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INNOVATION POLICY IN IRELAND: ECONOMIC IDEAS AND INSTITUTIONAL DIVERSITY

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1. INTRODUCTION

In a speech in 1905, Arthur Griffith set out his provocative and innovative vision of industrial development in an independent Ireland. Before detailing his programme, he took care to dismiss for his Mansion House audience the *"fallacies of Adam Smith and his tribe"*, closely identifying these with the malign influence *of "our British Lords Lieutenant, our British boards of education, and our Barrington lecturers"* (McLoughlin 1996, pp 3–4). I mention Griffith's offhand jibe as of more than antiquarian interest, as a reminder that competing ideas about political economy were once centre-stage in national discourse—this was, deservedly, contested territory. I intend to contest some territory in this lecture.

The substantive area of concern, policy towards *science, technology and innovation* (STI) needs little motivation. Policy-makers internationally certainly perceive this as a domain which warrants their attention and activism, partly because policy entrepreneurs see opportunities here for their wares, now that niche markets for other types of policy prescriptions appear closed, at least for the moment. STI policy can at least advance claims of fidelity to microeconomic/supply-side concerns, no essential conflicts with macroeconomic stability, and a welcome revival of concern with assuring long-run, sustainable increases in living standards, as opposed to more

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problematic and transient attempts to manage economies on a quarter-to quarter basis.

The paper trail of policy documents in Ireland evidences a comparable shift in focus, exemplified as far back as the 1992 *National Economic and Social Council* report report on national systems of innovation (NESC,1992), in the *Science, Technology, Innovation Advisory Council* (STIAC) review, the 1996 White Paper on STI, and in more recent policy initiatives, especially in respect of the funding of research rooted in the third level sector. These appear to at least begin to address an agenda long vigorously pursued by an Irish scientific, academic, technological and industrial constituency. This community might naturally see international motivations for according priority to STI policy as relevant in a country with so recent and so unhappy an experience of short-run economic management as Ireland, and with so clear a need to entrench and extend a possibly vulnerable economic renaissance.

For academic economists, the questions 'what are the sources of technological progress?' and 'to what extent can policy assist innovation?' appear now to be increasingly almost co-extensive with the central question of economic science: 'what determines the wealth of nations?'. To use the title of Joel Mokyr's (1992) compelling and accessible historical survey, economists now seek to understand the 'lever of riches'. This is, at least for mainstream macroeconomists, mainly a process of rediscovery, in that for most of the post-war period, they shared in, or perhaps more accurately, created, the same trance of short-run economic policy management which mesmerised policymakers. The macroeconomic research agenda has decisively turned, for fifteen years or more, towards bringing technological change and innovation within the ambit of economic explanation, in the hope of bringing to a long-running conversation, if not a new language, then a least a modern and rigorous idiom.

2. ECONOMIC IDEAS AND PUBLIC POLICY

That much being said for a substantive interest in innovation policy, I do wish to justify my predominant concern here with the interface between economic ideas and policy in this area in Ireland, as I do not present any novel theoretical concept, or review empirical evidence, nor critique a particular policy measure. To introduce an analogy I will exploit again, while recurrent and sometimes controversial themes in the STI policy debate are the relevance, nature and direction of linkages between basic or pure science and its applied counterparts, little attention is devoted in this debate in Ireland to articulating parallel linkages between what we might usefully characterise as basic economic science and its applied variant, public policy.

While the domains both of pure inquiry and application in science and in the social sciences self-evidently differ, this is nevertheless a curious lacuna in the rhetoric of STI policy in Ireland. It appears to me to signal a perception, in at least some policy documents, that the truly 'hard questions' of the economics of technological change

are effectively settled, so that a well-defined economic policy problem admits of an essentially technical solution. By this I mean particularly the tendency to rely on the language of 'market failures'—defined in relation to a very specific notion of market successes—in order to justify policy interventions, and the broadly unexamined re-iteration of the capacity of, and need for, central government to 'prioritise, integrate and co-ordinate' such interventions in the form of STI policy. This is an example of a faith in the scientific status of economic reasoning not typically attributable to non-economists, especially those who are 'real' scientists and/or business people.

The basic economic science of STI policy in Ireland appears to be a standard, mainstream, neoclassical economic framework of textbook fame. I am not overly concerned with any more specific, more modern, elaboration of this framework, which might admittedly encompass more sophisticated behaviours or more contingent results. What appears to matter in the interface between economic reasoning and policy processes are not specific theoretical or empirical results, but how the broadest themes of these models implicitly determine what is permissible on the policy agenda and what is 'beyond the Pale'.

My particular concern is to stress how the adoption of the rhetoric of neoclassical economics in the STI debate might prejudice our policy in perhaps surprising ways. This contention draws upon a re-invigorated tradition in political economy, rooted partly in the *Austrian School*, and in the related broader stream of economic liberalism, which together regard the neoclassical defence of the market as no defence at all. This tradition argues that neoclassical economics misrepresents the central economic notion of competition, and fails to represent innovation at all. Far from constituting a warrant for decentralised, market-driven solutions, the neoclassical approach is accused by this tradition of unconsciously supporting the very centralising and collectivist tendencies which it purports to critique. The readiness of technocrats to embrace this allegedly deceptive language is then explicable in terms of its consistency, and not conflict, with their pre-disposition to plan, control and intervene.

After such a manifesto, some hedging of bets would probably be politic. My purpose in making this argument is not to presume to actually resolve the substantive questions at issue, which self-evidently range over much of the domain of economic inquiry, and perhaps beyond. In reviewing the logic which leads to the conclusions I have sketched, I wish to perform an essentially rhetorical role, in the sense which has been urged upon economists by Deirdre McCloskey (1983, p. 482), as when for example she quotes Wayne Booth: *"rhetoric is the art of probing what men think they ought to believe"*. Moreover, rather than merely pointing, in a detached or even destructive way, to perceived cracks in the foundations of this area of policy, I do wish also to note more constructive possibilities which emerge from an alternative tradition. In particular, I wish to argue that insofar as economic liberalism assigns a crucial role to institutional diversity for the capacity of market order to facilitate innovation, a role which is absent from the neoclassical view, this alternative

tradition speaks to a theme which should make sense to a constituency concerned to frame science policy on a scientific basis.

3. THE NEOCLASSICAL MODEL AND THE LIBERAL CRITIQUE

The neoclassical defence of the market rests on a characterisation of instrumentally rational individual behaviour as the optimisation of a stable value indicator subject to constraints, and on three aggregations of such behaviour, known as the three theorems of welfare economics. These, more or less, in turn establish the Pareto efficiency of competitive equilibria of such interacting agents in the limit, the possibility of achieving any such equilibrium by redistributions which do not distort incentives, and the impossibility of consistently aggregating the preferences of diverse individuals over such social states.

The model of the individual presented is regarded as the obvious benchmark way in which to understand purposive behaviour, admitting real world departures from this idealisation. The first theorem is seen as establishing the paradoxical social harmony of asocial motivations, and also provides the idealisation to which public policy should aspire from the point of view of efficiency. It enables a categorisation of market failures as violations of the assumptions of the model, and gives grounds for rationalisable interventions to correct them. The second welfare theorem then separates equity from efficiency, in that any desired distribution of resources can be plucked from the multiplicity of efficient equilibria which the competitive market determines. The third theorem, known as *Arrow's Impossibility Theorem*, can be taken in two ways. On the one hand, it removes part of the claim to expertise from economists, in pointing to limits of what can be said to be for the 'common good'. As Feldman (1987, p. 894) stated:

"We feel we know, like Adam Smith knew, which policies would increase the wealth of nations. But because of all our theoretic goblins, we can no longer prove it."

On the other hand, the third theorem is interpretable as further evidence of limits to the allocation of resources by political procedures, in that they aggregate individual rationality to social incoherence, the caricatured 'visible foot' of politics as against the 'invisible hand' of the market (Magee, Brock and Young, 1989).

This model, although individualistic, finds no favour with economists from a broad tradition of economic liberalism such as Friedrich Hayek and James Buchanan amongst others. This follows first, from their insistence on the non-deterministic nature of free choice, properly understood. If a choice is determinate, if it can in principle be completely described as the outcome of an optimisation algorithm, it could not have been different from what it turned out to be, and thus was not truly a free choice, or more simply, not a choice at all. This is not a quibble, to be addressed by a minor variation of particular assumptions within the basic framework, as a neoclassical adherent would recommend. It is a problem inherent in the

framework itself; it is a category failure.

What is striking then about the aggregate picture which such individual behaviour generates is that it constitutes a market in which there is no competition, in any meaningful sense of the term. The organising idea of neoclassical equilibrium delivers this perverse result deliberately. Equilibrium is a state of rest in which all opportunities for exploiting gains from trade have been exploited, so that no-one has incentives to change their decision rules. There is no competition, because there is no trade, in what purports to be a model of the market. It then perhaps comes as no surprise, that there is not, because there cannot be, any innovation in this model either.

The primitive notions on which this edifice is built are that of a *good*, whether for production or consumption, the well-defined preferences of individuals, and *technology* itself, understood narrowly as sets of accessible blue-prints which describe how inputs can be transformed into outputs. Set against central questions in political economy, such as the causes, nature and consequences of new goods and services, of new (previously unknown) technologies-of innovation, this influential framework purports to address our problems by assuming we have already solved them.

An alternative tradition, particularly the *Austrian School*, argues that economic knowledge does not exist independently of the transactions envisaged and undertaken in specific markets; we in part learn about our preferences by observing the alternatives which markets generate. Entrepreneurs in turn discover these preferences and create new ones, and new productive possibilities in the market environment. Whereas for neoclassical economists, preferences and technology are 'deep parameters' of behaviour and nature, accessible to the scientist (and therefore to the planner) with sufficiently sophisticated econometric tools (Lucas 1976). For economic liberals, such assumptions are a 'pretence of knowledge'.[1]

4. THE SOCIAL PLANNER'S PROBLEM

In response to this, a central warrant for neoclassical analysis is that it gives precise content to the notion of markets failing or succeeding in that it sets up a particular definition of economic efficiency, namely the criterion of Pareto optimality. This notion is intimately connected with the idea that the relevant benchmark against which we judge the market is the outcome which an omniscient social planner might achieve. Stated this way, the sociological success of the neoclassical framework in providing a language for policy entrepreneurs, despite its substantive shortcomings, is not hard to explain.

A Hayekian or Buchanan rejoinder would argue the subjective nature of individual choice and the dispersed and contingent nature of knowledge means that the planner's conceit is *a priori* fatal; the criterion is vacuous. No outcome can be

evaluated independently of the process by which it emerged and the process of voluntary exchange has strong presumptive ethical force. The social planner construct of the first theorem is allowed extensive powers in the second redistributive theorem and this invites the *Public Choice school* to subject the capacities and motivation of the state to sustained scrutiny, positing public failure as the probable result of an ill-framed identification of market failure (e.g. Brennan and Buchanan, 1980). From a very different perspective, in a discussion which eventually finds a case for *"faint praise—not any less, not much more"* for the market, Amartya Sen (1985) points out that the second or 'converse' theorem may be taken to imply profoundly interventionist policies in envisaging the manipulation of the initial distribution of resources in order to force the market to select a particular desired equilibrium. As Sen (1985, p. 11) states:

"If the real case for the market mechanism—through the high road of the 'converse theorem'—is dependent on a major revolution in the distribution of resource ownership, then the case for laissez faire and for using the allegedly 'non-political' route of the market mechanism is thoroughly undermined. The 'converse theorem' belongs to the 'revolutionist's handbook'."

The third theorem arrives at a result which might appear to resonate with liberal resistance to ascribing goals to collectivities, other than the furtherance of the goals of the individuals whom they comprise. Its technical virtuosity, however, would be seen by economic liberals as redundant, insofar as it 'establishes' a result which they knew *a priori* and so presents social decision pseudo-problems which economists cannot 'solve' technically, but which do not overly concern individuals in real societies, capable of institutional creativity.

For economic liberals, the distinction between neoclassical analysis and arguments from the 'revolutionist's handbook' dissolves, and *not* because of empirical departures from assumptions which provide a natural benchmark. The assumptions and departures are irredeemably dependent on an inadmissible violation of the concepts of choice, knowledge and the future. Knowledge is not another good, to be consumed until costs equal benefits at the margin: how does one estimate the net marginal value of knowledge before one has it? If the future is the object of choice, it is unknowable because it does not yet exist and not because it is merely obscured by our misperceptions or computational inadequacies; likewise, the past was not uniquely determined; it could have been different. As Buchanan and Vanberg (1991, p. 174) point out:

"The contrast is between two critically different perspectives by which efforts to understand the world can be guided: (1) a *teleological* perspective and (2) a *nonteleological* perspective. We argue that it is its uncompromising *nonteleological* character that marks the critical difference between the understanding of the market process suggested by the subjectivist perspective and various standard conceptions of the market that, if only in a very subliminal fashion, have a teleological undertone.

And, as an aside, we want to submit that this 'residual teleology' constitutes somewhat of a hidden common link between standard economic teaching on the self-organizing nature of markets and the blatant teleology of the socialist planning mentality."

I will of course concede that the abstract tenor of all this might naturally irritate and frustrate the pragmatic policy maker concerned to solve immediate and tangible problems. Nevertheless, the consequences for the conduct of policy of such questionable foundations can be profound, as argued by Joseph Stiglitz, whose critique of orthodoxy, and constructive response to it, would surely find favour more generally than would the avowedly economic liberal figures to whom I have referred so far. Stiglitz (1994), presents an extended review of the collapse of centrally planned command economies, and critiques the mainstream's inherently problematic understanding of the nature of markets, and in particular, its failure to adequately represent the key concepts of competition and innovation. These failures, he argues, account for mainstream economics' inability to anticipate the fundamental flaws in the command economy model, and for the economics profession's at best uneven attempts to advise on the transition from the command economy to the market.

5. CONSTRUCTIVE ALTERNATIVES IN COMPLEXITY?

So where might constructive alternatives be found, in the specific context of innovation policy? Leaving aside, perhaps unjustifiably, Stiglitz's particular research programme in information-theoretic economics, I would like to raise the possibility that an emergent transdisciplinary approach, not yet mature enough in economics to constitute a school of thought, offers some intriguing themes. Most generally in the scientific community this approach is concerned with problem-solving in the face of intrinsic complexity, and in economics has found a home within a sub-field of computational economics (Krugman 1996).

In drawing on the possibilities of the transference of analogy between modern natural, physical and social sciences, this may offer a constructive route away from the critique of neoclassical economics as misapplied and misunderstood nineteenth century physics (Mirowski 1988a, 1988b, 1989). This is important in the context of the previous discussion insofar as a central Hayekian accusation is that neoclassical economics constitutes not science, but 'scientism' i.e., an unwarranted application of analogy from the physical and natural sciences to social analysis.

This study of complexity has encountered the theme of emergent order from decentralised and diverse units in a number of specific contexts, examples of which are:

- The discovery that *cellular automata*, interacting according to simple rules, could aggregate to surprisingly complex and natural graphic patterns and behaviours—so-called 'artificial life' or 'alife',

- the problem solving capabilities of *genetic algorithms* which emerge from a process which begins with a population of solutions, where selection takes place according to some fitness criterion, and innovation occurs through mutation and cross-over, by direct analogy with natural processes,

- and the massive adaptability of parallel distributed processing systems, such as *neural networks* which appear capable of coping with tasks which are not analytically tractable, e.g. speech, character and pattern recognition.[2]

These techniques have in common a reliance on 'bottom-up' computation, to achieve coherence and solve problems. Earlier 'top-down' approaches generally failed to meet expectations that a sufficiently well specified theory of a problem, allied with raw processing power, would suffice in allowing solutions to be engineered. The modern emphasis is on optimisation by processes which at the micro-level are simple, but which produce robust, complex and evolving macro-level solutions.[3] These themes are suggestive to economists of their own understanding of the potential for autonomous agents to resolve apparent discord unaided by central control.[4]

These approaches consistently identify as success factors in achieving solutions, the diversity of the constituent parts in each model and their essentially unco-ordinated behaviours in evolutionary, trial and error processes. What would otherwise appear as wasteful redundancy and a lack of coherence to the 'designing mind' prove to be crucial in facilitating innovation in a variety of contexts, which have in common their intrinsic complexity. In an economic contexts this seems to resonate with concerns sketched earlier to understand entrepreneurship as a process involving intrinsic uncertainty and incomplete knowledge, the market as an arena for the discovery and creation of knowledge, and innovation also, as dynamic and complex.

6. CONCLUSION

Even if, as one would have to concede, such themes are as yet no more than suggestive for economics and economic policy, I would argue that they have acute rhetorical force for STI policy. They point to a dissonance in policy on science and technology between on the one hand, an admission that the domain is characterised by intrinsic complexity and uncertainty, and on the other, a presumption to 'prioritise, integrate and co-ordinate' behaviour in that domain. This in part stems from legitimate concerns to assess and account for the conduct of public policy, but I hope that the tensions here can at least be acknowledged. I would particularly argue that the merits of institutional diversity might somewhat delimit what appears to be an almost instinctive urge to centralise and co-ordinate.

The salience of this concern in Ireland is illuminated, I think, by a consideration of the fairly recent modern history of scientific infrastructure in this country. I refer in particular to the extraordinary historical record of achievement by pre-Independence Irish scientists in a range of disciplines, as surveyed for example by Herries Davies (1985) and the way in which what appeared to be a related potential institutional basis for a science-based innovation established in the nineteenth century was allowed to wither and die around the time we appeared to achieve control of our national economic destiny. The scathing judgement which some such as Roy Johnston (1998) deliver on this record of neglect and failure may appear harsh, but that record certainly calls for an explanation. I would tentatively suggest that such an explanation would at least acknowledge the tendency of the central Irish state since Independence to appropriate to itself increasing institutional responsibility, in for example the control of local government and the educational system at all levels. It may then be that the 'villain of the piece' was not some presumed cultural and institutional antipathy to science *per se*, but rather the cultural and institutional uniformity which for so long characterised the process of nation-building.

A consideration of this historical record might positively inform current policy debates, and might reflect that unexamined institutional impulses can and should be subject to critical scrutiny, and that a lively, sometimes pointed, and emergent debate in economics can constructively contribute to that endeavour.

Endnotes

1. As in the title of Hayek's Nobel lecture in 1974, published as Hayek (1989).
2. On artificial life and genetic algorithms, see the non-technical account by Stephen Levy (1993).
3. For a book-length survey, see, for example, Coveney and Highfield (1995).
4. References to economic papers in this area are given by Leigh Tesfatsion (1996). See also Timothy Van Zandt (1995).

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DISCUSSION

Dr. David Jacobson: I would like to begin by congratulating Aidan on being chosen as this year's Barrington Lecturer, and to endorse his implied contention that questioning theoretical fundamentals is appropriate in a Barrington Lecture. As is well known, economists frequently disagree, but the argument that Aidan proffers goes beyond this norm; it is a radical argument, requiring, if it is accepted, significant rethinking about the potential contribution of economics not only to innovation policy, but to all other policies as well.

Like his substantive argument, Aidan's methodology is also sharply different from that pursued - at least implicitly - by most economists. He invokes McCloskey's "rhetoric" as a reference to what he does in his paper. I would like to take this a step further; McCloskey (1990) emphasises story-telling as a most important element of what she means by rhetoric. Now most economists would be loath to admit that their mathematically rigorous, statistically exact and internally consistent arguments are constructed in such ways as to tell stories that could easily be told differently. But this is what McCloskey suggests. Moreover, not only might the same methods tell a story differently, but alternative methods might tell either the same, or a different story with the same "facts". Deductive and inductive methodologies are just different ways of telling stories. These issues are, I think, at the heart of reasons why I agree with some aspects of this paper, and disagree with others.

What follows can be divided into two sections. First, a number of points in the paper will be developed, and/or arguments put forward as to why at least parts of the paper are correct. In the second section, some weaknesses will be identified and suggestions made as to how the paper can be improved.

Points of Agreement

The author adopts a critical perspective; questioning fundamentals is healthy in a discipline. There are many examples in science of the core of disciplines being defended against what subsequently turn out to have been valid attacks. The attacks must therefore continue to be made, otherwise a significant route to the improvement of disciplines will be eliminated. A recent example in economics is international trade theory, where for many years the neoclassical core - the essence of which is free trade - was defended against myriad counter-arguments supporting protectionism in certain instances. Krugman, though he himself continues to support free trade for what seem to me to be political and philosophical rather than neoclassical economic reasons, provided much of the theoretical basis for what has come to be called '*strategic trade policy*' (e.g. Krugman, 1987). His arguments about what was wrong with traditional neoclassical trade theory included the need to change assumptions, introducing increasing returns to scale and imperfect competition; these changes in assumptions as an adjustment in neoclassical theory - the methodology of which is basically deductive - had long before been made in

alternative, inductive theories by the observations (as opposed to assumptions) of the scholars in those alternative traditions (McGovern, 1994).

So, whatever the economics of science and technology happens to be, it is appropriate that it be questioned. With our knowledge of the process of evolution of international trade theory, for example, we must be concerned that this questioning does not result in the strengthening of an incorrect core. We must facilitate not just the standard disagreements among economists, but also the questioning of fundamental aspects of our theories.

A second aspect of the paper that seems to me to bring us further along the road to a better understanding of the economics of science, technology and innovation, is his direct critique of neoclassical theory and its application to science and technology. I agree with much of his criticism of neoclassical aggregation of individual rationality, of equilibrium approaches, and with his conclusion that among the results of the simple neoclassical view is an inability to provide adequate explanations for the processes of innovation. The contention that there is in the end no competition if there is equilibrium may not hold, depending on what is meant by "competition", but there are enough other arguments there for this weakness to be carried. This is not to say that equilibrium theorists have a good understanding of competition.

There is, as Schumpeter showed, a contradiction between innovation and equilibrium. Rosenberg (1994, p. 50) summarises Schumpeter's position as follows:

"The essential feature [of modern capitalism], in Schumpeter's view, is economic change... The behavior of capitalism is totally dominated by the continual working out of its inner logic, the essence of which is economic change resulting from the impact of the innovation process. Equilibrium analysis, on the other hand, focuses upon adjustment mechanisms that are peripheral, and not central, to the logic of capitalist organization and incentives."

Rosenberg goes on to show how Schumpeter rejects perfect competition as an ideal, or even as a possibility in industrial capitalism. The neoclassical understanding of what is meant by competition may coexist with equilibrium, but Schumpeterian competition cannot.

Aidan's paper has a third argument or contention that is difficult to refute, and that should be incorporated into any economic theory of science, technology and innovation, or, more to the point, any theoretical basis for STI policy. He states that there is complexity, diversity and uncertainty in the world of the application of technology, which make institutional diversity, and decentralisation, appropriate policy approaches. My own work in industrial economics in Ireland has brought me to similar conclusions; in particular, different sub-sets of firms - or industrial sub-sectors - usually require quite different sets of policies. There is no alternative to specific, empirical knowledge of the nature and evolution of the technologies,

institutions and relative market powers of firms in a sub-sector, see, for example, Jacobson and O'Sullivan (1994).

Points of Disagreement

I would like to turn now to what I see as some of the weaknesses in thie paper. First, I have serious doubts about the extent to which neoclassical theory does in fact contribute to STI policy. The very reports that are referenced in the lecture are liberally peppered with, and more importantly come to conclusions consistent with, non-neoclassical economists. These include, in particular, the institutional economists, and, as an important sub-set, the theorists of systems of innovation, like Nelson, Lundvall, Dosi, and Freeman (for a discussion on these economists and their contributions to systems of innovation theory, see Jacobson (1994)). In recent years they have been far more influential than any other scholars contributing to STI policy, not only in Ireland, but in much of the rest of Europe, too. The paper argues that if neoclassical economics has too much influence on policy then policy will be too centralised, too uniform. It is not clear that a neoclassical basis to STI will necessarily generate too centralised a policy. However, it is clear that the basis of current STI policy is not neoclassical. Aidan's argument here can be caricatured as: "If A, then B." The fact that not A, seems to leave this argument truncated.

There is a second, more fundamental criticism of the paper. It is fundamental in the very sense that Aidan's criticism of neoclassical approaches to STI is fundamental. He sees only Austrian, liberal economic alternatives to neoclassical economics. What about the evolutionary, Schumpetarian, institutional and even Marxist approaches to STI? Let us choose evolutionary economics in particular. There is some reference to evolutionary processes in section 5 of the paper, but it does not refer to what has come to be called *evolutionary economics* (Nelson and Winter, 1982; Chandler, 1992) and its contribution to the idea of systems of innovation (Cooke, 1996). Within this tradition, which, as it happens, also draws on Hayek, there is a clear rejection of the liberal argument for an across-the-board opposition to regulation and policy. As Nelson and Winter put it (1982, p. 371):

"Government R&D support programs have, since World War II, provided approximately half of the total funding for research and development. More generally, a significant portion of economic activitiy is conducted by public rather than private organizations. The evolution of economic apabilities and behavior must be understood as occurring in a mixed economy."

As a follow-on to this brief discussion on evolutionary economics, a further point in favour of non-Austrian alternatives to neoclassical economics can draw on the work of Chang (1994). He offers a transaction cost theory of state intervention which rests on the notion that a fundamental role of the state is the lowering of general transaction costs. In STI policy specifically, this might express itself in the state's facilitating - or perhaps even imposing - the establishment of particular standards.

What the theory provides is a means of determining, on the basis of a comparison between the state and the market as alternative means of achieving certain results, where and whether state intervention is appropriate. The analysis incorporates examination of both market and government failure.

I would like to conclude this comment on the 1999 Barrington Lecture by reiterating that there is much in the paper to commend. Any criticisms are offered in constructive spirit. The questioning of fundamentals is laudable; hopefully, Aidan Kane will go on in similar vein to develop his analysis so that he can contribute to the improvement of STI policies. My intention here has been to suggest directions that might be tried in the course of this development. May I end with a poem of my own composition that captures some of the common ground we shared in the lecture. It is entitled:

ECONOMISTS

Some call what you do the pursuit of science
Perhaps for most it's the art of compliance;
Fashion selects the world from your theories
Or gets the Truth from some lengthy time series.
These are your methods at your peril resist;
If in alternative paradigms persist
Rejection, removal, demotion, no grants!
Get tenure and glory from joining in chants
That repeat like a mantra "Let us assume,
Let us model". Let us argue, let us fume;
Deductive and inductive, both are extremes
Explaining reality? Not what it seems!
Researchers SHOULD struggle, the world is complex
Institutions, culture, religion, race, sex
All introduce problems that most will ignore
Though unravelling them may reveal the core
Of the issues confronting the modern state.
Let us praise economists who contemplate
Epistemologies that incorporate,
Encompassing factors that the obdurate
With their standard approaches assume away.
It's interdisciplinary interplay
That should be seen as the highest endeavour
The attractive track for the really clever.

(David Jacobson)

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Professor David McConnell: I would like to thank the Statistical and Social Inquiry Society for their invitation to speak to Dr. Kane's Barrington Lecture. I have taken the opportunity to write a lengthy reply as a means of emphasising the critical importance of certain aspects of the subject.

Ireland stands at a watershed. We can go on to become a mature inventive society in which the arts and the sciences are both flourishing or we can abandon the sciences. This would be nothing short of disastrous for our society when it is obvious that the sciences are not just the root source of most economic innovation in the moden world, but they are also a central part of modern culture, full of intellectual vigour and excitement, but also dangerous and now presenting the most profound challenges to modern society - our understanding of the brain and the mind, our collective responsibility for the welfare of our planet, our thoughts about the nature and origin of the universe, our respect for religious thought, our need to regulate arms and eliminate war and so forth. Although there are welcome signs that Irish science is being reassessed by *the Department of Education and Science*, the *Higher Education Authority* and other national institutions, current national science policy is actually destroying internationally respectable science in Ireland.

Dr. Kane's paper relates to some complex challenges within economics, for example how to measure the value of investment in innovation, how to decide how much to spend on innovation and in what ways should the money be spent, and what are the roles of government in such processes. To judge from his paper, research and innovation have not been incorporated in a clear way into general theories about the creation of wealth. However, I am not going to enter into spats within the family of economists about the merits of the classical, the neo-classical or the liberal theories of economics, or rows between the Keynsian, Chicago and Viennese schools. I am mainly interested in one thing: how to persuade the Irish government to invest judiciously in science and technology. Scientists see the case for investment in science for two quite different reasons: first, they have experienced the direct causal connection between research and wealth, and second they believe that science is an important part of modern culture. They know how particular discoveries have combined to change the global economy, where these discoveries were made, when and by whom. Scientists understand the general nature of the systems which allow such discoveries to be made and exploited for social and economic benefit and we must explain these systems to the wider public. If science is not part of our cultural experience, if the wider public is not educated about science and the scientific method, then it will be difficult to justify science or to attract young people to scientific careers.

Our society now faces an important decision. As we approach the end of the 20th century, Ireland is host to a foreign high technology industry operating complex factories with great efficiency. We are a *turnkey* economy, in which Irish citizens manufacture sophisticated electronic, pharmaceutical and chemical products which have been invented abroad, in plants which are controlled from abroad. This has been a happy and productive alliance between Ireland and the multinationals and I hope it continues. But appearances are deceptive and we now need to turn our attention to making the transition to an inventive or innovative economy in which we will make even better use of the talents of thousands of Irish scientists and engineers who in the past have either been forced to emigrate from what was a scientific wasteland, or to stay and have their talents dissipated in low or medium level work. Are we interested in creating an innovative economy and how do we do that? What happens if we do not become an innovative economy? How do we move the Irish economy up the 'value chain' through innovation?

As an experimental scientist I will confine myself to the connection between investment in scientific research, innovation based on science and the creation of wealth, and I will touch briefly on the connection between the sciences and the scientific professions, such as medicine. I will not be able to substantiate all that I say for reasons of time and space, but it is a distillation of nearly forty years of doing science in Ireland, and it may be useful. The main observations are that we are not yet a scientific people but we should be. It is not sound policy to be unscientific in a world which is being reinvented decade by decade by scientists, by which I mean

scientists, engineers, mathematicians, doctors etc..

Numerous reports provide objective evidence that this statement is correct, the latest of which is *"The National Investment Priorities for the Period 2000-2006"* (ESRI,1996). I will turn to it at the end. Although the report is very important because it does identify investment in science as a major source of wealth, the science budget proposed in this report is so seriously underestimated that, if followed, will probably lead to 'scientific meltdown'.

The Emergence of a Science Policy: A Tentative Start

After a barren and stifling period between 1920 and 1970, during which we neglected science and engineering almost totally, we began to take some tentative steps towards developing a modern scientific infrastructure. Professor Paddy Lynch wrote in 1966 that

"increased fundamental research as a foundation for future technological changes is most urgently needed. Financial support for fundamental research, which is mostly carried out in the universities, is extraordinarily inadequate..... While applied research is necessary, technical development is essential if applied research is to be effective, but without fundamental research, applied research and development would in turn become obsolete."

In 1969 the *National Science Council* (NSC) was founded under the Chairmanship of Dr. Colm O hEocha and the Vice-Chairmanship of Joe McCabe with a major brief to fund scientific research in the universities. It was an outstanding organisation but it had a short innings. It was emasculated by an awful OECD report in 1974 which in summary stated that the government science programme should be more applied. In fact the government science programme disappeared for about five years. The eclipse of Irish science continued until the *National Board for Science and Technology* (NBST) was founded in 1978 -79, under the leadership of Dr. Tom Hardiman. We should note here the inclusion of the term 'technology' in the brief, a natural idea at the time, but fashionable and in the end misleading. The foundation of the NBST coincided with the emergence of the European research programmes, for example the *Biomolecular Engineering Programme* of 1979. These were useful developments in Europe and in Ireland but national policy was inconsistent, personnel changed, and the scale and style of investment were not appropriate. Other OECD countries which had been investing steadily since the 1950s, wisely forged ahead while we did not even keep pace. Driven by desperation and helped by some perceptive officials in the NBST, scientists fought above their weight in getting European grants which kept a few laboratories going. After another promising start, the NBST rather like the NSC became embroiled in political and economic discussions. Scientists watched in horror as an institutional competition took place between the NBST and *the Institute for Industrial Research and Standards* (IIRS), and the NBST was taken-over in reverse. This led to the foundation of EOLAS and

then Forbairt, neither of which has been able to develop the Irish scientific infrastructure.

The Turnkey Economy: Technology By Diffusion, 1970-1999

Some good things happened in science in the period 1970-1999. Many more pupils studied some science at secondary schools, though laboratories were mostly inadequate, science curricula were weak, and many teachers were teaching subjects for which they had little qualification. Students without substantial aptitude for science drifted into it whereas many with real talents for science have been diverted into other subjects. Too many biologists were and are teaching physics and chemistry, a problem which is sure to get much worse as graduates with an aptitude for mathematics are drawn into the lucrative Information Technology sector. More students studied technological subjects at third level. In summary Ireland produced the manpower needed by the multinational high technology industries which were attracted to Ireland primarily by low corporation taxes, grant aid, the english language and our place in Europe. Our education policy was sufficient to support the 'turnkey economy'. We have become a high technology country without becoming either scientific or innovative.

Perhaps, I should not be too critical. Viewed from one perspective, this process seems to have been a textbook performance. When I am in trouble with economics, I turn to the fine text of my colleague Dermot McAleese entitled *Economics for Business*. Dealing with research as a source of wealth McAleese (1997) notes:

"First there is invention, the scientific discovery, which often originates from pure research, not necessarily motivated by commercial factors. Second the invention needs to be applied to the production of a good or service. Innovation refers to this application. The third step is the diffusion of the innovation to other industries, and other economies. Countries in the early stages of economic development typically concentrate on this last step".

Ireland has been extraordinarily successful in this last step, the acquisition of high technology industry by 'diffusion'. We now have a sophisticated industrial sector which makes some of the most advanced products in the world on a large scale. Nine of the top ten multinational pharmaceutical companies have production plants in Ireland and the performance of the microelectronics and IT sector has been equally remarkable. We have an economy which can be summarised by the statement "made in Ireland, invented and owned abroad". In an era of globalisation, it is normal to have a large multinational sector but without having the figures to hand, I suspect that Ireland is an extreme case, with an exceptionally large multinational sector and most of this sector concerned only with production. The turnkey economy is an achievement, but how do we move to the next stage of economic development in which we make full use of the natural resource of Irish scientific brain power and secure the greatest possible benefit from technology?

The key observation is this. If industry has prospered, this had little to do with the Irish scientific research infrastructure which to all intents and purposes was redundant except for its function in producing 'technical' personnel. While national industrial policy was focused on acquiring technology by diffusion from abroad, dedicated officials tried to keep research science going in the last two decades. But Irish science has languished. Limited public funds were diverted from basic science in public institutions to development projects in private companies. Irish science would have disintegrated in this period without funding from the European Union and the Wellcome Trust and some imaginative funding through the *Programmes in Advanced Technologies* (PATS). Scientists began to highlight the failures of successive governments. They founded *the Irish Research Scientists Association*. Unhappy comments appeared in *Nature*, the leading international journal. Ireland was quite literally the laughing stock of the OECD science world. The reports by the *Science, Technology and Innovation Advisory Council* (STIAC, 1995), the CIRCA report to the HEA (1996), and the Royal Irish Academy (RIA,1997) all record how bad things were.

One statement from the CIRCA Report (HEA, 1996) will suffice:

"The comparative financial data are well known. Public funding of higher education research in Ireland is among the worst in the OECD - 4 times worse that Norway, Finland and Netherlands, 3 times worse than Denmark. Even 1.8 times below Portugal. There is virtually no financial support for basic science, little post-graduate support and very inadequate funding structures..... The (university) sector is at the bottom of the OECD league..... Undercapitalisation of university equipment is therefore a major problem..... the position would seem to us to be quite untenable."

Yet as quoted in CIRCA, Prof. Richard Taylor of Stanford University, a Nobel prize winner in physics in 1979, said:

"From time to time, one encounters Irish scientists of considerable talent - usually based in some other country. I suspect that one could assemble at least one more first class university in Ireland if only one could repatriate the best people who have gone abroad"

The *Science, Technology and Innovation Advisory Council* produced a disappointing report which repeated the pattern seen before. It was long on institutional reforms, committee structures and so forth and weak on its appreciation of how science should be done in an advanced economy and how much money needed to be invested. The STIAC report did record the sad state of Irish science but could not bring itself to say what many of the members of the Council knew very well, that Ireland had to invest in STI at the same level and in the same way as the leading OECD countries. It made quite inadequate proposals on the total levels of research

funding and a ludicrous postdoctoral scheme. One proposal has yet to be vindicated. However the STIAC report led to the foundation of *the Irish Council for Science, Technology and Innovation* in 1997, a statutory body with the duty of advising the Government on STI.

The Evolution of an Inventive Economy

We now face a challenge. Having taken the first step in the development of a modern high technology economy, having shown that we can make and distribute complex things, that we can repair aircraft engines and do other intricate jobs most of which we have been taught to do by people from abroad, can we go to the next phase? Can we decide to change our turnkey economy into an inventive economy and how do we do it?

Perhaps we should ask the question in the following way. Is there a strategy which might at the same time (i) help to secure the continued presence of the multinationals which are in Ireland already; (ii) help to attract more multinationals to Ireland; (iii) foster the growth of indigenous high technology companies, and (iv) stimulate the formation of new Irish start-up high technology companies.

Dr. Kane is pointing to the answer to this question when he asks "what are the sources of technological progress?" and "to what extent can policy assist innovation?" and then states boldly that these questions appear to be "increasingly almost co-extensive with the central question of economic science: what determines the wealth of nations?".

Part of the answer is that research is the ultimate source of technological progress. If Ireland is to be at the forefront of technology it must be at the forefront of the research which is producing (i) the knowledge and (ii) the people, the research scientists, who can turn this knowledge into goods and services. In every OECD country it is recognised that this kind of knowledge and these people are primarily 'public goods' produced by state investment in the 'scientific infrastructure'. State funds need to be allocated to educate through research a large number of talented people as scientists and engineers. This education happens at the postgraduate level within universities and research institutes. Both the knowledge and the researchers transfer to the private sector. The young research scientists produce the knowledge which goes in to the private sector, and the private sector employs the research graduates as part of the team which takes the knowledge on to the market.

In the modern world it is wellknown that the root source of technological progress is the availability of talented, well-educated, highly motivated young scientists, and the industrial infrastructure depends on talented people who are employed at the limit of their abilities. As J.K. Galbraith (1967) noted in the 1960s that:

"....a rapidly growing body of educators and researchers emerges. This group

connects at the edges with scientists and engineers within the technostructure and with civil servants, journalists, writers and artists outside. Most directly nurtured by the industrial system are the educators and scientists in the schools, colleges, universities and research institutions. They (educators and scientists) stand in relation to the industrial system much as did the banking and financial community to the earlier stages of industrial development. Then capital was decisive..... In the mature corporation the decisive factor of production ..... is the supply of qualified talent"

The United States has in fact recognised this for at least a century, enticing through scholarships, as many young scientists as possible from abroad. In the post-war period young Europeans, Latin Americans and South-East Asians provided much of the American scientific manpower requirements. As the European scientific infrastructure has developed the United States has turned to mainland China and to India. Of the 8,000 PhDs awarded to foreigners last year in the USA, more than one third were awarded to students from mainland China, and all are automatically allowed to settle in the United States if they wish. The United States leads the world in science partly because it has been able to attract very large numbers of the best scientists to work and settle in the United States.

The US Biotechnology Industry as a Case Study

We can analyse any field of science to find out how the seminal discoveries were made, by whom and where, and how these have been commercialised. I would like to take the case of biotechnology which emerged from the science of genetics as a result of a few key discoveries made in the late 1960s. My career as a geneticist began in 1966 just at this time and I have worked close to biotechnology throughout my career. I have watched with admiration the new biotechnology industry emerging in the United States from competitive basic research programmes in the universities funded by state investment as a public good. Unpredictable discoveries generated in these research programmes have been brilliantly exploited by private companies who have employed the PhDs who were trained in the laboratories in the universities where the great discoveries were made. Not surprisingly the United States now dominates the biotechnology industry which was invented there.

Biotechnology can be defined as the application of biology on an industrial scale. Traditional biotechnology includes such ancient arts as brewing and baking, and post-war, the production of antibiotics by fermentation. The modern interest in biotechnology has arisen because of the invention of genetic engineering. Today the pharmaceutical and chemical industries, and agriculture are being revolutionised by biotechnology. Genetic engineering emerged from pure scientific enquiry into some rather arcane genetical phenomena between 1940 and 1970. Most of the research was carried out in universities and medical research institutes in the USA with some key contributions from the United Kingdom and France, all supported by government grants. There were no economic returns in the first thirty years, nor any

thought that there would be.

So what were the sources of technological progress? The ultimate source is quite clear. Some of the best scientists in the world wanted to know 'what is a gene and how does it work?' and they attracted talented students from all corners of the world. There were critical masses of these people in a few places, about twenty institutions in a few cities around the world, including Cambridge, Paris, Boston, San Francisco, Edinburgh, New York and Los Angeles. The main questions of gene structure and function were solved by 1970 and the story has been well told for the layman in Judson's (1995*) The Eighth Day of Creation*.

By 1970, many subsidiary questions in genetics were attracting the attention of the graduates who had been educated during the so-called 'heroic period'. One of these questions concerned two curious phenomena in bacteriology called restriction and modification. They appeared to contradict the neo-darwinian theory of evolution and were studied by a small group of scientists, perhaps less than ten, including Werner Arber in Basel and Hamilton Smith in Pittsburgh. One part of the solution to the questions about restriction and modification was published by Smith in 1970 and this was the key to genetic engineering and biotechnology. Smith discovered type II restriction enzymes, catalysts which chop DNA molecules into gene-sized pieces.

The commercial possibilities were obvious to a few university scientists, probably less than a hundred, maybe less than fifty, almost all in the USA, in Boston and California. The first genetic engineering experiment was reported in 1973 and the technology was patented by Stanford University. Newspapers and magazines wrote up the technology from time to time in the early 1970s. Primed by the revolutionary impact of microelectronics and computers, entrepreneurs and venture capitalists were circulating on the fringes of the major universities. One of them set up the first biotechnology company, *Genentech*, with some university people in California in 1975. The patent system was efficient and flexible and the universities were used to it, and there were tax breaks for investors. Genentech prospered and thousands of biotechnology companies were to be founded in the next twenty five years. The first substantial product was human insulin which reached the market in 1984, a market which is now worth $2 billion. The market is supplied by two companies, *Eli Lilly* of Indianapolis and *Novo Nordisk* of Denmark. Biotechnology is now revolutionising the pharmaceutical industry world-wide and agriculture in the Americas. The story is well told by the report of *the Office of Technology Assessment to the US Congress* (OTA,1984).

In 1975, I had an idea for a biotechnology product and I sought help from the *National Science Council* (which by then was creaking). I was told that the relevant Irish industry would not be interested. Today the product is made in the USA and the Netherlands, and is worth several hundred thousand pounds per annum. I persisted, trying to persuade the various government agencies to set up a biotechnology centre in Trinity but this idea was stymied. Some good contact was

made with a small company in Cork called *Biocon* and some useful research was carried out applying genetic engineering to the production of industrial enzymes. This led to studies with *Guinness, BP, ICI, Schering Plough* and *Novo Nordisk*. Some patents and products came out of this work. But by US standards, the Irish ventures were off scale.

Knowledge of the emergence of biotechnology in the USA, which grew, without being planned, out of a very strong scientific infrastructure, and the experience of trying to get biotechnology research going in Ireland, which had no scientific infrastructure to speak of, lead me to the conclusion that Ireland cannot build a mature high technology economy unless it first builds a strong scientific infrastructure. The key components of this infrastructure are the quality and quantity of the scientific personnel and their working conditions, and the way in which such scientists are employed within the major institutions of the state, both public and private.

The Technology Foresight Report 1999

In 1998, the *Irish Council for Science Technology and Innovation* (ICSTI) began a technology foresight exercise to produce a strategy to maximise the benefits from technology over the next fifteen years. The report was prepared by seven panels and presented to government in 1999.

The *Health and Life Sciences Panel of the ICSTI Technology Foresight Task Force* was composed of thirty people, the majority from industry. The panel identified biotechnology as the key technology within the health and life sciences. It advised that the biotechnology revolution is at an early stage. comparable to the state of the microelectronics in say 1960, and that there are many opportunities for discoveries in biotechnology which could be made in Ireland and which would be of great economic value. It is not too late to join the biotechnology revolution; if we do not join we will lose a large proportion of those industries and services in the biotechnology sector which will migrate to the high biotechnology countries such as Denmark and Germany.

The panel has proposed a *National Biotechnology Investment Programme* which will build an internationally competitive biotechnology infrastructure capable of making important discoveries, taking them from the laboratory bench to the marketplace, either by the formation of new Irish companies or through collaboration with well-established companies, Irish as well as multinational. This programme will encompass research and development (R&D) in all areas of the biological sciences, including medicine, agriculture, forestry and marine biology. Four sub-programmes will be funded, a research programme to produce knowledge and discoveries and to train scientists (£60 million), a translational research programme to take the research to patenting (£6 million), a programme to provide capital for start-up companies (£10 million) and finally a public education and information programme (£0.6

million). The total new cost of these sub-programmes will be about £75 million per annum. It will take 5-10 years to build up to full capacity. The IDA would be responsible for a fifth part of the programme designed to persuade major companies to establish research laboratories in Ireland.

The research programme is the foundation of the whole programme and I will discuss it in some more detail. It will be composed of about 2,000 people in two hundred research groups in universities, hospitals, *Teagasc* and elsewhere, carrying out internationally competitive research in a wide range of subjects. The prime objective of most of the research teams will be to carry out fundamental research at the leading edge of their fields. Inevitably such research leads to discoveries with commercial value and the research teams will have a commitment to commercialise their work. Projects will be funded primarily on the basis of scientific excellence on five year grants which will be awarded after stringent competition under international peer review.

After five years a research group which has been productive will be in a good position to compete for further funding. All groups would be competing with each other for funds, some would prosper and others fail. There should be a mechanism to fund young researchers to allow them the chance to compete later with the more established groups. The distribution between the universities and institutes of the funded research groups would be a simple matter of competition for the research funds. The main output of the groups will be four hundred professional biotechnologists per annum, knowledge, discoveries, patents, international contact with the leading biotechnologists world-wide, and a pool of expertise and advice comparable to that in any OECD region of similar size. The research groups will be of a standard that they could collaborate with or provide services to multinational companies not only in Ireland but also abroad. A few start-up companies will be founded each year, spinning off from the research groups. A few of these start-up companies will develop steadily into mature and successful companies, while others will be bought over by larger companies.

Research is of course a major international business. The research groups would win foreign research contracts. Dr. Humphries, Dr. Farrar and Dr. Kenna run the *Wellcome Ocular Genetics Unit* in the Smurfit Institute of Genetics in Trinity College. They have earned more than £7 million pounds in research contracts since 1986 of which £6 million came from abroad. They have contributed much more in taxes to this economy than they have received from government research funds. The *Lactic Acid Bacteria* research group at UCC and the *National Microelectronics Centre* in UCC have similar records.

The Scale of Investment in Science and Technology

It is important to ask how the *Technology Foresight Health and Life Sciences* panel decided on the scale of this proposal. First, since talent is the key, we asked

ourselves how much talent is in the country, how much could be assembled from the Irish diaspora, and could we attract foreign scientists to Ireland. We have a good idea of the present capacity and potential of the biotechnology research sector in the major Irish universities and in Teagasc and in the hospitals. We know how much Irish talent lies abroad - science departments track their graduates with a view to recruitment and collaboration. We believe that there are at least two hundred Irish biotechnologists at home and abroad capable of carrying out world class research, and we are sure that Ireland could attract top class foreign scientists if we provided them with the chance to do good science.

Second we know how the best universities abroad are organised. The key question is how many biotechnology research group leaders are needed for critical mass within a single institution. The Biology Division of my alma mater, the California Institute of Technology, had thirty six research groups in 1998 - all would be expected to be world class. Other universities are much larger, but the CalTech number shows what can be achieved if one has a rigorous selection system. It is reasonable to conclude that a major university should have about thirty biotechnology research groups with international reputations. There are seven universities in the country so there should be about two hundred such groups.

Third, we know the optimum size of a biotechnology research group. There is general agreement that this is about ten persons, the leader, four or five post-doctoral researchers (PhDs) and four or five research students. With the exception of the leader, staff members will spend no more than five years in such a group.

So by three counts, our capacity to carry out top quality research, the need to reach critical mass in doing research, and the size of a research group, the Health and Life Sciences Panel has advised that Ireland should be spending about £60 million per annum on the competitive research grant programme. *Forbairt* has just awarded new grants worth a total of £2 million for all the sciences, of which biology accounted for about £1 million, so we are proposing an increase in spending of about fifty times.

Having arrived at this figure of £60 million we should ask what are our competitors spending?. There are two kinds of competitors, public and private. The Danish government biotechnology research programme in the universities costs $160 million per annum, fifty to one hundred times the expenditure in Ireland. One federal research agency in the United States, the *National Institutes of Health* has a budget of $12 billion per annum, all of which is related to biotechnology, and there are proposals to double this budget by 2003. There are many other federal and state agencies in the US spending money on biotechnology. We can look at what businesses are doing. *Genzyme*, a second division genetic engineering company based in Boston, has an annual basic science R & D budget of $100 million. If small knowledge-based companies spend this sort of money on R & D, then it is clear that small countries which aspire to the same high technology status will have to do the same, just as Denmark is doing. Stanford University, admittedly a top university has

a total budget for research of $600 million.

Of course such comparisons are not straightforward. We need to look more carefully on how spending in Ireland should be compared with spending in other countries (or in companies) but there is no doubt that the competitive research grant schemes, which are the basis of the R & D infrastructures abroad, are underfunded here by fifty to one hundred times. There is another figure to take into account. Exports from the 'biotechnology sector' of the Irish economy are currently worth about £10 billion. the sector employs about 45,000 people. If we are to foster this sector we should be prepared to spend £75 million per annum on the R & D base which will anchor what we have got and lay the basis for substantial developments in the future.

The National Investment Priorities for the Period 2000-2006

In closing, I would like to consider the proposals in the ESRI (1999) "The National Investment Priorities for the Period 2000-2006 report published in March 1999. I will call this the ESRI Report. If Dr. Kane's address has been mainly of a theoretical nature, the ESRI Report has a serious practical objective, namely to advise the government how to invest over the next six years.

The ESRI Report pays a lot of attention to R & D and it represents another opportunity for scientists to try to understand how economists are treating R & D. It certainly says many good things about R & D and the scientist's sense of well-being will rise as he or she reads that *"economists have persistently identified the basis of sustained economic growth as technological progress generated through the application of R & D"* (p. 21). Later the report notes that *"societies which have relatively large stocks of knowledge and relatively high levels of human capital devoted to the production of knowledge, can enjoy sustained prosperity and will see their per capita income levels moving ahead of countries which fail to accumulate knowledge at the same pace"* and R & D is acknowledged to be the main *"engine of growth"* (p. 23).

Having adopted a strong view of the fundamental economic importance of R & D, it is plain the authors also know the weakness of the Irish situation. They comment that *"Ireland has a low level of total R & D investment by international standards"*. Public sector R & D is 0.14 percent of GDP, the lowest in the OECD and 30 percent of New Zealand. Most Irish government funding on R & D is non-competitive and non-transparent. The authors know the seriousness of the illness of the patient. What cure do they recommend? They say that *"there is a strong case for significantly increasing the level of public funding over the period of the Plan (2000-2006)"* but what they mean is revealed as follows, that *"the relative level of funding should be maintained at its present ratio of GDP over 2000-2006, increasing to an average of £250 million" (p. 218).* This is qualified by useful recommendations that *"genuine public good research should grow by substantially more than the overall total"* and that all R & D should be brought under a single programme.

But the overall advice that the whole programme should cost £250 million in 2006 million is alarming. Let us examine this figure of £250 million in more detail. The equivalent figure was £168 million in 1999. The key question is how much of this is directed at competitive basic and pre-competitive research which is the foundation of a scientific infrastructure. The answer given in the report is that only £10 million is truly competitive. This figure of £10 million can be put in context by mentioning that the tiny Genetics Department in Trinity College Dublin with seven academic staff wins about £1.5 million per annum in competitive research grants, most of which come from abroad. In other words the Genetics Department competitive research budget is equivalent to one sixth of the entire Irish Government competitive R & D programme. On the international scale the idea that Ireland should spend £10 million on competitive research is comical. The total research budget of Stanford University is about $600 million, mostly earned through competitive research programmes.

So while our competitors are investing even more heavily in science and technology, Ireland, which lies at the bottom of the OECD league, is being advised to sit still, to maintain the relative level of funding at its present ratio of GDP over 2000-2006. In effect the government is being advised to continue its 'policy' of encouraging by default the most brilliant young Irish scientists to emigrate, to stay away from Ireland if they want to do research at the forefront of their fields, and by implication to contribute to the development of foreign economies instead of our own.

Scientific Meltdown

Joe Lee (1990) wrote:

"Small countries ... must rely heavily on the quality of their thinking to adapt to changing circumstances. ... it may be argued that a main reason for the inferior performance of Ireland since independence has been the poverty of its thinking. The main difference between itself and the smaller European countries who have moved far ahead of it in the twentieth century is that, for all their mistakes, misjudgements and vulnerability to factors beyond their control, they have organised their main resource, their intelligence, far more effectively."

Lee is critical of the emphasis on technology, which he refers to as the "*cult of technology*" and "*the fetish of technology*". He doubts the "*wager on 'hard' technology*" and notes that Ireland was grabbing *"at the technology option with all the commitment of a drunk grabbing at a lamp post"*. He laments the failure of our government to relate "*the significance of thought, any thought, to the welfare of either society or the state"*. This criticism is not entirely fair in that the commitment to technology has been justified by the development of the '*turnkey economy*' which has brought many benefits to our society. But Lee is correct in noting by implication the key mistake that in the past we have emphasised technology without science and

we have underestimated the significance of original thought, whether in the arts, which concerned him most, or in the sciences. It is thought and imagination which lie at the root of an inventive society.

The consequences of not investing at the proper level in science are serious, especially in a world dominated by science, in which investment in science is increasing, where there is a shortage of scientific manpower and scientists can migrate and apply their talents with ease. In toto, the consequences for Ireland of not investing properly in science can be described as scientific meltdown, the gradual disappearance of respectable science and technology from Irish schools and universities, the disappearance of high technology industry and the undermining of those professions which are based on science. Without wishing to be alarmist, or to cry wolf, serious science in Ireland could follow Latin and Greek into virtual oblivion.

It is worth pointing to a number of specific consequences of low investment in science, which are related to one another as domino effects.

1. The best Irish scientists will not stay in Ireland, if they cannot compete internationally "at the bencch". Of course it would be silly to waste the talents of such people - we have an important renewable natural resource, Irish scientific brain power. If we send it away, this is equivalent to giving away to other countries a "renewable and inexhaustible" Irish oil and gas reserve. But there are two much more serious knock-on effects, the destruction of scientific research and teaching.

2. As the top scientists leave, the amount of top quality research will decline. Fewer Irish groups will be able to compete for European funds, which will be directed increasingly to those countries which have 'corresponding' national research programmes. There will be no point in giving European funds to Irish laboratories which demonstrably cannot use them. We will not be able to muddle through in some areas as we did in the relatively low technology era of 1970-1999.

3. The quality of training of the research students, paid at less than the dole, being educated in Ireland will drop even further below OECD norms.

4. The small pool of professional research scientists with PhDs, from which universities, government agencies and industries can draw for specific technical and research duties and projects, will disappear.

5. Fewer patentable discoveries will be made here and fewer start-up companies will be founded.

6. Less money will be earned from international research contracts, either from the

private sector or from foundations such as the Wellcome Trust.

7. Companies seeking well-educated research graduates will, more often than now, have to look abroad, and so will be drawn abroad.

8. High technology companies already in Ireland will not be able to source research locally or to consult locally.

9. High technology companies will be persuaded to set up new plants abroad, say in Denmark, because of the availability of top class graduates, research colleagues and research collaborators, a flow of knowledge through the local scientific infrastructure and opportunities to feed off the state-funded science and technology programmes within the universities.

10. The standard of science teaching at Irish universities will decline and so the science and technology infrastructure will go into a self-accelerating free fall. Although it is painful to admit, few Irish university science departments can claim to be in the top class internationally today. But most departments are still able to teach reasonably close to international levels. But the Irish system will slip further away from international standards as more of the best scientists are enticed abroad and difficult to replace. We already know how difficult it is to recruit good scientists. The reforms in the UK system such as the *Research Assessment Exercises* which have created a 'transfer market' between universities, and the attractions of large investments in science in other OECD countries, are making it even more difficult. As the good science faculty disappear, attracted by the research dowries in universities and industry abroad, the undergraduate students will be further disadvantaged, and the process of decay will reinforce itself.

11. The quality of science teachers in the institutes of technology and in the schools will decline, further exacerbating the situation. It is already difficult to recruit top class teachers of physics and chemistry.

12. Gradually as the quality of all science based teaching in universities and schools becomes unreliable, we will not be able to educate properly doctors, nurses, pharmacists, veterinary surgeons, engineers, agricultural scientists, computer scientists, forensic scientists, patent officers, food scientists or any other scientific professionals. Like some developing countries we will have to arrange for our scientific professionals to be educated abroad, and we will recruit more and more scientific professionals from abroad.

Conclusion

Dr. Kane's paper is being published at a critical time when the Irish government needs to reconsider how it receives and responds to advice about investment in

science and technology. I hope Irish economists will investigate in even more detail the connection between scientific infrastructure, the creation of wealth and the overall welfare of a society in this age of high technology. It seems to me that the best way to do this is to carry out case studies on those countries, industries, companies and universities which have led the high technology revolution of the last fifty years. The connection between scientific infrastructure and wealth has been clear to our competitor nations which is why those nations which have been investing in the sciences are those which are revolutionising the international economy. The ESRI Report is very helpful in explaining this connection.

However if Ireland is to avoid 'scientific meltdown' the state should aim to invest about £200 million per year , additional to present expenditure, in a competitive national science research programme with ancillary provisions for patenting, start-up companies and public education. Expenditure should be split about equally between biotechnology, all biology including agriculture and medicine, the hard sciences, including physics, chemistry, engineering and geology, and computer science. It will take five to ten years to assemble the groups of scientists capable of using £200 million per year in research and ancillary programmes of international quality. In its Technology Foresight, ICSTI proposes that £500 million should be spent over five years - this will be a good start provided the money is spent on research proposals which are chosen primarily on scientific merit by a peer review process as happens in the United States and other mature scientific societies.

It is with great pleasure that I second this vote of thanks to Aidan Kane and congratulate him on his Barrington medal and thank him for a stimulating paper.

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Dr. Roy Johnston: I am somewhat uneasy at the level of abstraction with which the economics community attempts to examine the *science, technology and innovation* (STI) process. I would be more comfortable with an approach rooted in the theory of the firm, and in the nature of the constraints experienced by a board of directors when making an investment decision.

I should suggest in passing that it should be possible to derive the laws of macro-economics from a statistical model of an ensemble of firms operating in an economy, by analogy with the way one can derive the gas laws from the statistics of the kinetic motions of the molecules. I take the liberty of suggesting this as an item for the agenda of the economic modelling community.

I noted at the time John Bradley published his economic model that he had allowed for several parameters which seemed to me to relate to, or perhaps even represent, the STI process, and I welcomed this as a possible link-point for discussions such as this. Later, when on behalf of the *Irish Research Scientists Association* (IRSA) I was exploring the possibility of persuading an economist to help them lobby the government (given that governments, for some reason, tend to listen to economists), I found it difficult to get support for the idea, and I did not pursue it further. Dr. Kane's paper however constitutes a link-point around which this approach might be re-opened.

An initial approach might be based on a detailed analysis of the differences in culture and environment between Ireland and Finland, taking perhaps as pilot-studies the business and innovative histories of the firms Smurfit and Nokia. I recollect maybe a decade ago commenting on this in a letter to the *Engineers Journal*. Smurfit stays in woodpulp and goes global in woodpulp. Nokia begins in woodpulp but at a certain stage, having saturated Scandinavia, decides to employ some good graduates and goes into telecommunications. It is now a world leader in a key high-tech sector.

We need comparative international studies of the STI process, in comparable-sized small states, exploring all factors in the political, socio-economic and cultural environment which influence the innovation culture. The differential between the Irish 1 percent and the Finnish 3 percent of GNP dedicated to STI, as exposed on RTE *Prime Time* programme yesterday, needs to be explained.

The role of the central state has always been crucial to STI, ever since the beginning of the realisation by states that 'knowledge is power'. The funding of the *Royal Society* by the state at the end of the 17th century consolidated a relationship that can be traced back to da Vinci and earlier. The key motivation has always been to give a competitive edge to the military system. In Ireland we have not had this motivation, to our credit, and the opportunity exists to dedicate an equivalent motivation to the civil STI process.

There is a need to teach about the STI process at third level education, in the humanities and the business schools, and to develop relevant teaching materials, specific to the needs of small 'fringe' countries like Ireland and Finland, and to ensure that STI 'best practice' is embedded in the culture.

Professor John O'Hagan: I like the other speakers before me wish to thank Aidan Kane for his paper addressing this very interesting topic. I wish though to address my comments to what David McConnell said in response to the paper by Aidan.

As always, David's arguments were stimulating and thought-provoking but they should on this occasion not pass without some comment. I think it may be unfair to suggest, as David did, that there has been a total failure to invest in human capital in Ireland in the last thirty years. It may be that this is true in relation to some types of human capital, but overall such an argument is not sustainable. Indeed, many people posit investment in human capital over the last three decades as the main explanation for the growth of the economy in the last five years or so.

I liked David's distinction between a 'turnkey' economy and an innovative economy. Turn-key has some negative connotations though, which I would like to challenge. For an economy/region as small as Ireland the ability to take on board and adapt new technology is a very important consideration and indeed a crucial factor in determining its ability to grow. Several of the fastest-growing regions of the world have displayed such an ability to adopt and adapt new technology developed elsewhere. Indeed, it may make more sense for a small region like ours to concentrate on this aspect of technology and leave innovation to other larger centres.

Following this, I would like to pose some questions to those here who, unlike I, work in the STI area. Is it not the case that there are huge economies of scale in research and development and that some minimal critical mass is required before a research and development function becomes a viable proposition? If yes, does this not mean that such research and development will be concentrated in certain centres of the world and that places as small as Ireland may have no such activity on any meaningful scale? If the answer to this is yes, the question then is does this matter? After all, in time everyone could benefit from advances in the STI area as

improvements are disseminated to those willing and able to adopt and adapt them. In this case, is it not better that Irish research and development personnel are working in meaningful and viable research centres elsewhere rather than be located here where no centre may be viable enough to produce significant technological breakthroughs? I pose these as questions, not statements, and would be interested in your reactions.

The final point I would like to make in relation to David's comments is that even if it were established that there should be a greatly increased STI presence in Ireland it does not follow necessarily that the state should provide the funding, either in full or in part, for this. Nokia in Finland was mentioned as a shining example of large-scale STI expenditure but this is a private company. The United States is also much referred to when STI is being discussed, yet most of the expenditure there I would suspect comes form the private sector. I would be interested to know in fact what proportion of STI expenditure is accounted for by state expenditure in some countries comparable to Ireland. The debate on STI in a small country like Ireland really has I feel to be placed in a rather different framework to that say in a large country such as Germany or the United States: the policy discussion and framework say in Bavaria or Connecticut might be a more useful reference point.

Dr. Grainne Collins: Economics is a subject with a very long history. This history was never an uni-directional movement towards 'enlightenment'; there have been many false dawns along the way. Many commenting theories and believes about how the world and, in particular, how the economic realm are structured co-exist, overlap or replace each other - never has this been truer in than in this century. The divisions are multifarious and often bitter - methodological individualists versus realists, applied versus pure, macro-model builders versus micro-scale researchers and, important for this talk, the division between those who believe the world tends towards equilibrium and those who don't. Aidan's paper came from the Austrian tradition that believes very much in methodological individualism (as does neo-classical economists) but which eschews all notion of equilibrium - instead attempting to establish the stabilising factors within society. The idea that Austrian economics was somehow an 'upstart - fly-by-night' tradition is inaccurate - depending on how these things are dated it is just as old as neo-classical economics. However, what is true is that it is not in the Anglo-Saxon tradition of economics.

Even within Anglo-Saxon economics neoclassical economics could be classified as a newcomer, the broader political economy approach of Smith and Marx (not to mention the contributions of Sraffa, Ricardo, Keynes) all pre-date it. However, I think the longevity of a theory while it might confer some intellectual credibility is a weak ground upon which to stand and fight - after all for how long did people think the world was flat? Rather the question that should be asked is - how well does it explain the world we live in and help us to reach the goals we set ourselves. (The last sentence contained a normative statement - another old but marginalised area of

economics.) This is my problem with neoclassical economics, things that I see as important in the world around me - gender, class, race, history are ignored or assumed away within the neoclassical tradition. Likewise Austrians says nothing of living in a world with deep social structures that have real effect. Therefore I look to a new doctrine, feminist economics, which calls upon the older traditions of institutionalism, realism and even development economics.

Feminist economics concurs with the Austrian tradition that there is no equilibrium except, maybe, on a Robinson Crusoe island. However, many Feminist economists argue that gender (and location/class/race/sexuality) has real effects that can not be reduced to the sum total of individuals expectations, opinions and behaviours (there is emergence), so departs also from the Austrian tradition. However, I hope that feminist economists are respectful of other economists struggling to deal with a complex world and answer the question - how do we provision for needs? Now there is a question that has a very long history in economics. I join with the other speakers in thanking Aidan for stimulating such an interesting debate.

Dr. Sally Hayward: Industrial policy, has all the overtones of mercantilism and corporatism. It is traditionally seen as government intervention, prompted by and for the benefit of production interests, often offering subsidies as an alternative to protection and, like trade protection, open to capture by production interests. For this reason, economists have often looked on industrial policy developments, as other market interventions with great suspicion. Much of this suspicion originates as a consequence of the theoretical and ontological lacuna in mainstream economics thinking in respect to industrial policy which has been exacerbated by the social construction of knowledge into science/non-science and its continued reflection and reproduction within and by academia.

Aidan in his Barrington lecture is to be applauded for recognising this very lacuna within the evolution of an 'innovation policy' in Ireland. Not least that traditional 'market failure' justifications for policy interventions, such as neo-classical thinking infers, have by and large guided the policy community in their approach to innovation policy. Such an endeavour is extremely worthwhile not least because of the current saliency of mainstream neo-classical thinking within policy communities world-wide.

On Economics and Technology Policy

Aidan accurately points to the general trend in industrial policy thinking which views technology and innovation as critical to increasing the wealth of nations - one of the primary concerns of any neo-classical economist. One of the issues raised is that there has been a general domination of STI policy by neo-classical thinking in Ireland. My first point is not to completely disagree with Aidan, but to suggest that there has been more non-mainstream economic thinking about STI than many other public policy debates. Part of the reason for this lies not so much in the victory of

competing paradigms over the hegemony of economics, but more in the recognition of the limited capacity of mainstream economics to deal with knowledge and learning as critical factors in economic growth. Whilst the ontological dominance of mainstream economics thinking is extremely powerful in shaping particular policy paradigms, not only in Ireland but equally in most policy institutions world-wide, a very comforting development has begun to take place in the policy-making process which demonstrates a shift in thinking about STI. Indeed, more importantly the interesting debates currently taking place about STI do not come from within the economics paradigm.

One of the problems for designing technology policy is that contemporary mainstream economics has a very inadequate conceptualisation of knowledge and learning. Mainstream, Marxian and Austrian economics are largely blind to the institutional and cultural variety within capitalism, because of the weaknesses at the core of their theory. The professions of formal economics has restricted analysis of technology to its impact on the production function and has conceived of technology in a very limited sense:

As Rosenberg, (1982, p. viii) outlines:

> *"Economists have long treated technological phenomena as events transpiring inside a black box. They have of course recognised that these events have significant economic consequences, and they have in fact devoted considerable effort and ingenuity to tracing, and even measuring, some of these consequences. Nevertheless, the economics profession has adhered rather strictly to a self-imposed ordinance not to enquire too seriously into what transpires in that box."*

Consequently it is not desirable to turn to orthodox economics for insight, nor it seems, can we gain improved understanding from texts in international economics, which generally reinforce the restricted economics view. According to Ingrim and Dunn (1993, pp 105-106):

> *"An improvement in technology means that larger output can be produced with given inputs of the factors of production. If the supply of these factors remains unchanged, such a technological change means that the production-possibility curve shifts outward to the right."*

This could be true of course - but it hardly exhausts the range of important questions that need addressing on technology and its role in economic development!

As far as understanding public policy in an areas such as technology goes, one inherent problem in mainstream economics lies in the economist's traditional static framework in which technology is treated as an exogenous 'bounty' available to all-comers at zero cost. Knowledge as a free and public good has long been disputed by scholars concerned with issues of access and control of knowledge. The field of

economics by large has a marked reluctance to engage with the nature of technology and related social processes. To find greater emphasis on the role of technology, we need to turn to other broad social sciences. Across this rich emergent literature within the social sciences on technology and innovation, it is widely recognised that technology is often complex, multi-dimensional, expensive to implement and specific to a particular firm, that a large part of it is tacit knowledge and passed down by trial and error, or embedded in institutions, rather than the systematic application of science (Dosi *et al.*, 1990). Taking this evolutionary view point, a very different set of conclusions emerge such as how firms and countries differ in their path of technological development, technology transfer happens at a different speed as firms and countries attempt to catch up or get into the game, that skills and knowledge are embodied not in codified artefacts but in people and their skills. All of which are markedly different conclusions to the 'market failure' problem and result in far more wide-reaching policy prescriptions than supporting basic research and a research infrastructure where spontaneous activity will spill over into the economic development process. The evolutionary view looks to R&D and innovation as an essential part of system dynamics.

Aidan's paper alludes to this but I suggest it could have turned to the rich methodological and ontological differences within the social sciences for example to political economy, to Schumpeter and the long wave theorists, to the literature on business studies, economic geography and international political economy to pursue its objective. The debate is going on *outside* economics not within! A fully developed discussion on *'Innovation Policy in Ireland'* cannot be reduced to the problematic of resolving tensions between economic science on the one hand and on the other, public policy.

A second and related point to the above concerns the specifics of Irish STI policy development. The historical development of an industrial policy in Ireland leading to our current position where technology/innovation policy plays a central role necessitates appropriate consideration. This includes a discussion of the socio-political context in which outcomes have been shaped, the role of significant 'actors' in that process and their varying concerns, the influence of the *European Community Structural Funding* of STI and its impact on the type of policies developed and the power of global macroeconomic forces that have impacted on Ireland's own institutions and responses to its development challenges, especially in respect to a recent noting that survival in the evolving global economy is increasingly dependent on the quality and innovativeness of the people, skills and talents available at a national level. It was surprising that a discussion of this nature did not include a review of the discernible shifts in thinking in respect to industrial policy in Ireland since the *Telesis Report* in 1982 through to the *First White Paper on STI* in the history of the Irish state in 1996.

My final point refers to the policy community. This is a rich ether rather than a monolithic entity. The paper underplays this and pays scant attention to the

significance of negotiation and bargaining in power relations within this community and the impact this can have on the pace and type of institutions and polices that are subsequently developed. In a sense - that mix of institutions, attitudes and behaviour which reflects the cumulative development of ideas from the past and helps shape their future direction, leading to distinct regimes or 'cultures' within different firms and different countries' responses to their own development challenges.

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