficient technology survives and that its less efficient rivals die out. The market, in other words, provides the selection pressures that ensure that technology always evolves along the most efficient path possible. Intervening in that process, therefore, which is what my prescriptions for lessening technological inflexibility do, can only make things *less* efficient than they would have been if we had not intervened. "People," as they say in Chicago, "may be dumb but markets are always smart."

If the neoclassical theory is right then my argument, and the policy prescriptions that go with it, collapse completely. So I make no apologies for devoting the rest of this paper to showing that it is not right; at any rate, that it is not *entirely* right.

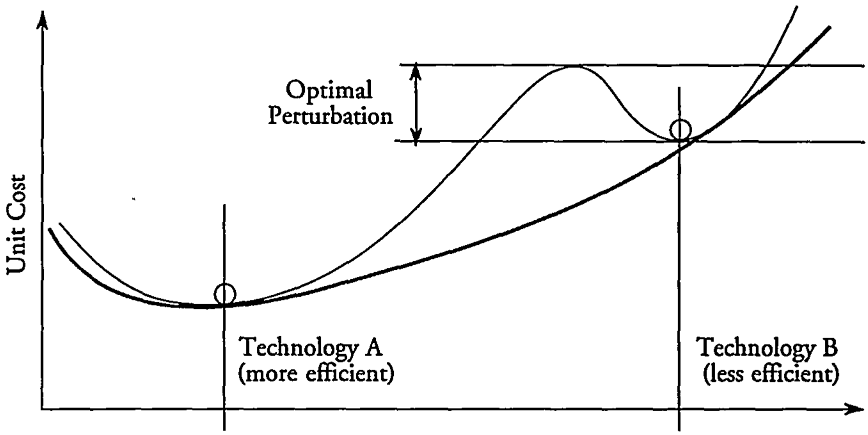
Dumb People and Dumb Markets

At the empirical level the neoclassical theory is like psychoanalysis: It is unfalsifiable. Every time a counter-example is produced, the neoclassicists patiently explain that it has occurred because the market has been prevented from operating properly: The hidden hand has been prevented from doing what it would have done had it been left to its own devices. Nuclear power, for instance, never had to raise its funds in the money markets, nor did it have to subject itself to the disciplines of insurance premiums and legal liabilities. The argument, therefore, has to be carried out at the *theoretical* level, and this, fortunately for me, has already been done by Brian Arthur. Arthur has shown that the neoclassical argument holds true only in those cases where there are *decreasing returns to scale.* In those situations where there are *increasing returns to scale,* small historical events, far from cancelling themselves out in the aggregate, determine the outcome[11]. One consequence of this is that we can become locked into one of several competing technologies, even though it may be less efficient than the others. In other words, markets, as well as people, can be dumb!

11 In cases such as this, the process is "non-ergodic" and subject to a high degree of sensitivity to initial conditions.

This crucial distinction between the neoclassical insistence that economic processes are insensitive to initial conditions and the reality in which this is often not the case is depicted below. Here we see two technologies, each nestled in its own stabilizing tough. Here, no amount of adjustments at the margin will ever carry us away from the undesirable technology and into the embrace of the desirable one; it would take what ecologists call an "optimal perturbation" to carry us over the hump that separates them.

Figure 1.
Escape from One Lock-In to a Better One.
(The bold curve depicts the neoclassical assumption that returns to scale decrease)



Let me conclude with a topical illustration of this monstrous curve (monstrous, that is, to the neoclassical economist). There is, at present, an enormous amount of research funding going to what are called *clean technologies*. The monstrous curve alerts us to the existence of two very different ways of increasing technological cleanliness. The first (what most people think of) involves scrutinising an existing technology for points where it can be made less dirty. Loss reduction officers, for instance, are empowered by companies that employ them to work their way back up through the whole production process to see if any changes can be made, here and there within it, that would reduce the quantity and/or nastiness of the waste streams. More creative individuals (often self-employed consultants) may look into ways of recycling those waste-streams (e.g., by connecting them into the feed-stocks of other production systems) or of neutralising one nasty waste with another nasty waste from another process. But, as well as cleaning up an existing technology, and as well as steering it in a cleaner direction, there is another possibility — a discontinuous jump from that particular line of technological development to another and completely different line. It is towards this sort of possibility that the linking of unsiteability to a redefined technology assessment will direct our attention.

The technology of water treatment, for instance, is chemical and biological — oxygenation, filter beds, activated sludges and so on. Sewage treatment plants, I readily concede, do a great job but they do end up with some nasty residues (particularly because of heavy metals). Nor, since they do not smell very nice, are people keen to live next door to them. Though they are not in the same league as nuclear waste repositories or hazardous waste incinerators, sewage treatment plants are certainly LULUs (Locally Unwanted Land Uses), and they often run into siting difficulties. There is, however, a new water treatment technology that is neither chemical nor biological but ecological.

This technology has been developed, over the past twenty or so years, by John Todd and his company, Ocean Arks. It is based on what Todd calls "living machines" — a cascade of twelve or so large plastic barrels, each of which contains an ecosystem that has never existed in nature. Since the waste that flows through this cascade is grossly polluted (it includes heavy metals and even cholera) the first eco-system is composed entirely of microorganisms — the only living things capable of living in such filthy water. But further down the cascade we get water plants and eventually vertebrates — carp, for instance. The water that flows out of the final barrel easily passes the most stringent drinking water standards, and the whole process is powered by sunlight and gravity. Heavy metals are fixed, selectively, by various bacteria and water plants which, of course, have to be harvested from time to time. Once dried, these residues are sold to the metal recycling industry. John Todd's revolutionary technology is certainly cleaner, and he, of course, is convinced that it is also more efficient economically than the conventional water treatment technology (so too are the venture capitalists who are now backing him). But, even if it is better on both counts, there is no guarantee that it will drive out its well-established competitor. For that to happen two conditions will have to be met.

- The new technology *will* have to be more efficient.
- Some actor will have to administer the "optimal perturbation."

It is towards the effective institutionalisation of these two conditions that the indicators of technological inflexibility (and, in particular, my argument for seeing unsiteability as one of those indicators) are directed.

Afterword

John Todd is very much committed to the egalitarian idea of fairness. He wishes to see a less polarised and more caring world — one in which we have all learned to "tread lightly on the earth." In consequence, he is anxious about his living machines' involvement in the marketplace. He fears that should his technology triumph, and sweep away all our present water treatment technology in a Schumpeterian "gale of destruction," people will feel able to carry on as before, relying on the new technology to clean up the messes that he wishes them not to be making in the first place. Hierarchists, too, would have less justification for their regulatory interventions if people did what Todd wants them to do and stopped making their messes, or if they didn't and relied on his living machines to clean up their messes quickly and cheaply.

In other words, re-focusing technology assessment on inflexibility reduction does nothing towards deciding whose idea of fairness shall prevail. But that, surely, is why we need it!