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Ireland's National Innovation System: An Exploratory Study of Supporting Institutions and Dynamic Actors

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Abstract *This paper begins with a brief look at the literature on national innovation systems (NIS). Building on the NIS approach, we present a simple conceptual framework. National innovative competence is dependent on the presence of dynamic STI actors, operating within the confines of compatible institutions. We distinguish the roles played by different STI actors and argue that heterogeneous actors engage in innovation for different reasons. Collaborative innovation is not always a natural consequence of engagement in innovation but is characterised by a distinct set of considerations. The latter part of the paper is concerned with the application of this conceptual framework to the case of Ireland. We identify the institutions pertaining to Ireland's current innovative performance. An outline of STI actors according to their role in the system is then presented. In turn we outline the various contributions of Irish STI actors and explore their motives for engaging in innovation and collaborative innovation.*

Keywords: institutions; innovation actors; national innovation system; Ireland; science and technology policy; incentives.

1. Introduction

The Irish national innovation system (NIS) makes for an interesting case study; it evolved into its present shape amidst a backdrop of strong economic growth, where innovation policy was purported to be at the centre of a strategy for consolidating Ireland's prosperity.[1] In a relatively short period, Ireland acquired a complex set of science technology and innovation (STI) actors supporting and performing innovation. STI actors operate within an environment characterised by a stable macroeconomy, a responsive education system, targeted financial incentives and an efficient public sector. The institutional structure of Ireland holds valuable lessons for developing small open economies. Recognition of the importance of knowledge communication for innovative competence has attracted interest in the determinants of systemic linkages.[2] We look into the case of Ireland and explore possible determinants of systemic linkages, with a particular emphasis on joint R&D ventures.

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The paper begins with a brief look at NIS literature. Building on the NIS approach, we present a simple conceptual framework for the analysis of nation-wide innovation determinants. The framework sees national innovative competence as dependent on the presence of dynamic STI actors, operating within the confines of compatible institutions. We distinguish the roles played by different STI actors (*policy makers, policy enactors, technology producers, technology users, technology lobbyists*). Different (actor- and role-specific) motivations prompt STI actors to engage in innovation. Importantly, collaborative innovation is not always a natural consequence of engagement in innovation but is characterised by a distinct set of considerations. The latter part of the paper is concerned with the application of this conceptual framework to the case of Ireland. We start by identifying the institutions relating to Ireland's current innovative performance. An outline of STI actors according to their role in the system is then presented. In turn we outline the various contributions of Irish STI actors and explore their motives for engaging in innovation and collaborative innovation.

2. The Irish Economy

Recent years have seen the rapid economic transformation of Ireland. During the 1990s Ireland experienced substantial increases in employment and output, prompting many to draw parallels with the development experience of East Asian countries.[3] The transformation experience set Ireland out as an example in the context of developing European economies and has given rise to a litany of explanations for its success. Foreign direct investment (FDI), the EU and its structural funds, the fruits of consensus politics and effective governance are all hailed as protagonists in relevant literature.[4]

The scale, if not the quality, of the turnaround can be attributed to the colossal magnitude of FDI receipts; it is telling that in the space spanning the period 1980–2003, Ireland's inwards FDI stocks increased six-fold.[5] National conditions and international coincidences allowed Ireland to attract FDI in innovation-intensive industries. Owing to their sectoral and technological concentration, such industries are often reduced to two main 'clusters'. Foreign-owned firms operating in the Information and Communication Technologies (ICT) and Biotechnology clusters jointly account for the bulk of FDI to Ireland. Domestic industry has also grown in these two clusters. However, the extent to which the current levels of growth in innovation-intensive industries are sustainable is questionable.[6]

Technologically-driven FDI is conditioned by both demand for its technological products and the uninterruptible supply of new ideas for them. Since Ireland has positioned itself as an international supplier of technological products,[7] arguably the factors influencing innovative output are of great relevance to national policy. Further growth in inwards FDI will depend, at least in part, on further technological developments and Ireland's ability to deliver them. Therefore, developing a compatible and dynamic NIS could prove pivotal to maintaining Ireland's current economic prosperity. This has been repeatedly expressed in policy-oriented documents by the Higher Education Authority,[8] the Enterprise Strategy Group[9] and Forfás.[10]

The central position innovation occupies in public policy adds to Ireland's distinctiveness. Improving innovative competences is increasingly perceived as a viable strategy for sustaining economic growth, rather than being confined to the fringes of industrial policy.[11] At the same time though, the extent to which technological development has been endogenous to Ireland's economic development is

open to question. A manifested improvement in innovative competences is certainly concurrent with the period of rapid growth. Research and development expenditure as a percentage of GDP has increased steadily throughout the 1990s and is continuing to grow.[12] The growing involvement of private enterprise in R&D expenditure (BERD) has been the defining characteristic of R&D expenditure growth.[13] Throughout the 1990s the Irish government too has consistently increased spending on S&T in general and R&D in particular,[14] and has articulated a coherent innovation policy with a high focus on human resources and coordination mechanisms.

Innovation output measures also indicate a substantial improvement over the same period. The number of USPTO patents originating in Ireland was almost three times greater in 1999 than a decade earlier.[15] International indices[16] of technological achievement attest to Ireland's current status as a '*global innovation leader*'.[17] As an indication, Ireland ranks 13th in the United Nations' Technology Achievement Index[18] and 18th in the ArCo Technological Capability Index.[19] This is an impressive performance for a country that as recently as two decades ago had not only little innovative output but was also losing much of its highly skilled workforce to emigration.

3. A Conceptual Framework

The economy's ability to communicate and assimilate existing innovations as well as generate original ideas is often referred to as *national innovative capacity*.[20] Generating new-to-world innovations as well as diffusing and adopting existing ones is seen as central to improving competitiveness and ultimately as a key determinant of sustainable development.[21]

A body of recent literature argues that innovative capacity cannot be improved by isolated, myopic increases in inputs. Instead technology policy must take into account the processes of learning and interaction that characterise a NIS.[22] Systemic linkages induce learning and the accumulation of a stock of knowledge, which in turn forms a basis for increasing innovative output. In addition to financial inputs, systemic approaches highlight the importance of knowledge transmission mechanisms as a determinant of innovative capacity. Such transmission mechanisms include inter-organisational linkages, the mobility of human resources and the diffusion of innovations.[23] To aid conceptualisation, we distinguish between relatively static supportive institutions on the one hand and dynamic organisational (STI) actors (in industry, government and academia) on the other.[24]

In an ever-changing world characterised by uncertainty, the relative stability of institutions encourages economic systems (and by extension innovation systems) to operate productively.[25] Frequently, the term 'institutions' is used as a heading for all residual elements the workings of which do not have an explicitly stated STI role. In the interest of clarity we adopt here the view of Nelson and Sampat[26] in thinking of institutions as *social technologies* that have come to be regarded as a regular feature of the national economy. Such social technologies may include (but are not confined to) the political system, formal education, the financial system, the country's legal and regulatory framework and the pervasive influences of national culture. The development of such institutions is inherently path-dependent and thus of great interest to a study with a national scope.

Classifying STI actors according to the roles they play within a system assists an understanding of the ways in which they contribute to national innovative capacity. Andersen[27] and Lundvall[28] distinguish actors into *technology users* and *producers*.

They are the most important elements in the system having by far the greatest impact as market forces ultimately govern their actions. *Policy makers* too play an instrumental role by providing overall direction and devising measures to advance innovation. Policy makers can strive to ensure that market forces operate unobstructed by regulating competition and rewarding innovative output through the provision of property rights. In that sense, policy makers are the actors with the most direct effect on a country's institutions. Long-term technology policy can make a difference by fostering a supply of highly skilled labour and adequate public infrastructures. Very often though the success of their policies hinges on the effectiveness of public sector bodies charged with carrying out policy, which we choose to term *policy enactors*. This is where a flexible and honest public sector apparatus can make a difference. Important information flows about the direction of inventive activity (including specialist advice, calls for funding and market signals) emanate from a distinct set of actors, which we choose to call *technology lobbyists*. Technology lobbyists fulfil a vital feedback role, complementing market signals between users and producers.

Our conceptual framework relies on the premise that there are fundamental differences in the motivations of STI actors for committing to innovation on the one hand and for seeking out collaborative linkages on the other. STI actors go through a two-step decision process, limited by capability and information constraints. At first they must decide whether it is in their interest to engage in funding and/or performing innovation at all. If they deem their resource investment to be worthwhile they must then decide whether they prefer to do so on their own or share the burden with another STI actor.[29] The second step involves a weighing of the net benefits of collaboration (particularly with regards to individual opportunity costs for accessing a specific knowledge area) against the benefits of maintaining exclusive access to their present and future knowledge stock. Importantly the motivations conditioning each actor's decision to innovate and network cannot be considered uniform across time or nations; they are highly context-specific and can only be established by means of detailed case study.

Recent years have seen the increasing internationalisation of the Irish innovation system. The growing involvement of EU policy makers, EU funds and the drive towards a European Research Area (ERA)[30] coupled with the intrinsically international character of large MNE innovators contribute to this trend. Nevertheless, a considerable institutional framework is already in place in Ireland to justify the study of technological performance (from invention or transfer to development to diffusion) from a national perspective. Choosing the nation-state as the unit of investigation yields the advantage that the results of observation and analysis can be fed back to policy at the national level—where technology policy has traditionally been formulated.[31] National bodies including technology policy makers, advisory organisations and actions such as legislation and educational policy, have repercussions that can be felt throughout the state.[32] Ireland's quite distinct economic performance within the European Union (particularly in contrast to the other 'cohesion' countries, Greece, Portugal and Spain) is a further indication of the national scope's relevance.

4. Ireland's National Innovation System

The present section explores the Irish NIS; we describe supporting institutions before turning our attention to Ireland's STI actors. Our aim here is to present

a snapshot of the current state of affairs with special reference to recent developments.

4.1. Supporting Institutions

Historical events as well as recent planning and rule setting have shaped Ireland's institutional framework. Ireland's recent institutional interventions had frequently an either implicit or explicit innovation rationale. Key domestic changes in state governance and economic policy came about as a result of consensus politics. Following a wide-ranging consultation process, a response to the economic crisis of the 1980s was articulated in the *Programme for National Recovery*, published in October 1987. It set the basis for what came to be known as 'social partnership' between trade unions, industry and government. It was, in effect, a formal agreement restricting wage increases in return for tax reduction, social provisions and the promise of increased employment. This way, the absence of threats to the production process enhanced the dependability of the Irish labour force and by extension its appeal in international markets for FDI. At the same time, regular renegotiation left avenues open for consultation, albeit in a starkly distinct way from the decentralised collective bargaining of conventional trade-unionism. Centralised bargaining among interested parties, as is possible in a climate of political consensus, provides a measure of certainty that the outcome of negotiations is in line with national targets. The fact that the social partnership is renegotiated every three years in the form of a National Agreement assisted the development of what House and McGrath[33] call 'reflexive governance'—where important feedback loops are maintained, which among other things, are permissible of technology lobbying. It is widely acknowledged that the structures emerging from the social partnerships have facilitated business growth through the FDI route.[34]

Broad political consensus allowed changes to be made that would previously have been difficult to implement. One of the most significant changes was the reorganisation of state finances. The tackling of state expenditure and state borrowing permitted the implementation of a low corporate tax regime[35] with particular provisions aimed at exporting firms. Tight fiscal policies allowed the reduction of inflation and a predictable macroeconomic climate conducive to business growth.[36] Moreover, the extensive privatisation of state corporations and the effective liberalisation of competition in state-dominated industries was a key change.[37] The gradual introduction and successful promotion of the low corporate tax regime (especially in international markets for FDI) was perhaps one of the most important changes. However, the timing of its introduction can hardly be linked to the economic boom of the 1990s, given the fact that corporate tax rates actually increased during that time.[38] Rather, the tax regime, like other policies, yielded results when other complementary conditions also came into place.

Ireland currently possesses a varied and experienced public administration apparatus, ready to implement policy and safeguard legislation. This is partly because the country's long experience with protectionism left it with an adequate regulatory framework and public administration infrastructure for safeguarding competition and protecting intellectual property rights (IPR). Key public bodies for innovation are the Competition Authority and the Patents Office. The Competition Authority plays an active role in regulating competition and enforcing anti-trust legislation. The Patents Office, in charge of considering and granting patents and trademarks, also acts as a receiver body for patents to the European Patents Office (EPO). The

Patents Office's role is important in resolving disputes by appointing arbitrators and seeing cases through the legal process.[39] Its role has been strengthened by Ireland's tax legislation, which now incorporates an exemption for royalty, or other type of income derived from qualifying patents.[40] Notable also are efforts to raise awareness about IPR and their benefits among small- and medium-sized enterprises (SMEs).[41] There is also evidence that Ireland's general public sector apparatus improved dramatically over the boom years. Using summative determinants including resource allocation, corruption, red tape, the quality of the judiciary and the size of the shadow economy, Afonso *et al.* measured public sector performance and efficiency[42] for 23 OECD countries in 1990 and then again in 2000. They found that in this 10 year period Ireland experienced a marked improvement in every aspect examined and was the only country with an overall relative change that was substantially above average. In terms of efficiency, Ireland ranks 6th in the 23 country sample, having again exhibited the greatest improvement.

One can expect the presence of conditions that make financial capital for risky ventures readily available to positively influence innovative output.[43] Financial liberalisation expanded the availability of financial capital for technological investment and innovation. Kelly and Everett[44] argue that structural changes and financial innovation and integration increased the elasticity of the supply of credit in Ireland. Demand for credit was also bolstered in the background of accelerating growth, improving macroeconomic policies, a fiscal surplus and the stability (and prospect of permanently lower interest rates) associated with the European Monetary Union (EMU). The strengthened supervisory structure of financial instruments (the banking sector, unit trusts and money market trusts) helped ensure that the increased availability of financial capital was not accompanied by inflationary pressure.[45]

There are still, however, hindrances in Ireland's financial system. The effective duopoly in Ireland's banking sector is blamed for an average working capital rate that appears unresponsive to changes in the European Central Bank's base rate.[46] However, the gravity of such an obstacle is unclear. Christensen[47] believes that high costs for borrowed capital are not the greatest obstacle to technological investment. He points to the importance of the familiarisation of financial institutions with the intricacies of technological ventures (high risk, long-term returns) as well as the presence of established borrower–lender relationships. Technological start-ups and SMEs in general face particular difficulties in approaching banks. The absence of established borrower–lender relationships is a specific obstacle; the Irish Small and Medium Enterprises Association (ISME[48]) has repeatedly expressed concerns that borrowing is perceived as expensive and can be difficult to secure. Although the government has made innovation-related capital available through a number of transient subsidy schemes and tax allowances, a mechanism catering for SMEs has yet to become institutionalised.[49] At the same time, as highlighted in a recent report by PriceWaterhouseCoopers,[50] the formal levels of venture capital for high-growth potential start-ups remain quite low by international standards. The quality of venture capital agreements is partly to blame; according to PriceWaterhouse-Coopers under present arrangements Irish entrepreneurs receive a relatively small percentage of private equity thus making venture capital appear a less than viable source of finance.

The ability of the education system to supply the necessary skills in the sciences and engineering is crucial for the performance and future evolution of an innovation system. Third-level education in particular plays an active role via the provision of primary research, as well as the accoutrement of infrastructure (laboratories,

libraries, network facilities) for the knowledge economy. Ireland's tertiary education sector has a long and established scholarly tradition on a par with Western-European standards.[51] Given the traditional focus of Irish universities in arts and humanities, the currently demonstrable skew towards science and technology graduates is a testament to the sector's responsiveness. At the same time, increases in the capacity of institutes of technology also contributed to the timely volume production of technical graduates. The country has the highest percentage of such graduates in the EU.[52] A culture that holds high regard for education is also a positive factor. Private contributions from both Irish households and firms make up an increasing percentage of expenditure in education.[53]

The Irish labour force is highly mobile. Personnel mobility in Ireland has historically meant moving closer to the centre or worse, emigration. This mobility proved crucial at supplying the right skills, when needed. Of particular relevance here is the mobility of science and engineering professionals. An international study found that the proportion of science and engineering professionals who change a job on an annual basis[54] is a relatively high 16.4% (based on 1997 data),[55] placing Ireland above the EU average. Relatively high mobility is not necessarily positive. Further study is needed in this area as increased mobility fuelled by a regime of full-employment may pose costs in pecuniary and knowledge terms.

According to Carlsson and Stankiewicz,[56] a history of intense entrepreneurial activity could be taken as an indication of 'critical mass', which carries the potential for radical innovations. In that respect, the presence of a historically dynamic entrepreneurial base could also be counted amongst the institutional strengths of Ireland. According to a recent survey by Fitzsimons and O'Gorman,[57] 193,000 individuals (one in 13 adults in Ireland) were either actively planning to start a business or had recently done so when surveyed in 2004. Ireland compares favourably internationally with regards to the level of Total Entrepreneurial Activity,[58] occupying the top-place among the EU15.[59] Lack of venture capital and other supply side obstacles have not depressed entrepreneurial activity; indeed there is evidence that it is demand-driven. Such a high level of entrepreneurial interest is all the more important given Ireland's high income per capita and low unemployment; Fitzsimons and O'Gorman[60] argue that it is indicative of high-added value entrepreneurship arising as a response to market needs rather than a lack of options.

The combination of high-skills, low labour-costs and a favourable tax regime made Ireland not only the destination of choice for FDI but one of a high value-adding nature. EU membership and access to the common market also contributed to the location decisions of MNEs originating there. Arguably, a shared cultural and linguistic heritage with the US compounded the location decisions of MNEs originating there.[61] There can now be little doubt that Ireland's institutional framework is currently facilitating its economic prosperity. What is also clear though is that many of the institutional improvements that are now taken for granted do not predate the present economic boom. It was a multiplicity of very specific institutional aspects, conspiring with certain actor dynamics and an extremely favourable internationalisation of investment, trade and technology that facilitated the development of Ireland's current innovation system.

4.2. STI Actors in Ireland

The presence of social technologies (or institutions) compatible with the needs of a NIS merely permit its development. It is the actions of STI actors (for the most

part economic) that have fuelled Ireland's innovation 'engine'. We identify these actors and, in line with our analytical framework, look into their current contributions and related incentives.

(a) Policy makers

The role of policy makers in shaping Ireland's STI landscape could be summarised under two major headings; *direction* and *funding*. The responsibility for drafting technology policy lies with a handful of organisations at the ministerial level. In accordance with international practice, technology policy in Ireland falls under the wider scope of industrial policy; it shares many of its assumptions, its institutional framework and accompanying instruments. Thus STI policy makers operate under the auspices of the *Department of Enterprise, Trade and Employment*.[62] Most other government departments also possess important STI roles. Of interest here is the implicit technology policy role of the *Department of Education and Science*, through its involvement in the management of human resources and research undertaken at universities.

The *Office of Science and Technology* is the organisation directly responsible for the promotion and regulation of STI matters. Its role is mostly one of co-ordination and resource allocation to the various policy enactors. The realisation that industrial policy matters are closely linked to innovative performance led to the creation of *Forfás*, a statutory body responsible for advising in matters relating to 'enterprise, trade, science and innovation'.[63] Forfás' advisory role is enabled by its wide-ranging and regular information gathering exercises. Forfás undertakes regular technology foresight studies mapping out needs and comparing them to existing capacity. It also investigates new technical developments and assesses their economic and social impacts for Ireland (the so-called 'strategic technology platforms', e.g. biofuel, nanotechnologies, wireless networks etc.). It additionally has a co-ordination role for important policy enactors such as *IDA Ireland*, *Enterprise Ireland* and *Science Foundation Ireland*.[64] Strategic direction is also informed by the government's *Chief Science Advisor*, capitalising on technical expertise and responsible for identifying future challenges and providing recommendations for policy.

Policy makers in Ireland are due credit as much for their contribution to the country's NIS as they are for their restraint. To a large extent the current proactive approach to policy represents expressions of legitimate concerns over the lack of supporting physical infrastructures in the periphery and particularly in rural areas. A measure of parity between the centre and the periphery will inevitably be based on the success of policy makers in supplying the necessary inputs at the regional level. A policy direction that aspires to be based on pragmatic market needs (present or future) is a good model for identifying market failures and goes some way towards ensuring that government actions will not prove a substitute for private initiative. Some caution is called for, however, with regards to long-term needs forecasting. Prevailing in Irish technology policy of recent years is a confidence[65] in predicting the future state of affairs in technological markets and preparing institutions and STI actors for future changes. While policy makers inevitably need to prepare for future developments, arguably this can only be done for the immediate future. Ireland's success in attracting innovation-intensive FDI is the result of technological developments whose impact for Ireland could not have been foreseen.[66] The fact that the innovation process is inherently complex and open-ended means that predictions about specific skills and infrastructure needs can be hazardous affairs.

The major innovation policy instruments used are R&D incentives and direct STI funding. There exist several tax breaks aimed at stimulating innovative activity, including tax exemptions for expenses incurred in all kinds of scientific and technological research, privileged depreciation rates for R&D capital and a relatively low tax on royalty payments. In an international empirical study, Hall and Van Reenen[67] demonstrated that in the case of Ireland, the lower costs of innovation allowed by the combined Irish tax breaks are associated with increased innovation expenditure. This success is partly owed to the heavily targeted nature of incentives, with different arrangements in place for smaller firms and firms in specific sectors (such as software firms). Policy makers have also funded STI in general, materialising in inputs in R&D, education and training, technology transfer and related technical services.

Central government sources along with the EU's community support framework (CSF) are the primary sources of funding. Whereas in the past Ireland's technology policy was funded to a larger extent by CSF contributions, the trend now is towards greater reliance on national sources.[68] Such a shift is positive not least because it indicates willingness to assume greater responsibility on the part of Irish policy makers. Additionally, for all its considerable benefits,[69] EU funding may unwittingly import policy solutions, which were designed for the European core economies with distinct orders of magnitude, developmental paths, economic structures, and degrees of internationalisation. Arguably, greater reliance on national sources enables greater flexibility in implementing context-specific prescriptions.

The largest chunk of STI funding (43% in 2003) is devoted to education, closely followed by R&D (30%), with the remainder reserved for technical services and technology transfer. Government expenditure on research and development (GERD) is particularly small by international standards; in 2003 just 0.4% of GNP was pledged towards R&D, placing Ireland second-last among its EU partners. There are indications though that the situation is improving rapidly. Government expenditure on research and development (GOVERD) increased by 10% every year after 1995.[70] At first glance, one may postulate that the initial absence of public funds may have helped generate market opportunities for private involvement in R&D. This possibility appears more remote though when one considers the (international) technological markets that technology producers in Ireland cater for. Nevertheless, the qualitative aspects of GERD in Ireland suggest that a small-scale public expenditure that is competitive, highly targeted and conditional on the presence of linkages as well as a carefully designed tax regime can have a large effect on innovative competence.

Policy direction and funding streams have traditionally followed a top-down route that unavoidably favoured the Dublin region over the rest of the country. As a response, much of the CSF funds have been channelled at closing the gap between the core and peripheral regions.[71] Policy makers operating at the regional level are playing a vital role in customising inputs to regional and local needs. EU funds have facilitated the establishment of a number of bottom-up initiatives aiming to address regional imbalances. *Shannon Development Corporation*, a regional development agency that caters for the needs of the greater Shannon area, represents one of the most prominent attempts. Since its inception in 1959 it has provided support structures, allocated funds to hi-tech start-ups, and sought positive measures to embed foreign multinationals within the regional economy. Its efforts to work with local firms and public organisations to strengthen collaborative arrangements have been highly successful, earning Shannon Development

Corporation widespread recognition.[72] It is also noteworthy that organisations without a clear STI role are recognising the significance of technology for regional development. *Údarás na Gaeltachta*, a regional authority for the promotion of the Irish language in the west of Ireland, is such an example. *Údarás na Gaeltachta* possesses an economic role in sustaining regional investment and employment, and along these lines recognises an interest in promoting innovative activity. Its expanded technology role involves the provision of financial assistance towards technological advancement, including research grants, technology licensing grants and joint-venture incentives.

The current interest in technology from policy makers at all levels is a reflection of the overall success of economic policy.[73] Insofar as innovative activity is perceived to be central to economic matters then government support is assured. It is conceivable though that the particular state of the economy at any given time can influence such a perception and by extension the government's willingness to draft technology policy and back it with significant financial commitments. According to Yearley,[74] technology policy and associated inputs suffered during the 1980s in the midst of austerity measures and frequent elections. This is because the yields of technology policy interventions are not realised immediately and, just like innovation itself, are fraught with uncertainty. Referring to the 1983–87 period, Yearley notes that;

> … the only contributions towards wealth creation that science policy analysts could offer were long-term, far from guaranteed to succeed and disruptive in the short term.[75]

The scale and momentum of present funding as well as the associated institutional diversity are signs that perceptions about the relevance of innovation-intensive industries for the economy are more than just ephemeral and provisions for STI are to remain in place regardless of short-term economic circumstances. A measure of quality and appropriateness of policy prescriptions is also maintained through social partnership structures and other technology lobbying avenues. An economic slowdown could, in theory, influence policy makers' perceptions of costs associated with STI funding. Therefore, given the *inter-alia* dependence between economic success and technological interventionism, the possibility that the future of technology policy may well be determined by broader economic concerns is not altogether removed.

While, the level of diversity hints at the recognition technology policy enjoys, there are signs that the current multiplicity of actors with overlapping responsibilities, layered across a hierarchy of governance, may be a less than efficient arrangement. Following extensive interviews with Irish innovation policy makers, Hilliard and Green[76] found that technology policy is strongly departmental and is characterised by the absence of cross-cutting approaches to governance. According to Hilliard and Green policy makers at different levels can have a varying understanding of priorities; they produce evidence pointing to 'shortermism', 'ministerial influence' and 'competing rationalities'. Although they recognise the need for diversity, they are critical of the current multiplicity of actors and argue that there is at least some scope for consolidation.

(b) Policy enactors

Ireland's NIS owes a great deal to the efforts of numerous public sector organisations charged with micromanaging matters relating to innovation. Policy enactors,

that is, organisations in direct day-to-day contact with research generating organisations, have played a role by affecting both the sectoral structure of industry in Ireland and the quality of the available inputs. Importantly, the habitual interaction policy enactors have with research performers has given them valuable experience of needs and a corresponding ability to customise solutions.

No other single policy enactor has had as great an impact on Ireland's innovation system and economy in general as *IDA Ireland (IDA)*.[77] Since its creation in 1949, the IDA's function has been the support and promotion of employment generating industry. From 1994 its role has become more specific, as it seeks to attract and facilitate foreign industry in Ireland (while the needs of Irish-owned firms are catered for by a separate organisation, *Enterprise Ireland*). Through its offices around the globe, the IDA advertises Ireland's qualities in international FDI markets. Such is the success of the IDA that the contemporary influx of FDI is widely recognised as being at least partly attributable to its '*successful marketing*'.[78] The IDA proved instrumental not only in enticing foreign corporations to invest in the country but also in vigorously supporting their operations once in place.

For those companies that choose to invest in Ireland, the IDA provides set-up support and specific incentives for expansion. The IDA also plays a crucial role in directing MNE activities towards innovation. For instance, the R&D Capability Grant Scheme is an IDA incentive scheme targeted at encouraging MNEs to locate and expand their R&D functions within their Irish affiliates. The grant avails funds to cover both investment capital costs and current costs and overheads relating to innovative activity.[79] Other schemes offered in conjunction with Enterprise Ireland, include fiscal incentives for R&D activity in manufacturing and internationally traded services firms (Research Technology and Innovation Scheme), administering incentives for collaborative research (the Innovation Partnership Initiative) and drawing attention to tax breaks for localised intellectual property management. In 2003 the IDA supported 1,054 companies providing employment to 128,993 individuals (or 6% of the total labour force).[80] Informed by means of a close relationship with MNE affiliates in Ireland and empowered by broad powers to assume initiative, the IDA has managed to offer highly customised solutions. Indeed, Wickham and Boucher[81] argue that the IDA's current success and worldwide recognition is based on the combination of political importance and institutional autonomy.

Although primarily intended to promote indigenous industry, *Enterprise Ireland* (EI), provides innovation and innovative collaboration support for all firms operating in Ireland. Enterprise Ireland's activities focus on the encouragement of growth and the internationalisation of indigenous industry with a view to maintaining current employment levels. A high degree of customisation to specific sectoral and regional needs and indeed to the requirements of firms of varying sizes is also prevalent in EI's schemes. EI[82] aims to provide tailored advice for companies capitalising on research in ICT, biotechnology, optoelectronics, power electronics, advanced manufacturing and materials. EI differentiates and actively supports small firms with an integral innovation element dubbed 'High Potential Start Ups'. Moreover, EI[83] encourages the adoption of product and organisational technologies that improve productivity by means of financial support. For example, funding for up to 50% of technology acquisition and related training expenditures is offered, with special provisions for SMEs.[84] In addition, EI seeks to increase productivity by means of education and training of personnel. EI places great value on the commercialisation of research, offering preferential funding for applied

research.[85] EI also aspires to promote regional development using local third-level institutions as platforms for start-ups, collaborative research and a growing number of research incubators. Encouraging vertical and sectoral alignment to MNEs as well as encouraging domestic firms to seek the comparative advantages of other economies is another area open to its policy prescriptions.[86]

The various research councils too, armed with substantial financial backing, are emerging as potent policy enactors. Of greatest relevance to the innovation system is the role played by the *Irish Research Council for Science, Engineering and Technology* (IRCSET). IRCSET caters for the human resource needs of Ireland's innovation system with a particular concern for the scaling of scientific skills at the doctoral and post-doctoral levels. IRCSET encourages STI actor cooperation by making part of its funding for postgraduate students conditional on the presence of university–industry linkages. *Science Foundation Ireland* (SFI) is the policy enactor with the responsibility for the support of basic science. SFI allocates funding for basic research in pioneering fields and oversees the engagement of actors from both industry and academia. The fact that the SFI is staffed to a large extent by scientists ensures a measure of understanding of research agendas. Experts in science as well as government and industry representatives award grants following competitive review of research proposals. Other noteworthy policy enactors include the *Technology Transfer Initiative* and the *Innovation Relay Centre*. Both these organisations aim to encourage the transfer of technology across borders and across fields as well as bridge information asymmetries among industry and academia.

(c) Technology producers

The production of technology in Ireland is characterised by sectoral agglomeration. The two main such sectoral 'clusters' comprise of firms operating in the fields of ICT and Biotechnology, accounting for 55 and 29% of BERD, respectively.[87] The ICT cluster includes industries providing software and computer related services as well as the production of electrical and electronic equipment, whereas the Biotechnology cluster includes the pharmaceutical and the instruments industry.

The OECD points out that the national scope in the analysis of innovation systems is justified by the fact that different countries evolve along different technological paths or 'trajectories'.[88] BERD in Ireland more than doubled in the 1995–2003 period.[89] Such an abrupt growth record is symptomatic of what could be described as the innovation system's technological path-dependency. The relatively young age of the basic scientific disciplines underpinning Ireland's two major sectoral clusters could account, in part, for the rapid pace of growth in innovative activity. As proposed by Schmookler,[90] it is conceivable that as the technical fields in question approach maturity, inventive activity begins to exhibit diminishing returns until it eventually reaches a plateau at a level of growth that is comparable with more established fields. In light of recent evidence pointing at a slowdown in the level of investment in both ICT and Biotechnology,[91] the continuation of strong BERD growth appears unlikely in the long-run, especially so in the absence of diversification in burgeoning technological fields. For such a diversification to become possible, either a second wave of inwards FDI of comparable magnitude (this time in new sectors) or the emergence of indigenous firms taking on the challenge[92] must come into being.

There are two very important characteristics distinguishing Ireland's technology producers. Firstly, the majority of technology production is driven by demand

located outside of Ireland. Second, technology producers exhibit a preference towards product innovations. Results from the Community Innovation Survey (CIS) show that roughly four-fifths (81%, as opposed to a 59% EU15 average) of all BERD in Ireland is directed at the development of product innovations with the remaining devoted to research on process innovations.[93] Both characteristics are related; unlike process technologies, which alter the mode of production, product innovations can easily be converted to exportable commodities. The emphasis on product innovations hints at demand-pull innovation, directly motivated by sales. The proliferation of trade in so-called 'weightless' goods,[94] adds credence to this argument. Exports of such weightless goods as electronics and pharmaceuticals accounted for over 70% of Ireland's total merchandise exports in 2003.[95] To the extent that process technologies are associated with productivity rises,[96] the emphasis on product innovations is indicative of technological production that is demanding in terms of labour. Crucially, the considerable presence of MNEs has awarded Ireland with the additional benefit of the production of technological goods originally invented elsewhere. It is therefore plausible that the high focus on product innovations as well as the prominence that the two main clusters enjoy in the economy may have contributed to Ireland's high employment levels.

Foreign multinationals have not only had a significant impact as FDI conduits but are also major R&D performers. This is to be expected, as much of their investment is in innovation intensive sectors. Even within those sectors though, MNEs account for the majority of BERD. The clustering of resources in particular sectors first and primarily by MNEs has provided Ireland with a unique advantage; critical mass in these industries has been achieved by external means without the economic costs associated with the many failed start-ups of an indigenously developed cluster. A majority of MNE technology producers are US firms seeking location-specific advantages, such as Ireland's geographic proximity to the EU, access to the single market and a shared cultural and linguistic heritage. These assets, in conjunction with and additional to the favourable tax regime and Ireland's skilled human resources and effective institutions, provide Ireland with an edge over similarly endowed economies.

The IDA takes pride in counting some of the most innovative firms in the world[97] as having an R&D-active presence in Ireland. Both the innovative output and activity of MNEs is certainly not negligible. According to Forfás[98] in 2003, foreign firms managed to register 365 patents, representing 48% of the Irish total. Barry argues that in a low corporate tax jurisdiction, such as Ireland, conventional R&D intensity measures, based on (inflated) output, tend to underestimate the true extent of innovative activity due to transfer pricing.[99] In response, Barry proposes measuring R&D intensity by the ratio of R&D expenditure per employee. Indeed, using employment as the preferred intensity measure, Irish technology producers appear to perform better in international comparisons than they do when R&D intensity is based on output. The average foreign-owned company spends substantially more, per employee, on R&D activities than the average Irish-owned company. Barry calculates that in 2001 Irish-owned firms spent €1,272 per employee on R&D while the same figure amounted to €3,773 for foreign firms.[100]

Indigenous firms, as a whole, appear to be less prone to innovate than foreign firms.[101] This has more to do with the nature of their operations rather than an intrinsic aversion towards innovation; Irish-owned firms are mainly concentrated in labour-intensive sectors (such as food products, beverages and tobacco).[102] SMEs are also concentrated on traditional sectors, which are capital rather than

innovation-intensive. A minority of small, dynamic SMEs seeking the benefits of 'technology convergence' forms an exception. Such firms find innovative new ways to recombine existing product and process technologies into new technological products. A possibility for their support comes in the form of multidisciplinary research. Many applications of research products only become obvious when their impact is assessed in a wider context, away from the confines of the particular discipline or sector where it first originated.

Sustained collaboration is dependent on a number of conditions being right. A recent policy-oriented document by Forfás[103] on 'Innovation Networks' recognises the need for the facilitation of sustainable R&D linkages. Forfás highlights the lack of schemes aimed at industry–industry innovative collaboration and proposes financial incentives (conditional on 'demand-driven networks') and the use of brokers to facilitate lasting networking arrangements along the lines of similar policies implemented in Denmark and Italy. The use of brokers could certainly help collaborative arrangements by nullifying information asymmetries. Arguably though, figuring out the scale and direction of financial support for collaborative R&D needs to be informed by the whole range of motivations (and associated costs) for participating firms.

In engaging in collaboration, organisational heterogeneity is a major influence. Both the potential and the likely outcome of collaboration appear to depend on the position of the collaborating firms along the supply chain, whether they are competitors, as well as their ownership (Irish or foreign). Research by Belderbos *et al.*[104] in Dutch innovating firms shows that competitor and supplier cooperation frequently results in incremental process innovations. In contrast, university–industry cooperation in R&D is more likely to result in readily marketable product innovations.[105] In that respect, the demonstrable preference of Irish technology producers for product innovations points to university–industry collaborations as their path of choice.

In a comparative study of Irish innovation policy, Roper found that in many cases MNEs are not embedded in the local economy.[106] According to Roper, Irish host MNEs tend to have few local suppliers and work on a collaborative basis with only a fraction of those. Whereas fiscal incentives appear to have worked on kick-starting innovation among MNEs, they have so far had limited impact on influencing collaborative behaviour. It is possible that this difficulty may arise as a result of their ownership structure. A string of recent FDI studies puts forward an explanation linking the propensity to collaborate with the ownership structure of local subsidiaries and affiliates. Louri *et al.*[107] distinguish between two ownership regimes for MNE affiliates in host countries (majority/minority ownership) and argue that the regimes bestow very distinct behaviour. In industries that are innovation-intensive, majority ownership is preferred as MNEs seek to protect their highly-valuable technological lead. The implication is that majority-owned affiliates are by definition less embedded in the host economy and are therefore less likely to collaborate. Hence, the presence in Ireland of MNEs who are the definitive technological leaders in their respective fields may not be conducive to collaborative innovation. In an econometric analysis of inter-firm linkages in the Irish electronics sector, Görg and Ruane find that Irish-owned companies are more likely to have linkages and in contrast, that large and expanding firms have lower linkages than other firms.[108] MNEs need a good reason for risking the loss of a technological lead; typically, it is the threat of exclusion from vital foreign markets that forces MNEs into joint ventures permissive of innovative collaboration. The present Irish tax regime

actually encourages majority ownership, if only because this ownership regime ensures control of transfer prices.

Moreover, Görg and Ruane found that the number of linkages increases over time and is more likely to occur among firms with a history of linkages.[109] In a case study of high-tech companies in Ireland, Ryan *et al.*[110] show that prolonged collaborative research ventures occurring amidst a climate of openness and combined with sound management practices see the emergence of trust, thus making further collaboration more likely. In an open society, trust emerges over time as a natural by-product of interactive relationships.[111] Importantly, if firms with previous experiences of linkages are more likely to engage in linkages again[112] then financial support and other incentives for the inducement of linkages need not be perpetual.

Universities and research centres are also major contributors to Ireland's NIS. Their contribution is two-fold; on the one hand, as the de facto organisations for basic (as opposed to applied) scientific research, they push forward the boundaries of the scientific fields underlying technological development; on the other hand, they act as hubs for the distribution of tacit knowledge by both training the science and engineering workforce (along with the institutes of technology) and by availing their stock of knowledge, expertise and research infrastructures to industry and government.

A common measure of original scientific output is the number of peer-reviewed publications. In that respect, the output of Irish scientists is rapidly increasing. In 2002, Ireland produced 647 scientific publications per million of population up from 527 in 1998.[113] However, a comparison against other EU countries is not favourable to the outlook of Irish scientific performance. Employing the same measure, in 2002 Ireland stood below the EU15 average and performed better than just the other cohesion countries (Greece, Spain and Portugal) and Italy. International comparisons also highlight the relatively low numbers of higher education researchers.[114] In tandem with their role as educators, universities in Ireland have been providing a steady supply of science and technology graduates. Among those aged 20–29, Ireland has the highest proportion of graduates in mathematics, science and technology (23%) in the whole of the EU.[115] The current mix in the supply of graduates has been the result of a concerted effort to micromanage the availability of places in universities and institutes of technology.

Higher education in Ireland exhibits a large dependence on public funding. As much as 80% of funds can be traced back to the government.[116] OECD data points to the fact that Irish academic institutions have been failing to attract private funding for research;[117] the relative dependence of university research on private funding[118] was lower in the year 2000 than in any other year in the previous two decades. It appears that Irish universities are 'traditional'; they have still not expanded their roles significantly beyond those of education and research, to include the entrepreneurial objectives present in the stylised modern university envisaged by Etzkowitz.[119]

University funding reform in many European countries has recognised the need to 'incentivise'. In Ireland this thinking is reflected on the competitive nature of the HEA's Programme for Research in Third Level Institutions (PRTLI), which is also favourable to cross-institutional collaboration. The successor programme to the PRTLI may explicitly seek increased university–firm linkages and place greater focus on commercial output. The possibility of linking funding to innovative output and overall performance as part of a set assessment exercise is an interesting one. Institutional evaluation in a performance exercise could be used as an instrument to induce greater university–firm linkages with a view to enhancing the potential for

the commercialisation of university-performed research. It should be noted, however, that funding cannot be linked inextricably to research performance as, in contrast with other university systems (e.g. UK, US) there is a regional need to maintain research active institutions. A survey of Irish education performed on behalf of the European Commission[120] showed that while existing structures throughout Europe reward academic output (i.e. in the form of peer-reviewed publications), similar rewards for research commercialisation are not in place. In order to encourage the commercialisation of research, CEC propose that financial incentives as they materialise in competitive funding streams are accompanied by other incentives such as professional recognition, career advancement and additional supportive resources.

(d) Technology users

Much of the experience of Ireland with FDI can be explained under the light of Vernon's product cycle theory.[121] Vernon proposes that the decisions of MNEs to transfer and generate new innovations are associated with labour costs, the scarcity of factor inputs and access to local or proximate markets. It follows that R&D intensity in production is related to the developmental stage of the host country. As a country develops and the cost-effectiveness of local labour declines, MNEs increasingly rely on the transfer of technology from their home countries in order to remain competitive. Additionally, increased host-country R&D by MNEs is prompted by the maturity of local markets and the need to differentiate innovation products and processes for local consumption. It follows that the degree of commitment to R&D exhibited by MNEs could be interpreted as an indication of the maturity of the intended technological markets.

Ireland, however, does not have only domestic demand to thank for motivating such MNE behaviour; the intended technological markets extend beyond Ireland's borders to its EU partners and the United States. According to the IDA,[122] in 2002 exports represented 93% of all MNE sales, a figure that was also similar for the three preceding years. Görg and Ruane[123] argue that the decisions of US-originating firms to locate in Ireland can be explained for the most part by Ireland's proximity to key EU markets. They point to the fact that almost half of US investment in Ireland is in the 'weightless' electrical and electronic equipment sector. By contrast, they also show that US investment is lowest in transport equipment, the products of which include anything but weightless motor vehicles and their parts. The international demand for Ireland's technological products is also evident from the dominance of high-tech commodities among Ireland's merchandise exports. The current rise of the services sector and its innovation-intensive nature offer some reassurance for continued growth in domestic demand for technological products.

The mainly international demand for Ireland's innovative outputs reinforces the argument for Ireland's location-specific advantages as a driver of MNE R&D performance. It also casts doubt on whether Ireland's successful experience is replicable by similar countries. Policy has so far focused on the market for FDI and has had primarily supply-side considerations. Realistically, the relatively small size of the domestic market limits its demand-pull influence.

(e) Technology lobbyists

Technology lobbying could be thought of as the innovation system's feedback mechanism. The actors who implicitly (as a by-product of other actions) or explicitly (by

exerting pressure) interact with institution-shapers provide crucial information for institutional change. This can be a beneficial mechanism insofar as the needs portrayed by individual technology lobbyists do not deviate significantly from national goals. Policy makers and by extension policy enactors are perhaps the most prominent institution-shapers and it is their interactions with technology lobbyists that are of interest here.

Irish universities influence research policy and associated grants through formal and informal means. A particular channel for such lobbying is via the various calls and proposals for PRTLI and other competitive research funding streams.[124] Importantly, areas open for competitive funding are settled following thorough *ex ante* consultation. The proposals themselves form a communication channel by voicing heightened scientific interest in a particular area and/or demands for specific infrastructure and supporting human resources. It could be argued that the experience of Irish technology lobbyists in successfully securing competitive funding from the CSF has helped the smooth implementation of PRLTI and the unobstructed flow of information.

Formal associations of interest groups lobbying along regional, sectoral, scale or technological lines are also common. Examples include the Regional Assemblies,[125] the Chambers of Commerce, and The Irish Small and Medium Enterprises Association (ISME). There is also widespread regional lobbying. Information for Shannon's regional needs are expressed in the 'Shannon Regional Innovation Strategy' initiated and performed by Shannon Development. It aims to identify and propose actions to strengthen the elements of Shannon's regional innovation system.[126] Examples of proposals made for the consideration of policy makers within the frame of the strategy include calls for considering the value of research incubators and technology parks.

The presence of intermediate-level governmental policy with a responsibility for the direct implementation of government initiatives (policy enactors) maintains useful feedback loops and provides a locus for the accumulation of context-specific experience. In that capacity, the contribution of the various policy enactors (IDA, Enterprise Ireland, Science Foundation Ireland etc.) in locating unfilled demand, customising inputs and identifying perverse incentives is considerable. By means of formal arrangements for reporting and their presence in relevant consultation committees, such bodies actively influence the efficient customisation of policy. Importantly, to the extent that policy-initiated national objectives are aligned with the pragmatic needs of STI actors, experience of such needs allows for a convergence of rationales. As the primary recipients of technology lobbying, the experience of policy enactors leaves little scope for principal agent problems.

5. Conclusion

The recent development of Ireland's institutional architecture has been shaped by its historical path. Policy changes initiated in the 1980s concurrent with favourable international conditions set the basis for Ireland's increasingly productive NIS. The Irish innovation system is currently driven by demand located abroad and on the supply side, is pushed forward by government efforts, technological developments and Ireland's particular technological trajectory. Ireland's specific set of institutions facilitated the emergence of a diversified set of STI actors.

The central role innovation occupies in public policy manifests itself not only in policy rhetoric (e.g. the *National Development Plan*)[127] but also in the multiplicity and

diversity of policy makers pursuing innovation matters. Crucially, policy enactors possess context-specific knowledge enabling them to customise inputs and lobby for appropriate policy. Contemporary Ireland plays host to numerous technological leaders, which not only take advantage of local conditions and institutions but also count on the support of an elaborate set of policy makers and enactors. Many STI actors also have a role as technology lobbyists, actively disseminating information to and from researchers, the entrepreneurial community and policy makers.[128]

Notes and References

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score of each country as a composite of statistics in the generation of new ideas, the diffusion of existing innovations, trade in technological goods and the country's infrastructural and human resource assets.

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18. *Ibid.*
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26. Nelson and Sampat, *op. cit.*, p. 40.
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97. Microsoft, Intel, Dell, Adobe, Symantec, IBM, Nortel, Honeywell, Lucent, Hewlett-Packard, Wyeth, Bayer, GlaxoSmithKline, Novartis, Johnson and Johnson to name but a few (IDA, *Ireland, Knowledge is in Our Nature*, IDA, Dublin, 2004a).
98. Forfás, 2005, *op. cit.*
99. Barry, 2005, *op. cit.*
100. *Ibid.*
101. While the majority of R&D performing firms in Forfás' (2005, *op. cit.*) survey are Irish-owned, they account for a miniscule percentage of the total number of Irish firms. The survey is prone to a sample bias towards innovating firms as the surveyors stately targeted their questionnaires to firms they expected to engage in R&D.
102. Barry, 2005, *op. cit.*
103. Forfás, 2004a, *op. cit.*
104. R. Belderbos, M. Carree and B. Lokshin, 'Cooperative R&D and firm performance', *Research Policy*, 33, 2004, pp. 1477–92.
105. *Ibid.*
106. Roper, *op. cit.*
107. H. Louri, R. Loufir and M. Papanastassiou, 'Foreign investment and ownership structure: an empirical analysis', *Empirica*, 29, 2002, pp. 31–45 .
108. H. Görg and F. Ruane, 'Linkages between multinationals and indigenous firms: evidence for the electronics sector in Ireland', *Trinity College Dublin Economics Technical Papers*, 9813, Dublin, 1998.
109. *Ibid.*
110. P. Ryan, M. Giblin and E. Walshe, 'From subcontracted R&D to joint collaboration: the role of trust in facilitating this process', *Innovation and Technology Management*, 2, 2004, pp. 205–31.
111. Lundvall, *op. cit.*; Edquist, *op. cit.*
112. As suggested from evidence by Görg and Ruane, 1998, *op. cit.*
113. Forfás, *Survey of Research and Development in the Higher Education Sector 2002*, Forfás, Dublin, 2004b, p. 14.
114. *Ibid.*
115. CEC, 2004a, *op. cit.*, p. 39.
116. Forfás, 2004b, *op. cit.*
117. OECD, 2004a, *op. cit.*
118. Private funding of university research stood at 5.3% in 2000, 10.2% in 1990 and 7.1% in 1981.
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121. R. Vernon, 'International investment and international trade in the product cycle', *Quarterly Journal of Economics*, 2, 1966, pp. 190–207.
122. IDA, 2004b, *op. cit.*
123. Görg and Ruane, 2000, *op. cit.*
124. The open-ended and competitive nature of European funding streams (e.g. the Framework Programmes, Marie Curie Fellowships) is especially pertinent.
125. The BMW regional assembly is particularly active in this respect; it communicates the perceived needs of the region through a comprehensive technology foresight study and by means of an annual conference on innovation.
126. Roper, *op. cit.*
127. Government, *op. cit.*