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Systems of Innovation and their Limits: The Case of Environmental Regulation of the Irish Pharmaceutical Industry

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Abstract

We examine aspects of the impact of a new regime of environmental regulation in Ireland on pharmaceutical companies. We argue that differences prior to the introduction of the new regime between companies concentrated in one specific region and those in the rest of Ireland can in part be explained by the emergence of a regional system of innovation. However, we show that appropriate response to the new, technology-forcing regime is not closely associated with location in that region. We conclude that there are limits to external institutions' ability to influence the innovation process and technological development of firms. We identify these limits as the central mediating role of firm-specific dynamic capability.

Key Words: System of innovation, regional policy, environmental regulation, dynamic capability

1 Introduction

EU environmental policy has the broad aim of influencing the innovation process and technological development within firms in favour of cleaner technology responses. The aspiration is that cleaner technology adoption, being the take up of methods that improve resource productivity, will reconcile the goals of increased industrial competitiveness and enhanced environmental protection. This is consistent with the argument of PORTER and VAN DER LINDE, 1995a and 1995b. In this paper we consider whether this policy goal is achievable through an examination of how pharmaceutical companies in Ireland have responded to more demanding environmental regulations. We argue that environmental policies and agencies can have regional aspects. Using data on pharmaceutical companies' environmental performance prior to the introduction of the new regulatory regime, we show that the way that local authorities monitored and regulated companies' polluting activities contributed to those companies' ability to respond to change. As we will discuss below, policy - both industrial and environmental - affected the evolution of the region and the consequence is greater competence within that region to adapt to changes in the extra-regional environment. In other words, there is a regional system of innovation in relation to environmental management competence.

We develop data sets from information extracted from the companies' applications for Integrated Pollution Control (IPC) licences. Our analysis of these data sets shows among other things that there is not a close association between location in the region and the ability of firms to develop the appropriate response to the new environmental regulation regime. That different firms respond differently to the same regulatory environment implies a need to go beyond PORTER and VAN DER LINDE (1995a) and to apply a theory of the firm. With the evolutionary theory of the firm and the analysis of our data, we conclude that external institutions face limits to their ability to influence the innovation process and technological development of firms. These limits we identify as the central mediating role of firm-specific dynamic capability.

2 Background

The 1990s saw a strong commitment to environmental protection in Ireland through the implementation of a progressive programme of environmental legislation. In 1992 the Environmental Protection Agency Act[1] established a national authority to assume the environmental responsibilities previously held by local authorities. Ireland introduced integrated pollution control licensing of industry[2] while it was still only at the proposal stage at the European Commission[3]. Not only did Ireland anticipate the 1996 EU directive on integrated pollution prevention and control (IPPC)[4] by a number of years, but the Irish legislation is also in some respects more demanding.

Central to the licensing philosophy is continuous improvement and a shift of emphasis to pollution *prevention* rather than pollution *treatment.* Pollution prevention technology, or cleaner technology, is defined as ‘approaches to manufacturing that minimise the generation of harmful waste and maximise the efficiency of energy use and material use’ (CHRISTIE, 1995, p.31). In cleaner technology, through changes to the manufacturing process, the generation of waste is avoided. The older, more traditional approach is end-of-pipe technology where waste streams emitted from manufacturing processes are treated to reduce or abate the toxicity of discharges to the environment so as to meet emission levels set by regulators.

In implementing IPC licensing, both Ireland and the EU are expecting to achieve significant economic advantages: IPC licensing is explicitly being used as a vehicle for encouraging firms to integrate environmental controls into manufacturing (cleaner technologies) in order to prevent (rather than treat) pollution. This improved use of costly inputs and avoidance of treatment costs could potentially allow firms to achieve economic advantages such as material savings, process efficiencies, reduced environmental control costs and market advantages (PORTER and VAN DER LINDE, 1995a). The explicit aim of the Irish IPC licensing system is the development in licensed firms of an environmental strategy focused on cleaner technology.

> The old command and control system of environmental protection has been shown to be inadequate. The IPC approach is a more participative one, allowing the company an opportunity to set out programmes for continuing improvement towards desirable standards through the promotion of the use of cleaner technologies rather than end-of-pipe treatment (EPA, 1997, p. 1).

Firms are still required to meet standards for the emission of pollutants, but above that they are now also required to demonstrate a continuous effort to upgrade their environmental performance. Licence conditions specify that firms put in place environmental management and information systems. Firms must also establish an environmental management plan (EMP) that sets goals and reports on progress. 'The targets set are expected to be demanding of the licensee and require effort to achieve them' (EPA, 1998, p. 10). The impact on firms of the new regulations is that environmental management has become a strategic business issue. The IPC regulations are demanding, and reflect the regulator's intention to secure continuing reduction of environmental impact. Firms that are not able to implement effective environmental management risk limiting their 'flexibility of action' (HOFFMAN, 1997, p. 6) as the demands of the licence will act as a constraint on their activities. The EPA has strong powers to deal with non-compliance and can have a serious impact on a facility's operations. Firms that do not meet their IPC responsibilities are open to more than just EPA censure. The law is also open to the community: '… non compliance with a licence, even in a minor respect, could destroy a defence to civil actions brought for damages' (SCANNELL, 1995, p. 1). Community approval is an important constraint for these plants. Plants that have not built trust with the community have found their flexibility of action constrained when it comes to obtaining official licences, such as planning permission and IPC licences. Firms that have a strategic outlook recognise that they require an unofficial licence to operate from their neighbours.

In its first year of implementing the new licensing the EPA was concerned solely with the licensing of the State's multinational bulk pharmaceutical manufacturers. The pharmaceutical sector in Ireland is largely comprised of foreign owned multinational subsidiaries manufacturing intermediate products for intra-firm export to packaging plants in the rest of Europe and the world. The industry is capital-intensive, high technology, highly-skilled, and characterised by large economies of scale. It is also a pollution-intensive process: the ratio of waste to product is often in the order of 10:1 (CUNNINGHAM and MORIARTY, 1993). The identification of the pharmaceutical industry as the first priority for licensing is a reflection of public concerns about the environmental impact of the industry.

Seventeen pharmaceutical firms were licensed in this first phase (1994 and 1995), and this cohort (with the exception of one firm[5]) forms the basis for the research on which this paper is based. Prior to the establishment of the EPA responsibility for the regulation of industrial activity was held by local authorities. It is generally acknowledged that Cork County Council had the most developed competence in regulating pharmaceutical manufacturers (MCLEAN, 1997) and that the legislation was more strictly applied and enforced in Cork than in other local authorities (MORAN, 1997). The cohort is not large enough to provide a detailed exploration of the relative stringency of all nine local authorities with responsibility for these firms. However, by focussing on Cork County Council (responsible for seven of the firms) versus other local authorities (responsible for the remaining nine) we are able to ask whether there are differences in firm capability that are associated with the competence of the local authority and other institutional factors.

3 Theoretical Framework

Evaluating this new regulatory approach requires an assessment of firms' ability to comply with the requirements of the regulations and an understanding of the impact on firms of achieving compliance. The research presented here will attempt to capture the different elements of capabilities for responding to environmental regulations. These are suggested by both the theoretical literature on the evolutionary theory of the firm and the literature on corporate environmental management. In summary, this research will establish the role of organisational capabilities in determining a firm's ability to effect the necessary technical change and to manage the adaptation to a changed external environment.

The essence of the evolutionary theory of the firm is that the firm is a repository of knowledge, that this knowledge resides in the organisational capabilities of the firm and that these organisational capabilities then determine the firm's performance. Underlying capabilities are routines, routinised patterns of behaviour which are themselves both the products of and repositories of organisational learning and knowledge (NELSON and WINTER, 1982). Organisational learning is an 'intrinsically social and collective phenomenon' (TEECE *et al*., 1994, p. 15), involving joint problem solving and coordinated 'search'. Although it may require the skills and knowledge of individuals, this still relies on 'employment in particular organisational settings' (TEECE *et al*., 1994, p. 15) for its expression. Organisational learning is also cumulative and path-dependent; what is learnt and practised is stored in routines ('the organisational memory of the firm' (NELSON and WINTER, 1982, p. 99)) and expressed in the firm's capabilities. Firm capabilities can be seen to be 'an idiosyncratic problem-solving knowledge capital' (FOSS, 1996, p. 8).

More recently the literature has begun to emphasise that not all capabilities have the same potential for achieving change. The ability to identify, develop and introduce new capabilities has been identified as an important capability in its own right, particularly important for managing the firm's response to change; 'the term 'dynamic' refers to the capacity to renew competences so as to achieve congruence with the changing business environment' (TEECE *et al*., 1997, p.515). CHRISTENSEN, 1996, defines capability as a 'lower-order functional or inter-functional technical capacity to mobilise resources for productive activities,' distinguishing this from competence, which is the 'higher-order managerial capacity of the firm or corporate management to mobilise, harmonise and develop resources and capabilities to create value and competitive advantage'.

The evolutionary theory of the firm has been used by a number of regional economists to develop theories of the 'learning region' and 'regional systems of innovation' (MORGAN, 1997; COOKE *et al*., 1998; MASKELL and MALMBERG, 1999). Focussing on the way evolutionary theory explains organisational learning, these writers argue that 'most firms learn from close interaction with suppliers, customers and rivals. Furthermore, processes of knowledge creation are strongly influenced by specific localized capabilities such as resources, institutions, social and cultural structures' (MASKELL and MALMBERG, 1999).

There are two forms of innovation-enhancing interaction in systems of innovation. One is within the firm, consisting of perceptions of opportunities and feedback loops among marketing, design, production, technology and other parts of the organisation. Within the firm this is linked to the 'firm specific knowledge base' (FISCHER, 2001, p.202). This intra-firm element of the system of innovation is derived directly from the evolutionary theory of the firm discussed above and frequently uses the same terminology[6]. The second form of interaction in systems of innovation consists of market and non-market relationships between the firm (or parts of the firm) and other public and private organisations. These include customer and supplier companies, research institutions and various types of local, regional and national state agencies. As FISCHER, 2001, puts it, technological progress is dependent on how 'actors interact with each other, internally and externally'.

The evolutionary theory of the firm thus provides the basis for understanding the innovative capacity of the firm. The theoretical elaboration of systems of innovation extends this in a conceptual framework that underlines the importance of relationships between firms and other actors and institutions in their environments. What we show in this paper is that both the micro level of the individual firm and the meso level of the regional context are important. However, for explaining how some firms did and others did not have the dynamic capability to respond to new regulation, in the case of pharmaceutical firms in Ireland the micro level was primary.

We test this theoretical relationship between firms and their regional context. First, we provide a measure of dynamic pollution-prevention capability. Then we examine for correlation between dynamic capability and location.

4 Measuring Organisational Capabilities for Environmental Management

Measuring capability is an attempt to measure complex, embedded, tacit and context-dependent patterns of knowledge and practice. In this research we have developed a dataset from documentation made available as part of the IPC regulations. The information available at the EPA is extensive; it includes the initial IPC licence application, monitoring results, reports of audit visits by the Agency, correspondence between the firms and the Agency and the firm's annual environmental reports. This rich source of data allows the development of a set of measures of organisational capabilities that might be expected to have determined the firm's ability to meet the requirements of the new legislation. These measures capture (i) indicators of historical capability prior to licensing; (ii) patterns of technical activity within the firm with respect to environmental technology; and (iii) the development and operation of routines for management of environmental activity. A summary of all capability measures is presented in Table 1. Analysis of the data collected using these indicators and statistical tests of association examines the role of organisational capabilities in the sector's response to a changed regulatory regime focussed on the promotion of technical change.

4.1 Indicators of historical capability prior to licensing

Using data made available at the time of licensing on past practice, it is possible to infer limited measures of capability relating to past environmental management. These measures reflect: the stringency with which firms were regulated historically (LOCN); compliance with previous regulations (BATNEEC); historic environmental control (GW); level of environmental knowledge (TIME). The requirements of the IPC licensing process can be used as a reassessment of the progress companies had made towards meeting their obligations under prior legislation.

4.2 Patterns of technical activity with respect to environmental technology

Under IPC licensing firms are expected to demonstrate a commitment to implementing pollution prevention over waste treatment. Analysis of the firms' IPC licence applications and the annual environmental reports (AERs) submitted between 1995 and 1999 allowed us to compile detailed information on 800 projects carried out in the cohort of 16 firms. What we call CT in table one is a measure of the percentage of a firm's total projects that fall within the category of cleaner technology, that is, all approaches that result in the production of less waste either through source reduction or recycling. Given the influence of the cumulative and path-dependent nature of organisational learning on a firm's capability to exploit technical opportunities we would expect to see firms developing related projects, that is, showing evidence of a specialised technical capability (STC). STC is measured as a concentration or clustering within firms of projects of a particular type.

4.3 Development and operation of routines for environmental management

From the EPA's guidance note (1997) it is possible to identify the key elements that the Agency expects to see in an environmental management system. These are: measurable objectives and targets; management procedures; and documentation. The Agency's intention was that these managerial processes would support demonstrable continuous improvement. In evolutionary economics terms, firms are required to have static technical capabilities for cleaner technology adoption and static managerial capabilities for environmental management. These are covered by SYSTEMS and MEASURES in Table 1.

[Table 1 about here]

In addition, from the literature on organisational capabilities, we would expect that responding to the challenges of the new licensing regime with an effective environmental strategy would require dynamic capability. This capability corresponds to the search routines defined by NELSON and WINTER, 1982: routines for the identification and development of new routines. To measure this we have assessed each firm for evidence of environmental search routines, that is, routines for information generation, problem identification and solution, and strategic development (STRAT-DEV). Table 2 outlines the criteria used to assign scores to each firm for managerial and dynamic organisational capability (SYSTEMS, MEASURES and STRAT-DEV). We report on the results relevant to this paper in Table 3.

[Table 2 about here]

5 A Regional System of Innovation?

In the 1980s the European Community brought in directives to strengthen the prevention of pollution, introducing the requirement for BATNEEC (Best Available Technology Not Entailing Excessive Costs).[7] Emission limit values (ELVs) were set in water and air licence conditions and firms were obliged to demonstrate that pollution emissions fell within the limits. The ELVs set by regulators at that time were established with respect to available abatement technology, that is, end-of-pipe waste treatment equipment that ensured waste streams from the production process were treated so as to comply with the permitted levels of emissions.

In issuing the first round of IPC licences to pharmaceutical companies in 1994/1995 the EPA issued revised BATNEEC standards for water emissions. The air emission levels were not tightened beyond the levels set in a 1987 Act, although the BATNEEC for air emissions was broadened to include pollution prevention technologies. In their application for an IPC licence firms were asked to identify whether or not they were in compliance with the BATNEEC standards, and where necessary to provide details of their plans to upgrade to these standards. For firms that had not achieved BATNEEC by the time of the IPC licence application the EPA made compliance a condition of the licence, specifying the pre- and post-compliance emission levels and the date for achieving BATNEEC.

The IPC licensing process was therefore in effect a reassessment of the progress companies had made towards meeting their obligations under prior legislation. Firms that were previously licensed under the varying standards of interpretation and enforcement operating in different local authorities were, in the course of the IPC licensing process, measured against a uniform, national standard. This provides an insight into the impact of differing regulatory standards pursued by local authorities.

[Table 3 about here]

The table suggests that there is a clear and strong relationship between the stringency of the pre-IPC regulation and the state of the firm's pollution control technology at the time of IPC licensing. There is a statistically significant correlation[8] between the location of a firm and the achievement of BATNEEC in both air and water.

- Seven of the 16 firms were compliant with both water and air BATNEEC at the time of IPC licensing.
- Of these seven firms, six were Cork based firms; only one compliant firm – Yamanouchi – had been regulated by a local authority other than Cork County Council.
- Nine firms had not complied with both water and air BATNEEC at the time of IPC licensing; only one of these firms – Hickson – had been regulated by Cork County Council.

This standardised BATNEEC evaluation suggests that a stringent regulatory regime will achieve a higher level of compliance with regulation: firms that were located in Cork were more likely to have technology in place to meet the emission limit values prescribed by the EPA in the new IPC licences. A more interesting test for evidence of a successful regional system of innovation would be the presence of locational effects in the ability of firms to meet the challenges of the new, technology-forcing regulations. Regional systems of innovation are argued to support firm learning. Can we say that firms located in Cork had benefited from this in the development of their dynamic capabilities?

Why would we expect there to be a relationship? Irish industrial policy - attracting multinational corporations to set up subsidiaries in Ireland - in relation to pharmaceutical and chemical companies was region specific, encouraging firms in this sector to locate in the Cork harbour area. Cork County Council was therefore responsible for a relatively large number of firms and this allowed them to build up greater resources and experience in enforcement.

Expertise in environmental technology for the pharmaceutical industry was also developed in the local third-level institutes. Both University College Cork (UCC) and Cork Institute of Technology (CIT) have research centres in this area. The Clean Technology Centre (CTC) at CIT was founded in 1992 with funding from the pharmachem sector. The centre describes itself as ‘a strategic partnership between Irish industry and academia’. It is recognised internationally as a centre of excellence in providing environmental consultancy and acting as ‘a national resource allowing all concerned with the environment to avail of a pool of expertise’ (CTC, 2002).

Another effect of having a concentration of pharmaceutical firms was that the environmental performance of these firms became a high-profile issue for local citizens and the focus of NGO pressure. This external scrutiny provided increased impetus for rigorous enforcement by Cork County Council; it also provided pressure for industry self-regulation from responsible firms who did not want their reputation compromised by the actions of other firms. The former head of enforcement at Cork County Council, now Director for Licensing at the EPA, attributes it to ‘partly public pressure, partly NGO pressure, partly regulatory pressure and partly it was just the peer pressure’ (MCLEAN, 1997).

So there is some evidence to support the idea that a system evolved in which institutional interaction increased the levels of competency within firms, among their local regulators and the NGOs. The specific localized capabilities, in MASKELL and MALMBERG’s, 1999, terms, influenced processes of knowledge creation. However, our results show that there is only a weak statistical correlation between location in Cork (LOCN) and the possession of dynamic capabilities (STRAT-DEV).[9]

The key outcome of the IPC regime is the adoption of cleaner technology projects. There is no statistically significant correlation between location in Cork (LOCN) and ability to take on cleaner technology (CT). The ability to take on cleaner technology (CT) is statistically associated with the measure of dynamic capability (STRAT-DEV)[10], suggesting that those firms that have organisational processes for learning and problem-solving have responded better to mandated technical change. It is clear that when it came to the challenges of the new regulations, firms that had high levels of dynamic capability were able to respond with the appropriate take up of cleaner technology.

The evolutionary theory of the firm provides a basis for understanding why some firms and not others were able to develop beyond end-of-pipe pollution prevention to ongoing process improvement. The firms that did had high levels of dynamic capability. And one of the reasons why these firms had high levels of dynamic capability was because they were in Cork, where interactions within the region enhanced the firms' capacity for learning. However, this research also shows the limits to regional learning effects. The regional influence is neither necessary nor sufficient for the development of high dynamic capability and development of dynamic capability appears to be more strongly associated with firm-specific factors than with regional learning effects.

6 Conclusion: Firm-specific Factors v. Regional Effects

All firms have been able to implement some cleaner technology projects; however, firms differ in their ability to adopt cleaner technology projects. The EPA has signalled to firms that the least favoured solution is the introduction of abatement equipment to treat waste; while some firms are making minimal (less than 10 percent of projects) use of this technology, other firms are much more heavily reliant (more than 30 percent). Specifically firms with dynamic capability are more likely to have been successful in the uptake of cleaner technologies. Firms that have a high score for dynamic capability are more likely to have leveraged their skills and experience across a series of related projects, indicating a strong, specialised capability for a particular cleaner technology approach.

Recognising that managerial processes are required to support cleaner technology uptake - ‘the common element is not technical but managerial – cleaner production is essentially a way of thinking about the energy and materials costs of a product and the impacts along the product’s entire value chain’ (CHRISTIE, 1995) – licence conditions specify that firms put in place environmental management and information systems. Again firms have differed in their ability to implement these mandated organisational changes. There is an association between these static managerial capabilities and dynamic capability. There is a very high, statistically significant correlation between the existence of the dynamic capability for environmental strategic development and the development of environmental systems, as well as between the existence of the dynamic capability and the development of environmental measures. Figure 1 provides a summary of the associations between different measures of capability. (The dotted line shows weak association, absence of lines shows no association and solid lines show significant associations.)

[Figure 1 about here]

Firms are differentially able to respond to technology-forcing regulations and these differences are associated more with differences in organisational capabilities than with locational differences. Any attempt to understand and analyse the potential for environmental regulation to promote both environmental protection and enhanced productivity requires an understanding of internal firm behaviour. This result highlights a limit of the theories, such as that advanced by PORTER and VAN DER LINDE (1995a, 1995b), that regulations have the potential to stimulate increased industrial competitiveness. In their analysis the focus is on the regulatory instrument as the primary agent of change. In the situation where firms in the same industry, facing the same regulation, show differing abilities to respond in the direction desired by policymakers, without a theory of firm behaviour it is not possible to explain or analyse (and therefore develop policy remedies) for these differences. The evolutionary theory of the firm, with its emphasis on organisational capabilities as the driver of technical change in firms, provides a framework for the development of a coherent model of the relationship between environmental regulation and firm technical change.

We have shown that environmental policies and agencies can have regional impacts. The way that local authorities monitor and regulate companies' polluting activities can contribute to those companies' ability to respond to change. Policy (both industrial and environmental, in the case of the pharmaceutical industry in Cork) affected the evolution of the region and the consequence is a regional system of innovation in relation to environmental protection in pharmaceutical companies. Of the two forms of interaction within the system of innovation – as outlined by FISCHER, 2001 – policy has most influenced market and non-market relationships between the firms and other public and private organisations. The other form of interaction in the system of innovation is intra-firm, linked to the firm-specific knowledge base. Our results suggest that this intra-firm element of the system of innovation was less susceptible to influence by policy and agencies.

There are thus policy implications arising from this research. The results presented here suggest that a regulatory instrument designed to stimulate cleaner technology is not sufficient to promote change in firms. The organisational processes identified by the regulators do not appear to be associated with higher use of cleaner technology. Our research shows that firms will struggle to implement organisational change as much as technical change. The research indicates that the firms that have mastered both elements of the EPA's strategy, cleaner technology and environmental management already possess a capability for problem-solving and change. It can be seen that this capability is also associated with historic environmental performance, suggesting that its existence predates the introduction of the new regulations. Given first that the key dynamic capability has evolved out of firm-specific learning and past experience, second that it remains the basis for durable differences between firms and third that it cannot easily be acquired, clearly there are limits to the ability of regulation to stimulate firms to undertake technical change in a desired direction.

The broader implications of these findings are that policy initiatives aimed at promoting the development of regional learning systems may also face limits to their ability to engender innovative behaviour and organisational change. We have identified these limits in our case as the centrality of firm-specific dynamic capabilities.

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MEASURE	ACTIVITY MEASURED	USED TO SHOW
HISTORIC CAPABILITY MEASURES		
LOCN	Stringency of regulation prior to IPC licensing.	**Influence of regulatory environment.**
BATNEEC	Compliance with air and water BATNEEC standards	**Level of investment in environmental technology.**
GW	**Presence/absence of contaminated groundwater from past environmental incidents.**	**Routines for effective environmental control. Inferred static technical capability**
TIME	Time taken to provide the EPA with full and complete IPC application.	**Level of codified environmental knowledge. Inferred static managerial capability.**
TECHNICAL CAPABILITY IN CLEANER TECHNOLOGY		
CT	**% of firm's total projects (from licence application to 2000) that are cleaner technologies.**	**Static technical capability in cleaner technology.**
STC	**Projects of a given type account for >20% share of firm's total projects, > average share for all firms.**	**Specialisation and path-dependency in technical knowledge**
ENVIRONMENTAL MANAGEMENT CAPABILITY		
SYSTEMS	**Score assigned on strength of system of procedures and documentation**	**Static managerial capability in environmental management.**
MEASURES	**Score assigned on strength of development of data collection and measurable targets.**	**Static managerial capability in environmental measurement.**
STRAT-DEV	**Score assigned on strength of routines for continuous environmental improvement.**	**Dynamic capability in strategic development for environmental management.**

Table 1: Summary of Measures of Capability

Systems ***The development of a system of documentation and procedures***	**4**	• **Routinised and integrated EMS** • **EMAS accreditation***
	3	• **EMS established but not fully operational** • **Adapting existing EMS to IPC requirements**
	2	• **EMS developed after IPC licence granted** • **On-going work to develop EMS** • **EMS system but with an abatement focus**
	1	• Indication of intention to develop EMS • Criticism by EPA of EMS weaknesses
	0	• **No dedicated environmental manager** • **No formal EMS**

Measures ***The development of measurable targets based on systematic data collection***	**4**	• **Measures in 5+ areas** • **Long established or broad coverage** • **EMS driven by measures**
	3	• **Measures in 4+ areas** • **Used for targets and actions** • **Established and integrated into EMS**
	2	• **Measures in 2+ areas** • **Evidence of use for targets/actions** • **Intention to integrate into EMS**
	1	• **Measures in only 1or 2 areas**
	0	• **No measures or** **Only once-off use of measures**

Strategic Development *The development of the systematic pursuit of continuous environmental improvement*	**4**	• **Established routines for data collection and problem identification** • **Established programmes for generating pollution prevention projects** • **Established use of cross-functional continuous improvement teams**
	3	• **Systematic identification of pollution prevention projects** • **Recent introduction of continuous improvement teams** • **Integration of problem-solving capability into EMS**

2	• **Recent/limited adoption of routinised data collection or problem-solving** • **Data collection without use in follow-up problem-solving**
1	• **No systematic pursuit of pollution prevention** • **Evidence of environmental management problems due to incomplete information**
0	• **Absence of pollution prevention projects** • **Explicit abatement-only focus** • **Significant delays in IPC application process due to lack of information**

Table 2: Criteria for Scoring Environmental Management Capability

Note: * EMAS = Eco-Management Audit Scheme. This is a demanding European standard

FIRM	LOCATION	BATNEEC COMPLIANCE	STRAT-DEV CAPABILITY
Janssen Pharmaceutical	**CORK**	✔	4
Novartis Ringaskiddy	**CORK**	✔	4
SmithKline Beecham	**CORK**	✔	3
Pfizer Ireland Pharmaceuticals	**CORK**	✔	3
Eli Lilly	**CORK**	✔	2
Cara Partners	**CORK**	✔	2
Hickson Pharmachem	**CORK**		0
Yamanouchi Ireland	**DUBLIN**	✔	4
Klinge Pharma & Co	**KERRY**		4
Leo Laboratories	**DUBLIN**		2
SIFA Ltd.	**SHANNON**		2
Schering-Plough	**WICKLOW**		1
Swords Laboratories	**DUBLIN**		1
Merck Sharp & Dohme	**TIPPERARY**		0
Roche	**CLARE**		0
Warner-Lambert	**DUBLIN**		0

Table 3: Measures of Regulatory Stringency, Compliance and Capability

(Source: Hilliard, 2001)

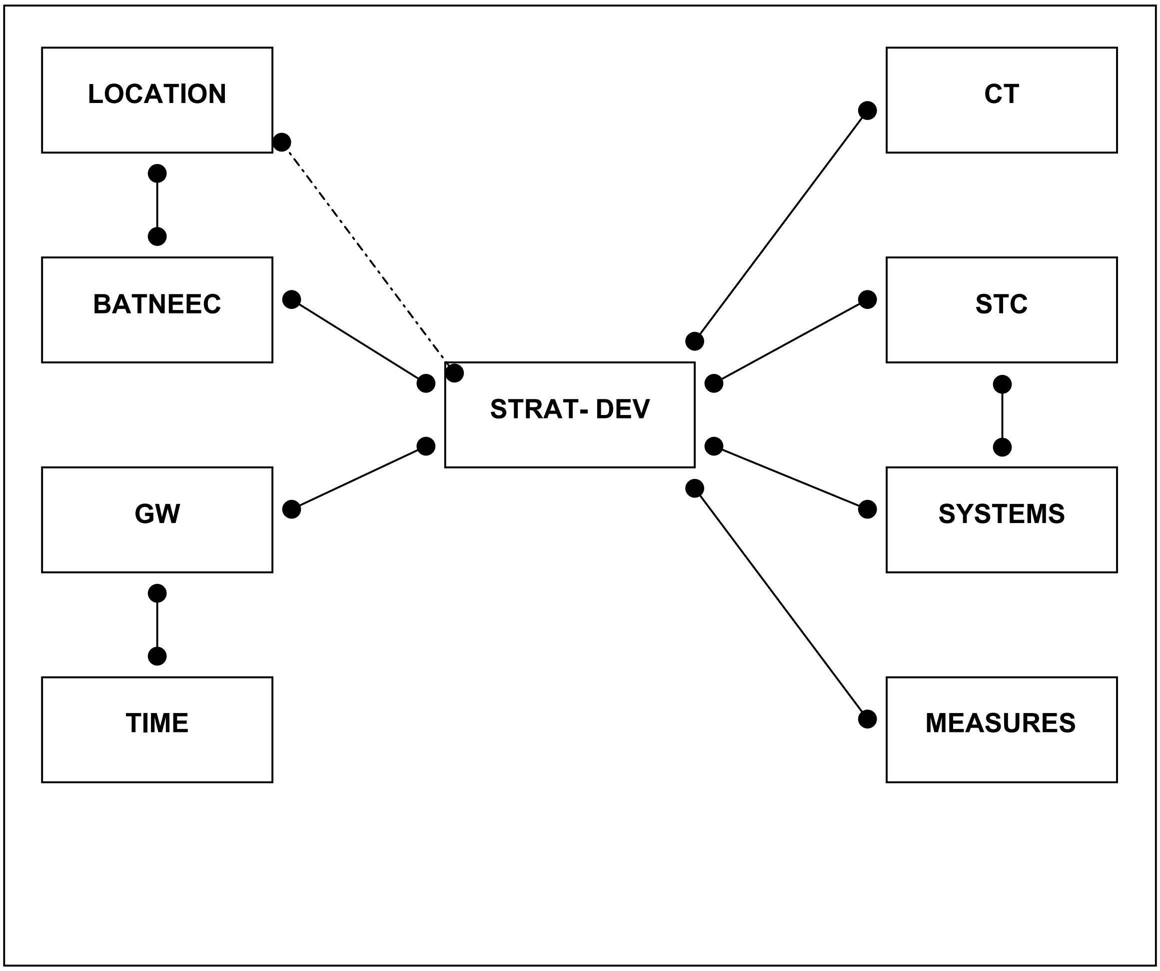

Figure 1: Map of correlations between capability indicators

About CISC

The Centre for Innovation & Structural Change (CISC) is a multidisciplinary research centre which undertakes programmes of research and research training related to the innovation processes and policies that underpin the knowledge-based economy and society. CISC is based at NUI Galway is partnered with DCU Business School and the Michael Smurfit Graduate School of Business at UCD, with other national and international collaborative arrangements.

The origins and consequences of innovation and technological change can be interrogated at many levels, and interpreted from different perspectives. Thus, CISC's research is interdisciplinary and its structure collaborative. The complexity of innovation and structural change motivates CISC's disciplinary openness and methodological diversity within the community of scholarship. Participants include economists, geographers, management scientists, as well as specialists in industrial relations, human resource management, and information systems. Research at CISC is structured into five priority research areas:

Systems of innovation.
Industry clustering
Internationally traded services
Inter-organisational systems
High performance work systems

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[1] Environmental Protection Agency (Establishment) Order, 1994 (S.I. No. 213 of 1993).

[2] Environmental Protection Agency (Licensing) Regulations, 1994 (S.I. No. 85 of 1994).

[3] *Proposal for a Council Directive on Integrated Pollution Prevention and Control*. Commission of the European Communities COM (93) 423 (Final).

[4] EU directive 96/61/EC

[5] One plant was not included as the manufacturing process is markedly different, being biotechnology and fermentation based; the other 16 firms are carrying out organic synthesis or other high-solvent activities.

[6] See for example DE LA MOTHE and PAQUET, 1998, who, writing of the firm as part of a local or regional system of innovation, focus on the 'routines, … rules, conventions and institutions that provide the process of decision-making and learning with unity and stability'.

[7] BATNEEC is a framework concept whereby regulators define the level of environmental control to be employed by firms based on what is technically achievable. Regulators must also take account of two sets of economic criteria: (a) the gains in environmental quality achieved weighed against the costs to industry (cost-benefit analysis) and (b) the affordability of these technologies in the sector (SORRELL, 2001).

[8] The Kendall rank order correlation coefficient is 0.746, significant at the 99 percent confidence level.

[9] The Kendall rank order correlation coefficient is 0.3024, significant at the 90 percent confidence level. The Kendall partial correlation coefficient, controlling for the influence of BATNEEC status, is 0.2810, also significant at the 90% confidence level.

[10] The Kendall rank order correlation coefficient is 0.6812, significant at the 99 percent confidence level.