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Benchmarking Regional Innovation: A Comparison of Bavaria, Northern Ireland and the Republic of Ireland

Stephen Roper

School of Management and Economics and Northern Ireland Economic Research Centre, Queen's University Belfast, BT7 1NN.
E-mail: **s.roper@qub.ac.uk**
Fax: 0044-2890-439435

Abstract:
Regional regeneration strategies based on developing innovation capability have received much support in recent years. Evaluation of the effectiveness of such initiatives has, however, been limited largely to an assessment of the impact of such strategies on policy frameworks and attitudes. Based on innovation survey data covering nearly a decade, this paper outlines a number of external innovation benchmarks for core and peripheral regions within the EU. The benchmarks considered cover the innovation objectives, constraints, resources, linkages and outputs of manufacturing firms.

Despite considerable efforts in recent years to develop the innovation capability and institutional support framework for innovation in Northern Ireland and the Republic of Ireland, the benchmarks still point to a substantial performance gap between the Irish and German study regions, and provide little evidence of convergence over the 1991-99 period. The benchmarks also suggest other more general points emphasising a general shortening of product lifecycles[1] and a related shift towards more radical innovation. More disappointing is in that in each of the study regions the development of environmentally friendly products is given a low and diminishing priority by manufacturing firms.

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1. Introduction

Interest in the effects of location on firms' innovation activity is longstanding. Writing in 1992, for example, Alfred Kleinknecht and Tom Poot asked 'Do Regions Matter for R&D?' and examined whether firms' location in the Netherlands shaped the extent or nature of their R&D investments. While they found no evidence that firms in urban agglomerations undertook more R&D than similar companies in rural areas, they did find that firms in rural areas placed more emphasis on process related R&D (Kleinknecht and Poot, 1992, pp. 230-231). Subsequent empirical studies provide more conflicting evidence about the importance of location as an influence on firms' innovation activity[1]. Recent conceptual developments, particularly associated with the literature on endogenous growth driven by technological change, have, however, prompted a different question, namely 'Does R&D matter for regions?' In other words to what extent can R&D, or more generally technological development, provide a basis for regional economic development (e.g. Frenkel, 1997)? Interest in the potential for technology-led, regional development strategies has also been stimulated by the example of successful regions (e.g. Heidenreich and Krauss, 1998; Yun, 1998), and the search by regional governments for more effective alternatives to traditional regional policy (e.g. Hassink, 1993). In particular, within the EU the policy debate has focussed on initiatives designed to stimulate regional technological development, notably through the Regional Innovation Strategies (RIS), Regional Technology Partnership (RTP) and Regional Innovation and Technology Transfer Strategies (RITTS) programmes. Evaluation of these programmes has been extensive but has typically been limited to the operational aspects of the projects and their effects on regional policy agendas (e.g. ECOTEC, 1999). One underdeveloped aspect of the monitoring or evaluation of such initiatives, and indeed the success or otherwise of

[1] Other subsequent studies addressing similar issues also provide conflicting evidence. Studies by Shefer and Frenkel (1998) on Northern Israel, Brouwer and Kleinknecht (1996) on the Netherlands, Harris and Trainor (1995) on Northern Ireland and McCartney and Teague (1997) on the Republic of Ireland have suggested the potential importance of agglomeration economies linked to urban or metropolitan locations. Devlaar and Nijkamp (1989, 1992) for the Netherlands, Koschatzky et al. (1998) for Germany and Roper (1999) for Ireland provide contradictory evidence.

other regional supports for innovation etc., has been the development of external innovation benchmarks. Our focus here is therefore on the development of a set of survey-based regional innovation benchmarks. These are applied using information from company surveys conducted over the last decade to compare innovation activity in the EU 'core' region of Bavaria and the more peripheral areas of Northern Ireland and the Republic of Ireland. Key questions relate to the objectives of firms' innovation activities, measures of innovation capability and innovation activity, and whether, given the alternative regional strategies adopted, there is any evidence of convergence.

In a UK context, the timing of these comparisons is opportune given the increasing level of regional autonomy resulting from the creation of the Regional Development Agencies (RDAs) in England (Roberts, 2000), and the devolution of control of economic development policy to the Scottish parliament and assemblies in Northern Ireland and Wales (Ashcroft, 1998; Birnie and Hitchens, 1998). Indeed, David North recently highlighted the role of innovation promotion in regional economic strategies of the RDAs; "the 'sine qua non' of regional economic development (North, 2000, p. 10)[2]. Similar sentiments are echoed in Northern Ireland's 'Strategy 2010' which stresses the imperative for Northern Ireland to become 'an innovative society receptive to the creation, assimilation and exploitation of new ideas'. (DETI, 1999, p. 159).

The remainder of the paper is organised as follows. Section 2 outlines the main conceptual foundations focussing on the evolutionary nature of innovation and the importance of the institutional context (or Regional Innovation System) within which firms innovate. Section 3 provides an overview of the economic, policy and institutional environment of the study regions over the last decade, and section 4 and describes the innovation data. Sections 5, 6 and 7 present the main empirical results focussing on the aims of firms' innovative activities, the resource base for innovation (both within and around each plant) and the level of innovation outputs respectively.

[2] North (2000), p. 10, for example, quotes from the Regional Economic Strategy of the East Midlands Development Agency their aspiration to 'develop a strong culture of enterprise and innovation, putting the region at the leading edge in Europe in our exploitation of research, recognised for our spirit of innovation.

Section 8 summarises the main findings of the regional benchmarking exercise and draws out the methodological and policy implications.

2. Innovation and Regional Development

Underlying the regional innovation benchmarks is the evolutionary nature of the process of innovation (Nelson and Winter, 1982; Metcalfe, 1997). In any area the nature and direction of technological change will be shaped by the decision rules, learning capabilities and adaptive behaviour of local firms (Metcalfe, 1997), social conventions (Morgan, 1997), and the intensity and extent of organisational and inter-personal interactions (Maillat, 1995; Grabher and Stark, 1997). Regional comparisons of innovation will therefore depend on the learning capabilities and adaptive behaviours of individual firms, the inter-connectedness of innovating organisations and the wider institutional structure which supports the innovative activity of firms (Metcalfe, 1995, pp. 447-449).

In this view, firms have limited competence or knowledge in the face of a complex operating environment and so develop routines for decision making (Nelson and Winter, 1982). Metcalfe (1995, p. 450) then argues that 'important corollaries of the routine-based approach are the inertial nature of decision rules, their insensitivity to small changes in the environment and the adaptation of routines as a consequence of learning behaviour'. In other words, firms have bundles of capabilities or resources that determine the sophistication and/or effectiveness of their decision making routines, and perhaps more importantly, their ability to learn or modify routines in response to their success (Morgan, 1997; Rees, 2000). The presence of an R&D function within a firm, for example, may stimulate innovation directly through the type of technology-push process envisaged in linear models of innovation. R&D staff may also, however, contribute to firms' creativity as part of multi-functional groups (Song et al., 1997), or may allow firms to utilise extra-mural networks or information sources more effectively (Veugelers and Cassiman, 1999)[3]. Other studies have stressed the potential importance of high-grade human resources for generating

[3] Relatively few empirical studies have until recently included variables explicitly reflecting the skill composition of firms' workforces as a determinant of innovation. See, for example, the material reviewed in Cohen (1995) and the papers included in Kleinknecht (1996). More recent studies based on

diversity and innovation. Commenting on their comparison of UK and German engineering and chemicals firms, Mason and Wagner, for example, commented that '… even those firms who have no aspirations to do more than adopt innovations developed elsewhere now increasingly require the services of highly qualified engineers and scientists in order to identify and make use of relevant information if they are to have any hope of staying in touch with more advanced competitors' (Mason and Wagner, 1994, p. 68).

While the strength and co-ordination of firms' internal resource-base may be crucial in determining their innovation capability, external linkages or networks also play a potentially important role (Oerlemans et al., 1998). Alongside their ability to release resource constraints, external linkages may also help by stimulating creativity, reducing risk, accelerating or upgrading the quality of the innovations made, signalling the quality of firms' innovation activities (Powell, 1998) and increasing firms' ability to appropriate the returns from innovation (Gemser and Wijnberg, 1995). The qualitative characteristics or 'quality' of firms' external links may also be important, however[4].

Another important element of this evolutionary view of the innovation process – in contrast to the more deterministic linear model – is that firms' innovation activity is, at least to some extent, shaped by their strategic and commercial aspirations (Roper, 1997)[5]. Firms' innovation objectives will in turn be shaped by the attractiveness of the markets in which firm is operating and particularly by issues of appropriability and technological opportunity (Cohen, 1995, pp. 214-231). Demand conditions in firms' home and export markets may, for example, also affect firms' expected post-innovation returns and therefore their willingness to invest in innovative activity (Cohen, 1995, 211-214), a factor that may be particularly important in international comparisons.

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firm-level surveys have addressed the question, e. g. Shefer and Frenkel (1998), Love and Roper (2000).

[4] Buckley and Carter (1999), for example, consider the general issues raised in the management of knowledge-co-ordination between firms while Stewart and Conway (1998) address similar issues in a more specific discussion related to innovation networks.

[5] Felder et al., (1996), for example, demonstrate the importance of firms' innovation objectives on the R&D and innovation investments of German manufacturing firms (see Table 5.3, p. 142-143), while Veugelers and Cassiman (1999) highlight the importance of firms' innovation objectives in the external sourcing decisions of Belgian firms.

Supporting the innovative capabilities of individual firms are the local and national institutional frameworks embodied in the notions of the national system of innovation (NSI) (e.g. Nelson, 1993) and regional innovation system (RIS) (e.g. Braczyk et al., 1998). To quote Metcalfe, (1997, pp. 461-462) a national or regional system of innovation is 'that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technology. The element of nationality follows not only from the domain of technology policy but from elements of shared language and culture which bind the system together, and from the national focus of other policies laws and regulations which condition the innovative environment'. Within an NSI or RIS, organisations fulfil three main functions:

(a) *Knowledge applying organisations* including private firms, consultancies etc. seek to identify market openings and translate knowledge into an explicit form to address profitably these opportunities.

(b) *Knowledge generating or sourcing institutions* such as universities, research institutes and government or industry research laboratories. Generally such organisations have humanitarian or social objectives, are publicly funded, and conduct their activities largely independently of immediate market needs or requirements.

(c) *Knowledge mediating or co-ordinating institutions* – which seek to identify and bring together knowledge applying and knowledge generating organisations. This may be on a bespoke basis, e.g. by assisting firms to identify potential higher education partners or vice-versa, or through the provision of network services by professional societies, chambers of commerce etc. Typically such institutions are publicly or collaboratively funded or not-for-profit organisations with either national, regional or industry development objectives.

The effectiveness of a NSI or RIS will, however, depend not only on the capability of its component institutions but also on the extent to which these institutions are connected through formal or informal networks[6]. The institutional context for innovation in any locality will also have both national and regional elements.

Beyond the national or regionally specific characteristics of the NSI/RIS, the level of innovative activity will also be influenced by what Hassink (1993) calls the 'ongoing shift from Fordist mass production to post-Fordist flexible specialisation' (p. 1009) or what Best (1991) less prosaically describes as the shift towards the 'New Competition'. Both emphasise profound changes in firms' competitive environment, dominated by the internationalisation of production activity, rapid technological change, and shifts in consumer demands. For the individual firm these changes emphasise the importance of innovation and flexibility as the basis for creating and sustaining competitive advantage. For regions, changes in the competitive environment also pose new challenges epitomised by the emergence of new high growth regions focussing on high-tech development and/or tertiary activity, while regions whose economies are based on more traditional, structurally-weak sectors continue to decline[7].

Hassink (1993) also suggests, however, that these ongoing changes in production organisation bring with them the potential for the type of local agglomeration economies epitomised by the literatures on clusters and industrial districts[8]. This potential – it can be argued – creates a new policy opportunity for regions to generate new business and growth trajectories. By enhancing the learning process in, and between, companies and other institutions, regional governments or development authorities can enhance the innovative capability of the region, generating variety or, in more concrete terms, a broad range of innovative behaviours and innovations (Metcalfe, 1997). Morgan (1997), for example, arguing from a Welsh perspective,

[6] The UK NSI, for example, has been criticised for having strong knowledge generating institutions but weak mediating and co-ordinating institutions and connectivity (Walker, 1993).
[7] Hassink (1993) contrasts, in particular, developments in the Ruhr and Baden-Wurttemberg regions of Germany, while others have documented the high-tech developments of Silicon Valley (Saxenian, 1996), Cambridge (e.g. Druilhe and Garnsey, 2000), Israel and the Republic of Ireland (Roper and Frenkel, 2000).
[8] Others suggest that globalising pressures are more important as multinational companies internalise transaction costs and develop competitive advantages based on proprietary technologies (see, for example, the discussion in Dunning, 1993, pp. 597-617).

advocates the potential of a regional regeneration strategy based on the development of networks of companies and links between companies and other development organisations.

3. The Study Regions

The study regions were chosen to highlight core-periphery differences within the EU, and to illustrate the impact of different types of RIS. Bavaria is both within the 'core' group of EU regions, with GDP per capita consistently above the EU average. Northern Ireland and the Republic of Ireland both had GDP per capita significantly below the EU average in 1990-1991 but have since experienced very different growth profiles. In Northern Ireland, GDP per capita has continued to lag 20-25 per cent below the EU average while dramatic economic growth rates in the Republic of Ireland have seen GDP per capita rise sharply. Indeed, by 1996, GDP per capita in the Republic of Ireland was 96 per cent of the EU average, compared to only 80 per cent in Northern Ireland (Table 1)[9]. Similar patterns are evident in unemployment rates with Bavaria having consistently less unemployment than the EU average. In Northern Ireland and the Republic of Ireland, unemployment rates were above the EU average until the mid-1990s, but have fallen more recently reaching 8-9 per cent by 1998 (Table 1).

Some other contrasts between the study regions may also be important in terms of their impact on the regions' innovation potential. First, higher levels of per capita income in Bavaria may mean that firms in Bavaria face a local demand for higher quality, more sophisticated and perhaps more innovative products than firms in Northern Ireland and the Republic of Ireland (Gudgin, 1995). Secondly, population densities, which have been positively linked to higher rates of innovative activity particularly in high-tech industries (e.g. Frenkel and Shefer, 1998), are notably higher in the German region (Table 1). Thirdly, in 1996, the German region had higher levels of R&D investment and patent applications per capita than Northern Ireland or the

[9] Some care is necessary in interpreting these GDP figures for the Republic of Ireland due to the importance of profits repatriated by externally-owned companies. In 1996, this meant that GNP at market prices was only 88.8 per cent of GDP (Source: CSO, Table 2, NIE Dept of Finance). In 1990 the same figure was 89.7 per cent. In other words while the GDP figures for the Republic of Ireland overestimate the average level of per capita income in the Republic of Ireland the growth profile from 1991 onwards does give a realistic impression of welfare changes.

Republic of Ireland (Table 1). In terms of R&D spending the most significant differences exist in the business and government sectors, where R&D expenditure as a percentage of GDP in Bavaria was double that in Ireland. R&D spending by higher education was more evenly spread across the study regions at 0.34-0.56 per cent of GDP.

Fourthly, important differences exist between the structure and development of the regional innovation systems of the study regions. In the Republic of Ireland, for example, as the low level of public investment in R&D suggests, "The attention to R&D in the public sector and universities in the Republic of Ireland still lags far behind other EU and OCED countries, and the R&D innovation system relies heavily on the private business sector, especially multinational corporation inward investors" (NIEC, 1999, p. 74). In Northern Ireland, the imbalance is instead towards the dominance of local R&D by the public sector and higher education with relatively low levels of R&D investment by locally-based businesses. Hence: "Imbalance in the Northern Ireland system lies in the dominance of public-sector R&D capabilities in Government and the lack of research institutions outside government and the universities" (NIEC, 1999, p. 125). In contrast, Bavaria benefits from the fact that Germany is a 'highly industrialised country with a well-developed innovative infrastructure' (Grupp et al., 1998).

Although the largest of the study regions in terms of total population, Bavaria has a mixed industrial structure with significant mechanical engineering, aerospace, automotive and electronic engineering sectors. Another feature of Bavarian industry is the prevalence of widely dispersed small- to medium-sized manufacturing plants. The average size of establishment in 1990 was 70.2 workers compared to a West German average of 153.7 (Jones and Wild, 1994). The RIS of Bavaria has attracted substantially less attention than that of its neighbour Baden-Württemberg, however, Bavaria comes second overall in Germany, in patent intensity per 1000 employees in 1996 (see Blind and Grupp, 1999) and has comparable levels of R&D spending (Table 1). The geographically and sectoral dispersion of Bavarian industry, and the importance of small to medium enterprises, poses particular problems for innovation and technology transfer.

4 Data Sources

The regional innovation benchmarks are based on three related surveys of innovation activity among manufacturing plants carried out over last decade. The first of these (the Product Development Survey or PDS) was a postal survey conducted between October 1994 and April 1995 relating to plants' innovation activities over the 1991-93 period (Roper et al., 1996). The PDS survey covered all regions in the UK, the Republic of Ireland and Germany with the following response rates: 23.7 per cent (1300 responses) in Germany, 20.6 per cent (1700 responses) in the UK and 32 per cent (520 responses) in the Republic of Ireland. For the regional benchmark analysis we focus on the respondent plants in Northern Ireland (348), the Republic of Ireland (529) and Bavaria (229).

Our second survey of innovative activity (the Product and Process Development Survey or PPDS) covered Northern Ireland and Republic of Ireland only and related to plants' innovation activity over the 1994-96 period. The survey was conducted between November 1996 and March 1997 and response rates were 43 per cent (293 responses in Northern Ireland and 28.6 per cent (459 responses) in Republic of Ireland (see Roper and Hewitt-Dundas, 1998). Our most recent survey the Product and Process Development Survey 3 or PPDS3) covered Northern Ireland, the Republic of Ireland, and Bavaria and was undertaken between October 1999 and April 2000 (Roper and Anderson, 2000). Plants were asked about their innovation activity over the 1997 to 1999 period with response rates as follows: Northern Ireland, 41 per cent (419 responses); the Republic of Ireland, 29 per cent (624 responses); and Bavaria 16 per cent (345 responses).

The three surveys have a number of common features which make them ideal for deriving regional innovation benchmarks. First, the surveys were structured to be regionally representative, or as in the case of the PDS in Germany, were constructed with large enough sampling fractions to enable regionally representative results to be derived (see Love and Roper, 2000). Second, within each region, sample structures were constructed to expose differences in innovation behaviours between plants in different employment sizebands (Acs and Audretsch, 1988, 1993) and manufacturing sectors (Geroski, 1990). Perhaps more important, however, is the fact that each of the surveys were conducted at plant (or establishment) level rather than at the level of

company. The advantage of this approach is that all stages of the innovation process will be present from the initial idea to the production of final products and that the surveys would therefore identify issues raised by plant managers in undertaking each stage of the innovation process. From the UK perspective, at least, this issue of the capability of plants to exploit research results is of particular importance. The risk inherent in a plant-based approach is that it might miss intra-company technology transfers, particularly between centralised R&D or development facilities and manufacturing sites. In the survey questionnaires, however, allowance is made for relationships between innovating sites and other group plants or resources.

Other commonalities relate to the survey instruments themselves. In each case the original questionnaire was compiled in English and pilot tested in the UK and/or Ireland. In the 1993 survey, for example, a UK pilot survey of 200 plants was undertaken (Roper et al., 1996, p. 63), while the 1996 survey was pilot tested with 100 plants (Roper and Hewitt-Dundas, 1998, p. 64)[10]. Following the pilot surveys and subsequent minor changes to the questionnaires German research staff with considerable experience of innovation surveys undertook translation into German. The German questionnaires were pilot tested in Germany and, wherever possible, back-translated by a native German speaker into English.

5. Benchmarks: Innovation Objectives and Constraints

In 1999, and perhaps reflecting the increasingly globalisation of markets for manufacturing goods (e.g. Best, 1991), plants' innovation objectives were broadly similar across the study regions. Figure 1 gives the proportion of all manufacturing plants in the study regions indicating that each innovation objective was either 'important' or 'very important' in 1999. More than three-quarters of manufacturing plants in each area give priority to extending their product ranges and increasing market share (Table 2, Figure 1). Surprisingly, however, given its prominence in recent EU policy documents such as Agenda 2000, the development of environmentally friendly products was plants' lowest priority with only a quarter of plants in each study region seeing this as 'important' or 'very important' (Figure 1).

[10] No pilot survey was undertaken for the 1999 survey in the UK and Ireland as the questionnaire was almost identical to that used in the 1996 survey.

Other differences between local operating conditions may be shaping plants' other innovation priorities. For example, high labour costs in Germany mean that reducing production costs is seen as a priority by around 60 per cent of plants in Bavaria but only 40-49 per cent of plants in Northern Ireland and the Republic of Ireland. Conversely, matching competitors, which was seen as a priority by 55-62 per cent of businesses in Northern Ireland and Republic of Ireland, was emphasised by only 23-26 per cent of plants in Bavaria (Table 2). This latter point reflects the incremental nature of innovative activity undertaken by many German plants in contrast to the more radical and market responsive approach adopted by UK and Irish plants (e.g. Culpepper, 1999, p.47; Roper, 1997).

In terms of the changes in plants' innovation objectives over the 1991 to 1999 period (Figure 2):

- In Northern Ireland, increasing priority has been given to product replacement and extending plants' product range, with a reduced emphasis on improving product quality, cost reduction and the introduction of environmentally friendly products.
- In the Republic of Ireland, as in Northern Ireland, extending the product range increased in importance while quality improvement, cost reduction and increasing market share decreased in importance.
- In Bavaria, increasing priority was given to replacing and extending plants' product ranges, cost reduction and entering new markets. Matching competitors and developing environmentally friendly products again declined in importance.

Two pieces of evidence here suggest shorting product lifetimes and the increasing importance of radical rather than incremental innovation. First, plants gave increasing priority to product replacement, and secondly the decline in the importance of quality improvement suggests that plants are placing more emphasis on developing new products rather than improving their existing product ranges. This move towards more radical innovation may pose particular problems for German firms which have historically maintained their competitive position through incremental innovation or customisation rather than more radical innovation (see, for example, the references in Culpepper, 1999, p. 44). Some differences in innovation priorities were evident,

however, between plants in Northern Ireland and Republic of Ireland and those in Bavaria. In particular, reducing cost pressures was increasingly important in Bavaria but seen as of declining importance in Northern Ireland and Republic of Ireland.

Constraints on plants' innovation activity may be important in limiting plants' ability to achieve these changing objectives. Benchmarks for the constraints on innovation activity were derived as the proportion of plants indicating that each factor was either 'important' or 'very important'. Figure 3 gives the percentage of all manufacturing plants in each study region highlighting each innovation constraint in 1999. As expected, and like previous studies (e.g. Roper et al., 1996), low expected rates of return, the riskiness of undertaking innovation and lack of finance predominate, along with a perception that market opportunities were limited (Figure 3). Other factors (i.e. legislative requirements, attitudinal barriers, and lack of information) were seen as less important barriers to innovation in each study region.

Some differences in the barriers to innovation did exist, however, between the study regions. First, while a lack of expertise for innovation was not evident in Northern Ireland it was highlighted by a significantly larger proportion of manufacturing businesses in Republic of Ireland (Figure 3). One possibility is that this may reflect the influence on innovation of 'Celtic Tiger' growth rates that have led to tight labour markets in the Republic of Ireland. Secondly, 32 per cent of plants in Bavaria highlighted the riskiness of innovation compared to 22 per cent in Northern Ireland and Republic of Ireland, and thirdly a lack of opportunities for innovation was highlighted by 41 per cent of plants in Bavaria but only 25-28 per cent in Northern Ireland and Republic of Ireland. Combined with the fact that German plants also indicated that a low rate of return was an important barrier to innovation, this suggests that market conditions in Germany at the time of the 1999 survey may have been more difficult than that in the other study regions[11].

[11] OECD (1999), for example, indicates that GDP and investment growth in Germany in 1999 were expected to be well below trend and that business confidence and industrial orders fell sharply in 1999.

Considering the way in which plants' perceptions of innovation constraints have changed through time suggests a much more dynamic picture in Northern Ireland and the Republic of Ireland than in Bavaria (Figure 4). In Bavaria, the percentage of manufacturing plants regarding each innovation constraint as either 'important' or 'very important' has remained broadly similar suggesting stability in both the quality of plants' internal resource base and the support offered by the institutions of the local RIS. In the Republic of Ireland and more notably in Northern Ireland, however, the percentage of plants highlighting each innovation constraint has declined rapidly since the early-1990s. For example, in 1993, 41-42 per cent of plants in Northern Ireland and the Republic of Ireland highlighted the riskiness of innovation as an important constraint, a level higher than that in Bavaria. By 1999, the proportion of plants in Northern Ireland and the Republic of Ireland citing the riskiness of innovation as an important constraint had fallen to 21-22 per cent, a level below that of Bavaria. Similar trends were also evident in terms of the lack of finance, lack of information, and lack of partners.

Again two explanations are possible. First, if the innovation intentions of plants in Northern Ireland and the Republic of Ireland had declined this might have meant barriers to innovation were less important. This is unlikely, however, as Figure 2 suggests the stability of plants' innovation objectives in each of study regions. Perhaps more likely is that the reduction in the barriers to innovation in Northern Ireland and the Republic of Ireland reflects policies in both regions to improve the innovation capability of firms and strengthen the RIS through the provision of grant assistance for innovation, improvements in the availability of information and help for potential innovators to find commercial or research partners. In Northern Ireland, for example, grant-based measures such as Compete, which primarily supports near-market R&D by manufacturing businesses, have worked to reduce the riskiness and increase the potential returns from innovation (Roper, 1998). Measures designed to stimulate innovative partnerships are better developed in Republic of Ireland with the Projects in Advanced Technologies (PATs) encouraging university-industry co-operation in R&D and the National Linkages Programme (Tomaney, 1995) designed to improve co-operation along the supply chain. Supplementing both measures – and also covering Bavaria, of course, are related EU initiatives such as the network of

Innovation Relay Centres, collaborative research projects and framework programmes.

6. Benchmarks: Inputs and Organisation of Innovation

In this section we consider benchmarks for plants' innovation resources (i.e. R&D, graduate employment), the internal organisation of the innovation process (i.e. the extent of multi-functional working) and the strength and nature of plants' external linkages. Each of these factors has been shown to be important in determining both whether or not a plant undertakes innovation and the subsequent market success of that innovative product or process (e.g. Brouwer and Kleinknecht, 1996; Love and Roper, 2000)

In terms of R&D spending, earlier regional comparisons have suggested that in 1996, aggregate levels of R&D investments by business, government and higher education were higher in Bavaria than in Northern Ireland and the Republic of Ireland (Table 1). Survey data provides some insight into the distribution of this R&D activity between plants, with the proportion of manufacturing plants undertaking some R&D also being higher (62 per cent) in Bavaria than in either Northern Ireland (51 per cent) and the Republic of Ireland (56 per cent, Table 2). Figure 5 summarises changes in the proportions of plants undertaking R&D since 1993 for all plants. In Bavaria there has been a small overall decline in the proportion of plants undertaking R&D over this period, a pattern repeated across each of the three plant sizebands (Figure 5). In contrast, although the overall proportion of plants undertaking R&D in Northern Ireland and Republic of Ireland remains below that of the German study region, it has increased since 1993. In the Republic of Ireland, this increase was due to a rise in the proportion of plants with 100 plus employees undertaking R&D, while proportion of smaller plants undertaking R&D fell marginally. In Northern Ireland the pattern was slightly different, with an increase in the proportion of R&D performers in the 20-99 and 500 plus employee sizebands outweighing a decline in the 100-499 sizeband (Figure 5).

The increase in the proportion of plants undertaking R&D in Northern Ireland and the Republic of Ireland is welcome given longstanding concerns in both areas about the

relatively low level of R&D spending by businesses (e.g. Industrial Research and Technology Unit, 1992; STIAC, 1995). And, given the declines in the proportion of plants undertaking R&D in Bavaria, some regional convergence has occurred. In part at least this convergence may reflect similar factors to those influencing the constraints on innovation activity discussed earlier. Steps have been taken in both Northern Ireland and the Republic of Ireland to boost the level of business R&D spending while economic conditions in Germany at the time of the 1999 survey were probably discouraging R&D investments (OECD, 1999).

Another factor which has in the past been shown to be strongly linked to plants' innovation potential, and is, perhaps, less likely to be sensitive to the business cycle than R&D investments, is the level of graduate employment (Figure 6). Overall, the lowest level of graduate employment in the study regions is now found in Northern Ireland (7.1 per cent) compared to 7.7 per cent in Bavaria and 8.9 per cent in both the Republic of Ireland (Table 1). This, however, is a marked contrast to the situation in 1993 when levels of graduate employment in Northern Ireland (6.7 per cent) and the Republic of Ireland (8.8 per cent) were actually above that in Bavaria (4.7 per cent). In other words, from 1993-99, Bavaria had overtaken Northern Ireland in terms of the level of graduate employment (Figure 6). In part this may reflect global trends towards a more highly skilled manufacturing workforce but may also reflect pressures within Germany as further and higher education become more attractive compared to traditional apprenticeship training (Culpepper, 1999, p. 49).

Clearly, however, undertaking R&D and having a high level of graduate employment are not sufficient to generate innovation. Also necessary is efficient co-ordination and information sharing within the firm, one reflection of which is the extent of multi-functional working. Although not covered by the 1996 and 1999 surveys, information on the extent of multi-functional involvement in the innovation process is available from the 1993 survey (see also Roper, 1997; Love, 2000). Figure 7 summarises the percentage of all manufacturing involving more than one functional group in seven elements of the product innovation process in 1993. Multi-functional involvement in the innovation process was most common in each region in product testing and least common in the marketing phases of the product development process (Figure 7). As expected from previous studies using PDS data, multi-functional working was more

common among plants in Northern Ireland and the Republic of Ireland than in the Bavaria (Figure 7). Previous studies have linked the difficulties of implementing multi-functional working in Germany to rigidities stemming from apprenticeship based training (e.g. Streeck, 1996; Finegold and Wagner, 2000) and the more incremental and developmental nature of innovation activity in Germany (e.g. Roper, 1997). Culpepper (1999, p. 53) summarises the situation as follows: 'the organisation of work in multi-functional teams rejects the concept at the heart of the German skills system, that a skilled worker brings to the process a (portable) technical skill that is his or her contribution to production'. The weakness of the UK and Irish apprenticeship systems, and progress towards flexibility within the UK and Irish labour markets, are likely to have made any such barriers in Northern Ireland and the Republic of Ireland less important.

One possible approach to overcoming any such internal rigidities is for plants to develop links with outside organisations with complimentary or reinforcing competencies (e.g. Buckley and Carter, 1999; Crone and Roper, 2000). Figure 8 summarises the percentage of all manufacturing plants involving external organisations of varying types in their innovation activity from 1996-99 (see also Veugelers and Cassiman, 1999). In each of the study regions the most common innovation links (covering 25-35 per cent of innovators) are, unsurprisingly, along the supply chain to either customers or suppliers (Figure 8). Links to other group companies existed for around 20 per cent of all manufacturing plants, but were more common in the Republic of Ireland reflecting the importance of externally-owned businesses particularly in the high-tech sectors (Gorg and Ruane, 1997). Links to consultants were also notably more common in the Republic of Ireland than in either Bavaria or Northern Ireland, however, horizontal linkages to competitors were equally common in each of the study regions existing for 5-10 per cent of innovating plants (Figure 8). In terms of plant' innovation links to the non-business sector, very similar levels of interaction were noted in each of the study regions (Figure 8). Around 20 per cent of plants in each of the study regions had links to universities, while fewer than one in ten plants had links to private research institutions. More marked differences existed between the study regions in the strength of plants' links to industry and government operated laboratories.

7. Benchmarks: The Extent and Success of Innovation

We consider two main innovation output measures: the proportion of plants introducing new or improved products during each three year period (i.e. 1991-93, 1994-96, 1997-99); and, the percentage of sales accounted for by new products. The former can be interpreted as an indicator of the *extent* of innovation activity in the region and the latter as an indication of innovation *success*.

As we might expect from the earlier discussion of increasing competitive pressures, the extent of innovation activity increased in overall terms from 1991-93 to 1997-99 period in Northern Ireland and, most sharply, in Bavaria (Figure 9). Increases in the extent of innovation activity in Northern Ireland, and Bavaria suggest some regional convergence. One consequence of the overall increases in the extent of innovative activity, combined with the tendency towards shorter product lifetimes and intensified global competition, might be an increase in innovation 'success' or the percentage of plants' sales derived from innovative products (Figure 10). What we observe, however, is a marked contrast between Northern Ireland and Republic of Ireland on one hand, where the percentage of sales derived from innovative products has actually fallen since 1991, in Bavaria, where the percentage of sales of new products has increased (Figure 10). Even more striking is that in 1991 Northern Ireland and the Republic of Ireland actually had higher overall proportions of new products in sales (22-23 per cent) than Bavaria (15 per cent), an advantage they had lost by 1999.

Taken together these measures of the extent and success of innovation imply a similar situation in Northern Ireland and the Republic of Ireland, i.e. an increase in the overall extent of innovation but a decline in innovation success. This itself reflects a marked contrast between SMEs on one hand and larger firms on other. For SMEs in Northern Ireland and the Republic of Ireland a decline in the extent of innovative activity is consistent with a decline in innovation success (or the percentage of sales derived from new products). The situation for larger firms is more worrying as the extent of innovation has increased but innovation success declined. One clear possibility is that – for whatever reason – larger firms in Northern Ireland and the Republic of Ireland were introducing more marginal innovations over this period which achieved limited market success.

8. Discussion

The complex social and systemic influences that drive innovation in any specific region defy simple categorisation. In multi-regional comparisons the situation is complicated further by the influence of national market conditions such as high levels of GDP in Bavaria, and high rates of economic growth in the Republic of Ireland. Also important are national and regional differences in institutional structures relating to vocational training, technology transfer, venture capital etc. Despite this complexity some clear commonalities and contrasts emerge between the study regions.

Perhaps reflecting the type of global trends in competition highlighted by Best (1991), plants' innovation objectives were very similar in each of the study regions. A general trend was notable, however, towards more radical innovation, with plants increasingly emphasising the development of new products rather than the improvement of their existing product range. One more worrying element of plants' innovation objectives was that the development of environmentally friendly products was given a low and diminishing priority. Businesses identified a number of factors that constrain their ability to achieve these objectives. Risk, lack of finance, and limited market opportunities were highlighted by plants in each area throughout the 1991-99 period but marked contrasts exist in the changing importance of innovation constraints. Plants in Bavaria highlighted very similar constraints throughout the period while there was a sharp decline in the proportion of plants in Northern Ireland and the Republic of Ireland reporting that their innovation activity was being constrained. Contrasting macro-economic conditions in the study regions may be part of the explanation along with attempts by government in Northern Ireland and the Republic of Ireland to improve firms' innovation capability and develop the institutional support structure for innovation.

The next group of regional benchmarks relates to the scale and organisation of plants' innovation resources. In terms of the scale of their R&D investments, for example, firms in Bavaria have been consistently invested more than those in Northern Ireland and Republic of Ireland. In addition, a larger proportion of plants in Bavaria undertake R&D than in either Northern Ireland and the Republic of Ireland although there has been some convergence since 1991. In terms of graduate employment, plants in Northern Ireland and Republic of Ireland had some advantage in 1991. By 1999,

however, a more rapid expansion of the number of graduates in German plants meant that Northern Ireland and the Republic of Ireland were overtaken by Bavarian plants. This meant that both in terms of the scale and extent of R&D activity and graduate employment, plants in Bavaria had the strongest resource base for innovation. There is evidence, however, that the co-ordination of these resources may be less effective in Germany with fewer plants operating multi-functional groups as part of their innovation activity. More uniformity was evident between the study regions in terms of plants' external links to other businesses and universities.

For plants in Northern Ireland there does seem to have been something of an improvement in the environment for innovation during the 1990s. A perception of fewer innovation constraints has contributed to an increase in the extent of R&D activity, although this continues to lag well behind that in Germany. Intra-plant and inter-firm co-ordination during the innovation process in Northern Ireland at least matches that in Germany. The increase in the extent of R&D activity and the improvement in the environment for innovation in Northern Ireland are less apparent in the benchmarks for innovation outputs. The extent of innovation in Northern Ireland has increased, but has fallen further below that in Bavaria (from 3.0 to 7.5 pp). Like the Republic of Ireland, however, a perhaps more worrying result is that innovative products introduced by Northern Ireland plants were proving less successful than previously. For smaller plants this may reflect a decline in the extent of innovation in Northern Ireland, for larger plants, however, it suggests that the innovations being made are more marginal. One possibility, evident in case-study evaluations of R&D support measures (e.g. Roper, 1998), is that government support for R&D activity is encouraging innovations which are technically feasible but lack market applicability.

The situation in the Republic of Ireland reflects that in Northern Ireland, with plants' difficulties exacerbated by shortages of appropriately skilled labour. As in Northern Ireland the extent and scale of firms' R&D activity has increased but remains well below that in Bavaria. Also like Northern Ireland, multi-functional working in the innovation process is more common than in Bavaria, with similar levels of inter-firm linkages. The extent of innovation in the Republic of Ireland is consistently above that in Northern Ireland, although the gap has narrowed from 8.1 pp in 1993 to 4.4 pp in

1999. In general terms the benchmarks therefore suggest a stronger innovation profile in the Republic of Ireland than in Northern Ireland but innovative activity continues to lag well behind that in the German study regions. The need – recognised in recent policy statements and expenditure announcements – is to significantly increase the level of R&D spending and to continue the process of institutional capabilities to support firms' innovative activity.

Of the three study regions, however, Bavaria is alone in achieving increases in the extent and success of product innovation for each plant sizeband over the 1993-99 period. While this may reflect the development of more high-tech industry in the region, it is a development which has been accompanied by significant government spending and institutional developments. For example, from 1992-97 there was a sharp increase in the basic support by Lander and Federal government in Germany for science in Bavaria, with spending increasing 25 per cent in nominal terms compared to a 12.7 per cent increase in the old Lander and a 12.2 per cent rise in Baden-Württemberg. Similarly, institutional developments in Bavaria were made to support high-tech industry and innovation including the establishment of the Bavarian Research Foundation in 1991 to foster collaborative research in new technologies, Bayern Innovativ (1995) set up to stimulate technology transfer to SMEs and parallel developments in provision of venture capital (e.g. Bayern Kapital Landshut). Despite these developments links between firms and institutional innovation partners in Bavaria remain relatively underdeveloped as does the extent of multi-functional working.

In more general terms, the benchmark comparisons suggest little evidence of convergence between innovative activity in the study regions. In terms of the extent of innovation, Northern Ireland and the Republic of Ireland continue to lag increasingly behind plants in Bavaria. In terms of the success of innovation the situation is even more stark with Northern Ireland and the Republic of Ireland losing ground relative to Bavaria. Accounting for these performance differences in terms of the efficiency with which plants in each area innovate is difficult given the overall similarity (or advantage of Northern Ireland and the Republic of Ireland) in terms of intra-firm co-ordination and inter-firm linkages. More convincing are arguments related simply to the extent of the regions' commitment and investments in R&D and innovation. To

illustrate the extent of the differences between the study regions Table 3 gives R&D expenditure by performing sector in 1996. Part A of the table expresses R&D spending as a proportion of each region's GDP. As indicated previously business and government R&D spending in Northern Ireland and the Republic of Ireland in 1996 as a percentage of GDP was between half and two thirds of that of Bavaria, with R&D in higher education at similar levels. This comparison, however, underestimates the real difference in spending due to higher GDP per capita in Bavaria (Table 1). For Northern Ireland this would involve a trebling of business spending on R&D, a three to four-fold increase in government R&D spending and a doubling of spending on research in higher education. For the Republic of Ireland a similar doubling of business spending and three to four-fold increase in government spending would be necessary. High levels of spending on research in higher education in the Republic of Ireland mean that this is already in line with levels in Germany.

Even an expansion of R&D investment of this scale, however, is unlikely to be sufficient for Northern Ireland or the Republic of Ireland to 'catch-up' with Bavaria over a ten or even twenty-year horizon. Because of past investments German plants have effectively built up a stock of R&D expertise and knowledge that it will be difficult for Northern Ireland and the Republic of Ireland to match. To achieve faster convergence would require even higher levels of R&D investment.

Table 1: Basic Regional Indicators, R&D and Patent Comparisons

	Bavaria	Republic of Ireland	Northern Ireland	Federal Republic of Germany	United Kingdom
Population 1996 (000s)	12018.7	3626.1	1663.3	81914.8	58801.5
Population Density 1996 Persons/km^2	170.4	51.6	117.5	229.4	241.2
GDP per capita 1995-97 (EU15=100)	127	96	80	110	99
Unemployment rate April 1998 (%)	5.7	7.9	8.8	9.8	6.2
Patent applications Per capita 1996	270.91	39.38	16.05	181.47	82.25
R&D Expenditure as % of GDP in 1996	1.60	1.30	0.96	1.50	1.93
Of which: Business Sector	1.04	0.64	0.48	0.83	1.27
Government Sector	0.22	0.10	0.14	0.25	0.28
Higher Education	0.34	0.56	0.34	0.42	0.38

Note: GDP per capita figures were originally in ECU per capita and expressed as a percentage of the EU15.

Source: Statistics in Focus, Eurostat

Table 2: Regional Innovation Benchmarks: 1999

	Northern Ireland	Republic of Ireland	Bavaria
Constraints on Innovation (% plants)			
Riskiness of Innovation	21.9	22.3	31.8
Low Expected Rate of return	39.7	37.6	44.2
Attitudinal barriers	7.5	12.4	8.5
Lack of finance	29.9	30.3	33.9
Few market opportunities	25.1	27.5	37.7
Lack of information	9.5	14.5	11.6
Legislative requirements	11.7	16.8	22.8
Lack of partners	6.4	10.6	10.6
Lack of expertise	17.8	28.4	14.1
Objectives of Innovation (% plants)			
Replace existing products	54.7	48.7	47.3
Extend product range	77.9	78.9	77.3
Increase market share	80.9	75.5	92.3
Enter new mkts	69.6	63.5	64.9
Reduce production costs	48.7	40.5	57.9
Environmentally friendly products	23.9	27.6	28.1
Improve product quality	71.3	64.8	74.6
Match competitors	61.6	54.9	27.6
Undertaking R&D (% of Plants)	51.9	56.3	55.0
Graduates (% of workforce)	7.1	8.9	8.0
Multifunctional Working (% plants)			
Identifying New Products	60.6	65.3	42.1
Prototype Development	52.2	60.9	32.1
Final Product Design	65.8	62.5	45.9
Product Testing	74.1	74.0	55.5
Production Engineering	54.0	41.7	18.2
Market Research	25.7	24.2	7.5
Developing Market Strategy	27.4	23.8	6.0
Links to Innovation Partners (% plants)			
Other Group Companies	22.5	28.9	17.0
Clients/Customers	31.4	32.8	23.3
Suppliers	31.0	34.6	28.4
Competitors	8.6	9.3	5..3
Consultants	16.2	25.4	11.6
Govt Research Labs	8.3	12.1	5.9
Industry Operated Labs	7.8	9.9	7.5
Private Research Institutes	8.2	9.8	4.2
University/Higher Education	18.3	19.1	14.4
Product Innovation (% plants)	62.8	67.2	70.3
Sales as % New Products	15.9	17.4	20.5

Sources: See text.

Table 3: R&D Expenditure By Study Region Corrected For Differences in GDP per Capita

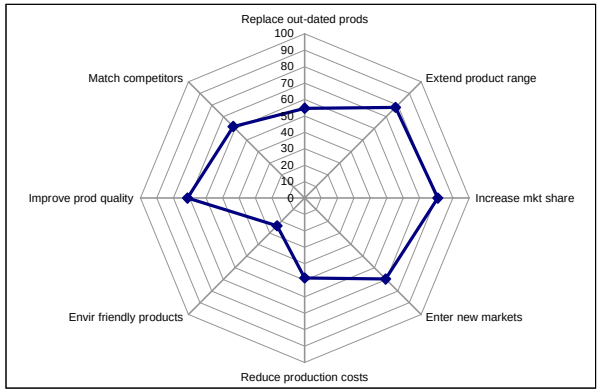
	R&D Performing Sector			
	Business	Government	Higher Education	Total
R&D Spending as % of GDP				
Bavaria	1.04	0.22	0.34	1.60
Northern Ireland	0.48	0.14	0.34	0.96
Republic of Ireland	0.64	0.10	0.56	1.30
As % of Northern Ireland GDP				
Bavaria	1.65	0.35	0.54	2.54
As % Republic of Ireland GDP				
Bavaria	1.38	0.29	0.45	2.12

Notes: Parts B and C are derived by scaling figures in part A by the ratio of Northern Ireland or Republic of Ireland GDP per capita to that of Bavaria.

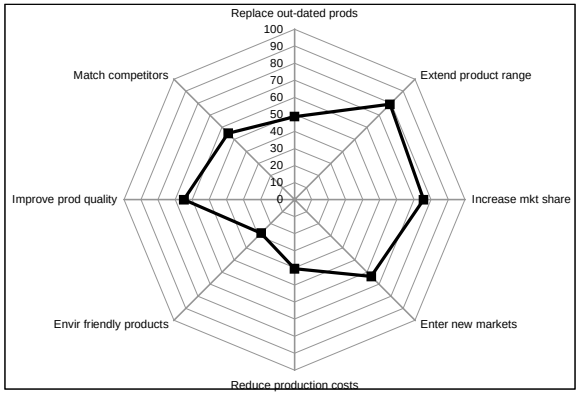
Source: Table 1

Figure 1: Innovation Objectives of All Manufacturing Plants: 1999

Northern Ireland



Republic of Ireland



Bavaria

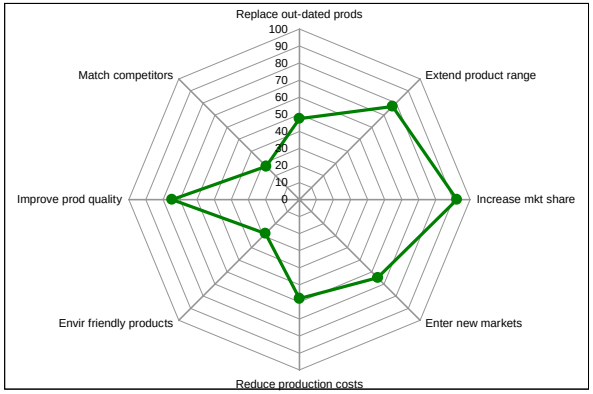


Figure 2: Objectives of All Product Innovators: 1993-1999

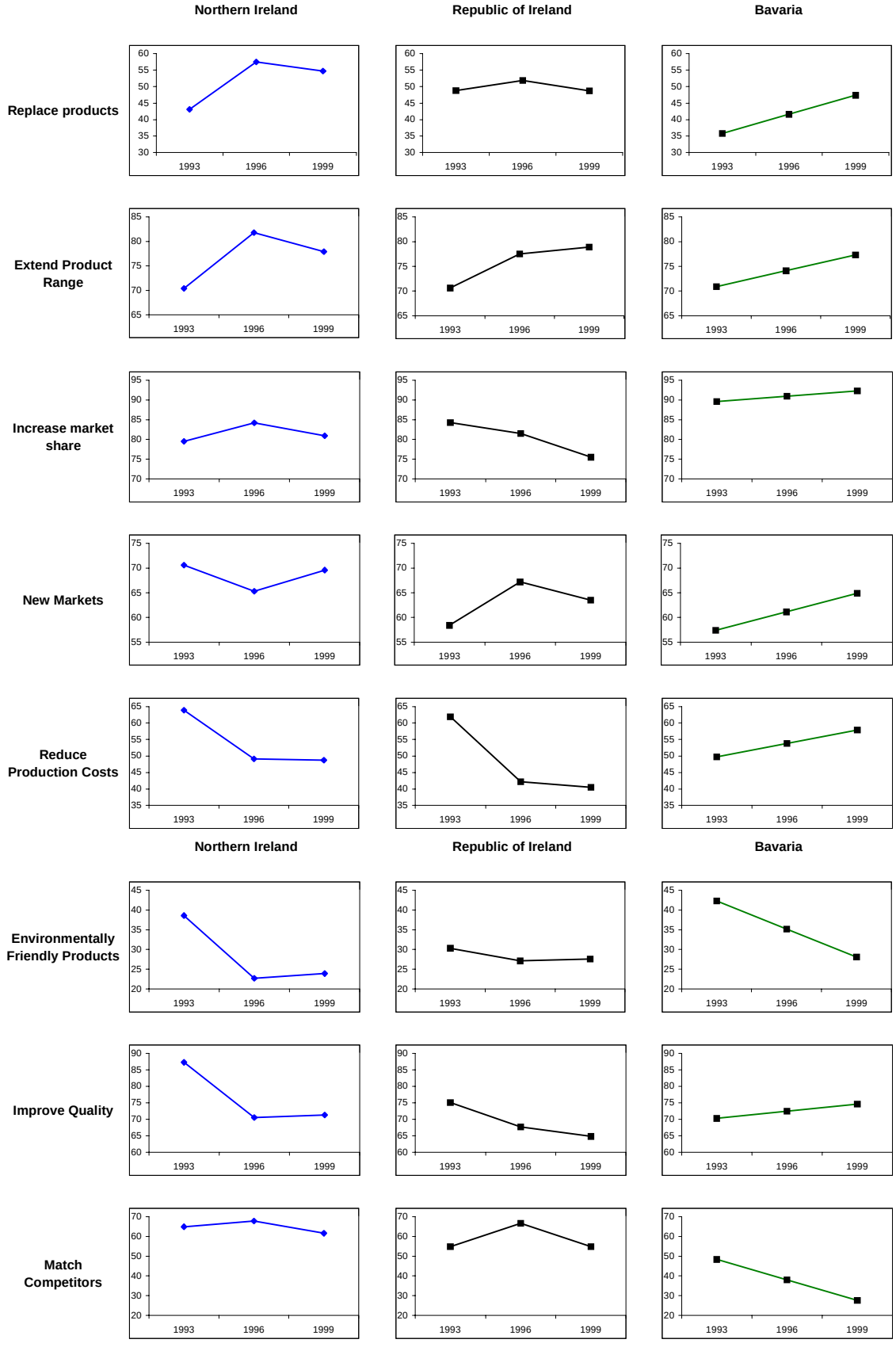


Figure 3: Innovation Constraints on All Manufacturing Plants: 1999

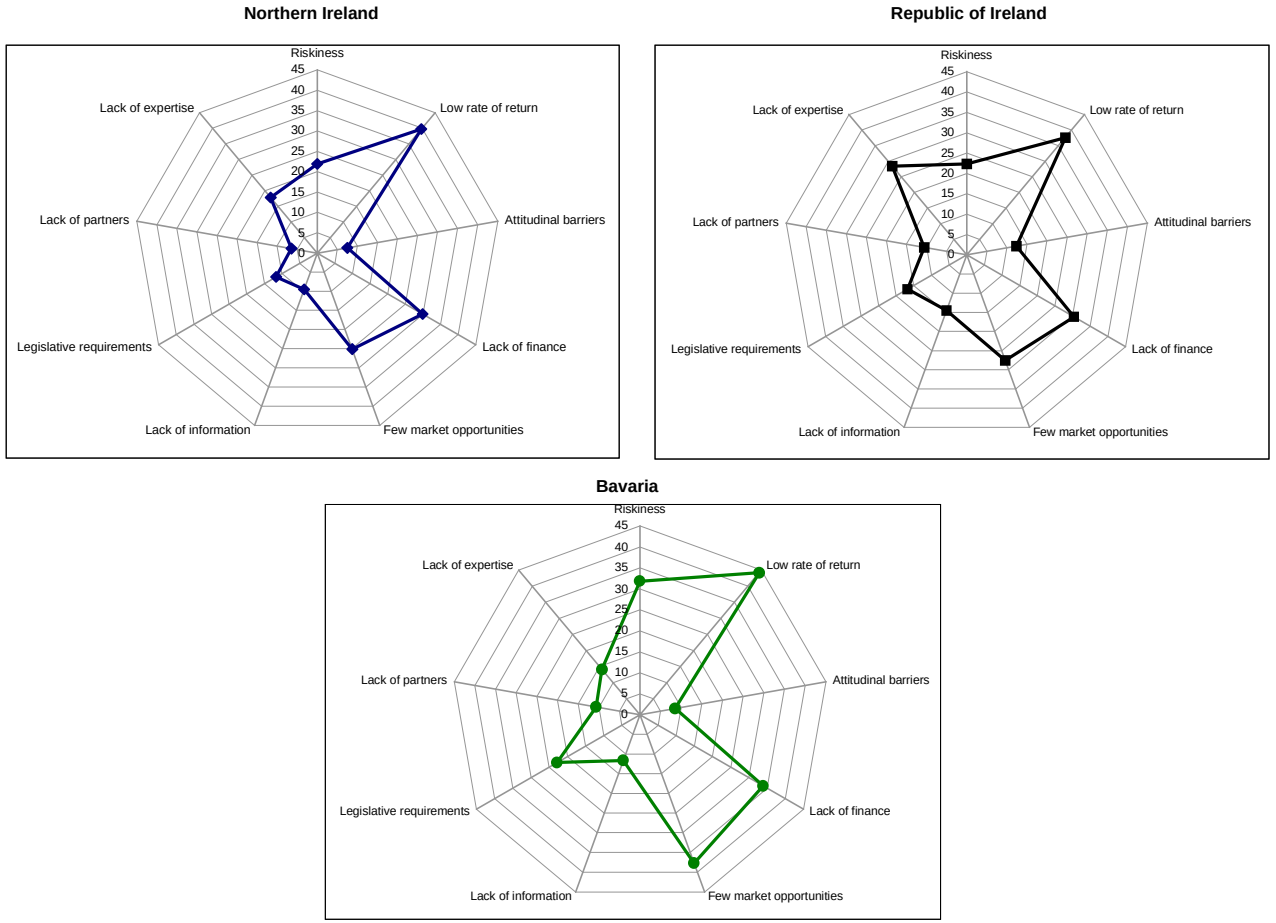


Figure 4: Changing Innovation Constraints on All Plants: 1993-99

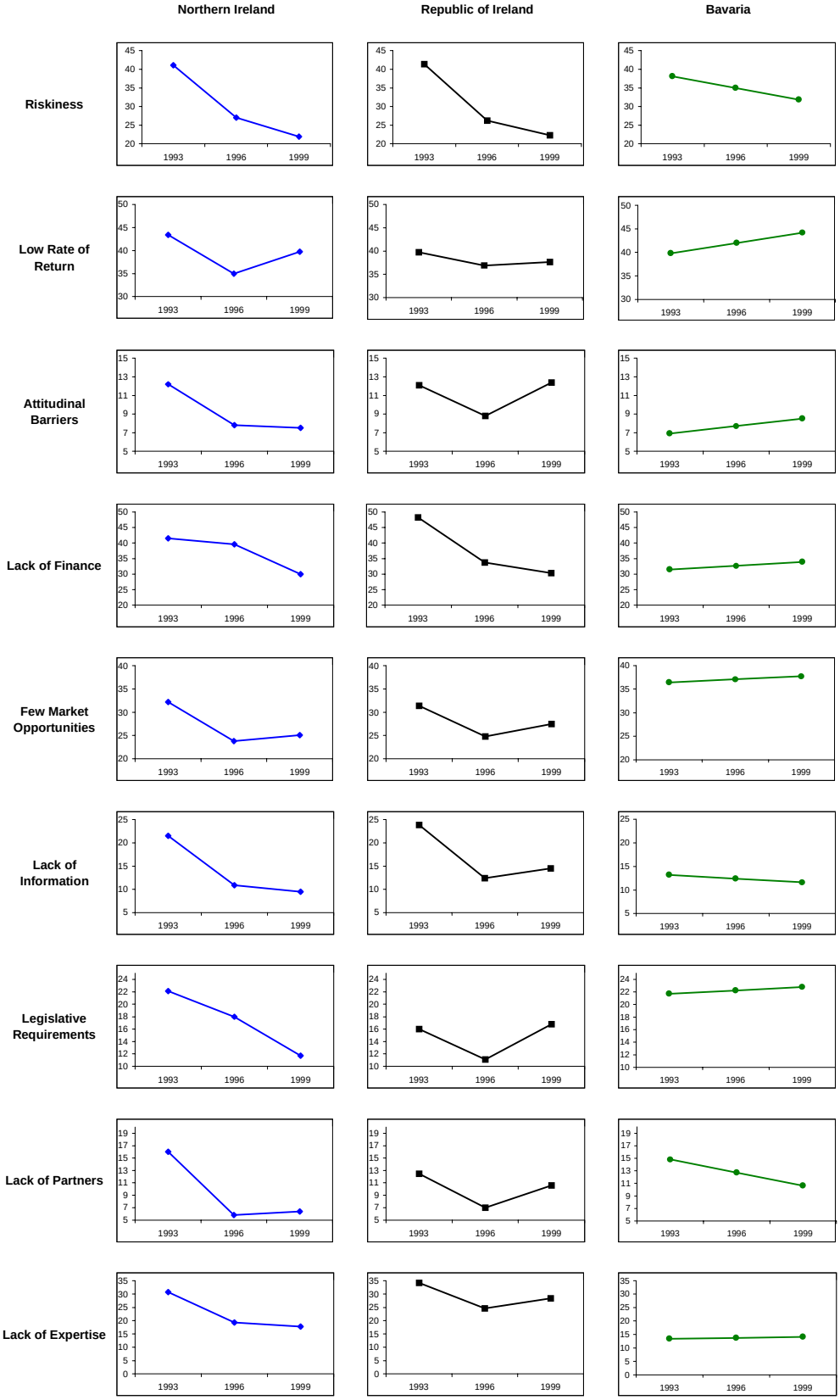


Figure 5: Percentage of Plants Undertaking R&D

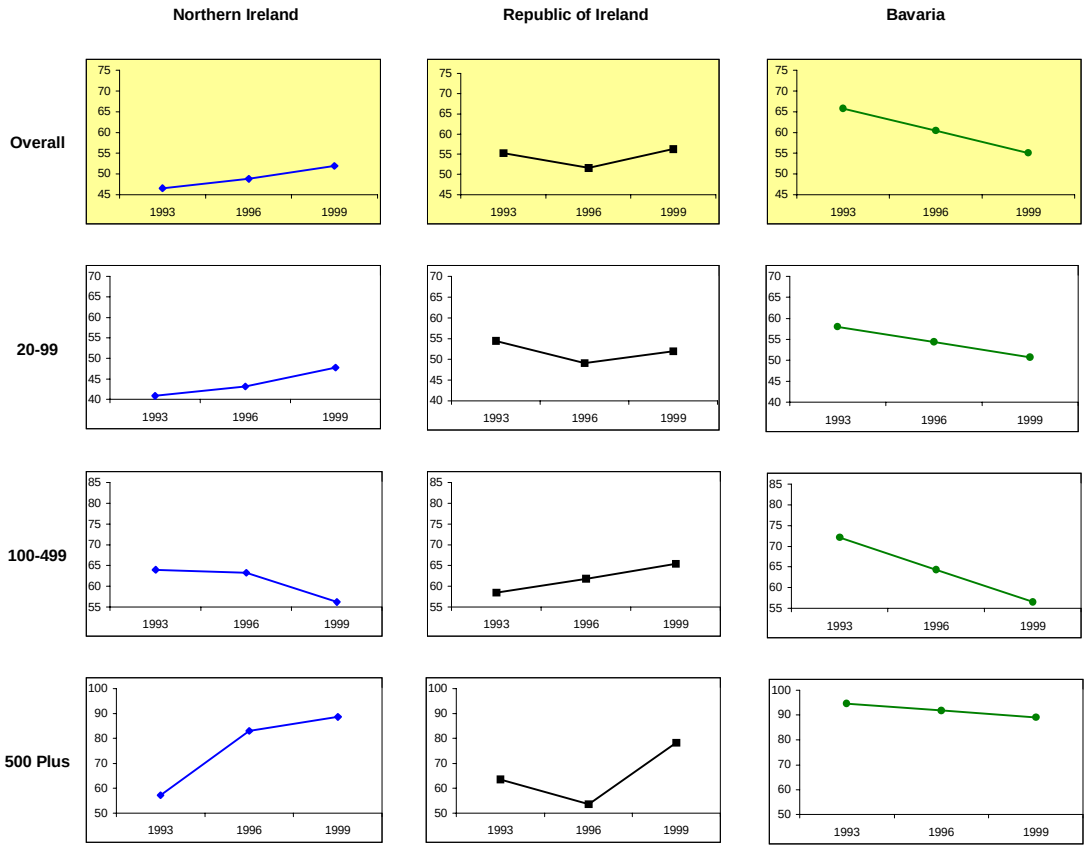


Figure 6: Percentage of Workforce Which Are Graduates: All Manufacturing Plants

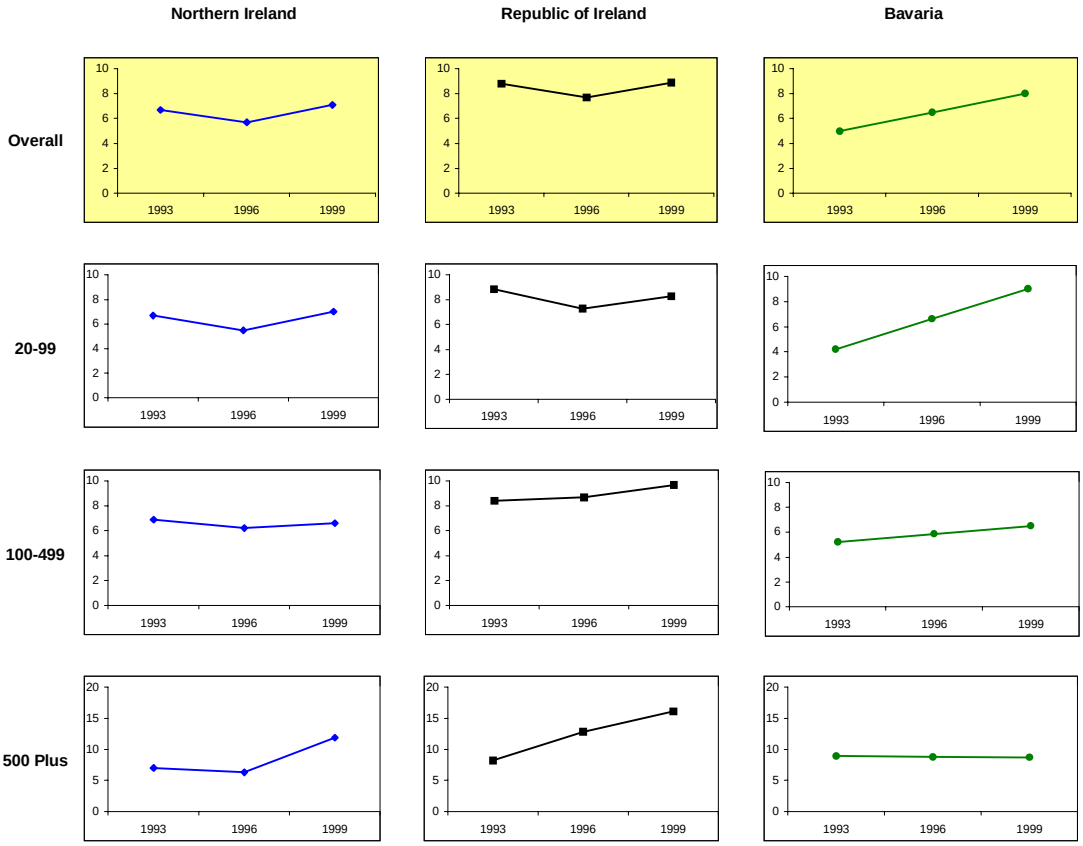


Figure 7: Percentage of All Innovators with Multi-Functional Working: 1993

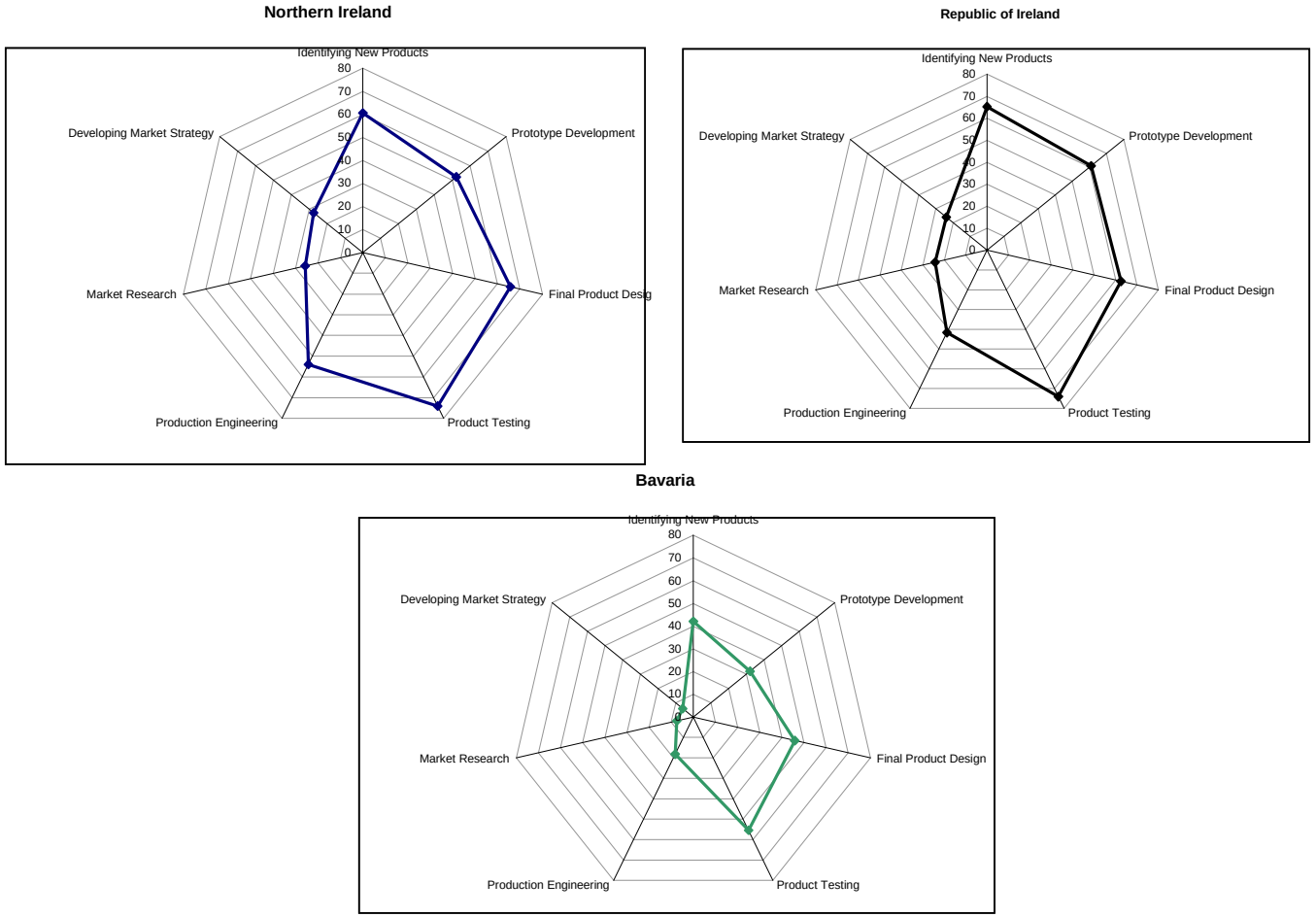


Figure 8: Percentage of All Plants with External Links for Innovation:

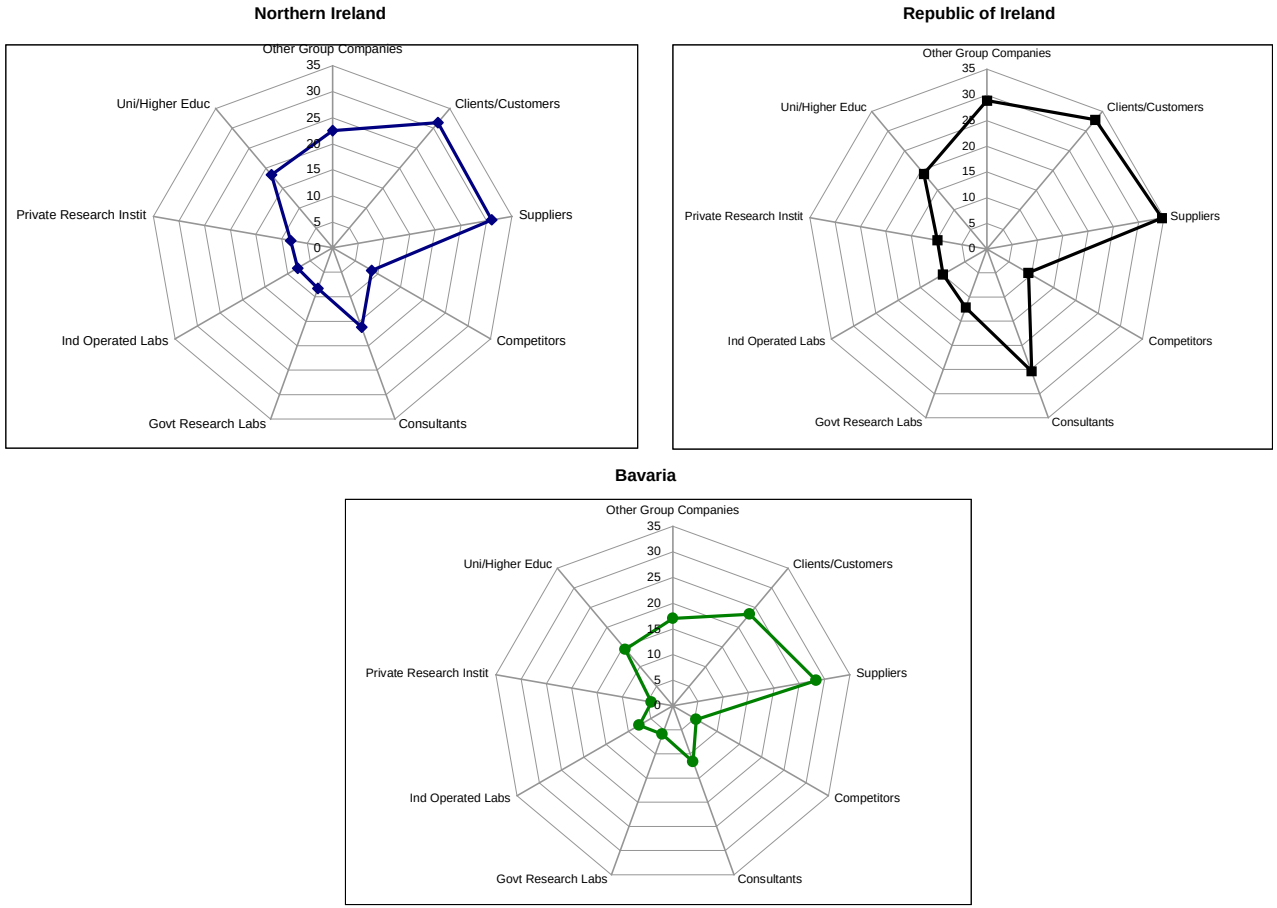


Figure 9: Percentage of Plants Undertaking Product Innovation

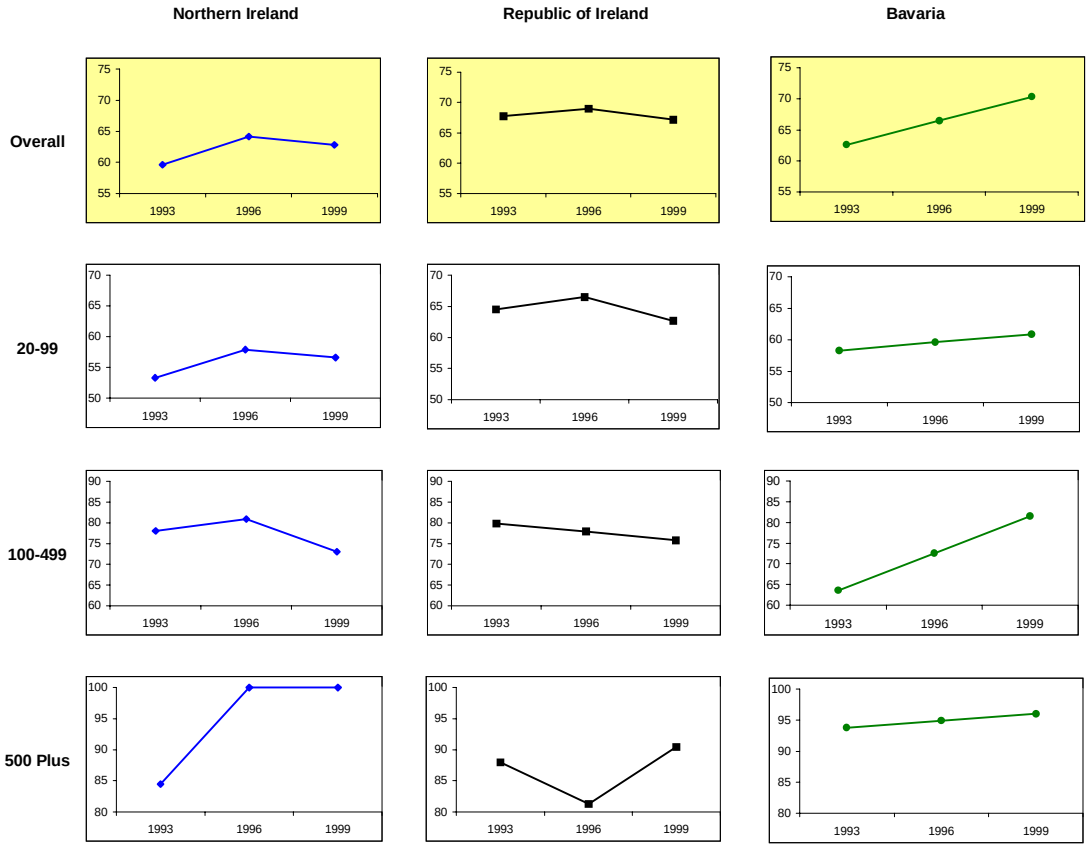
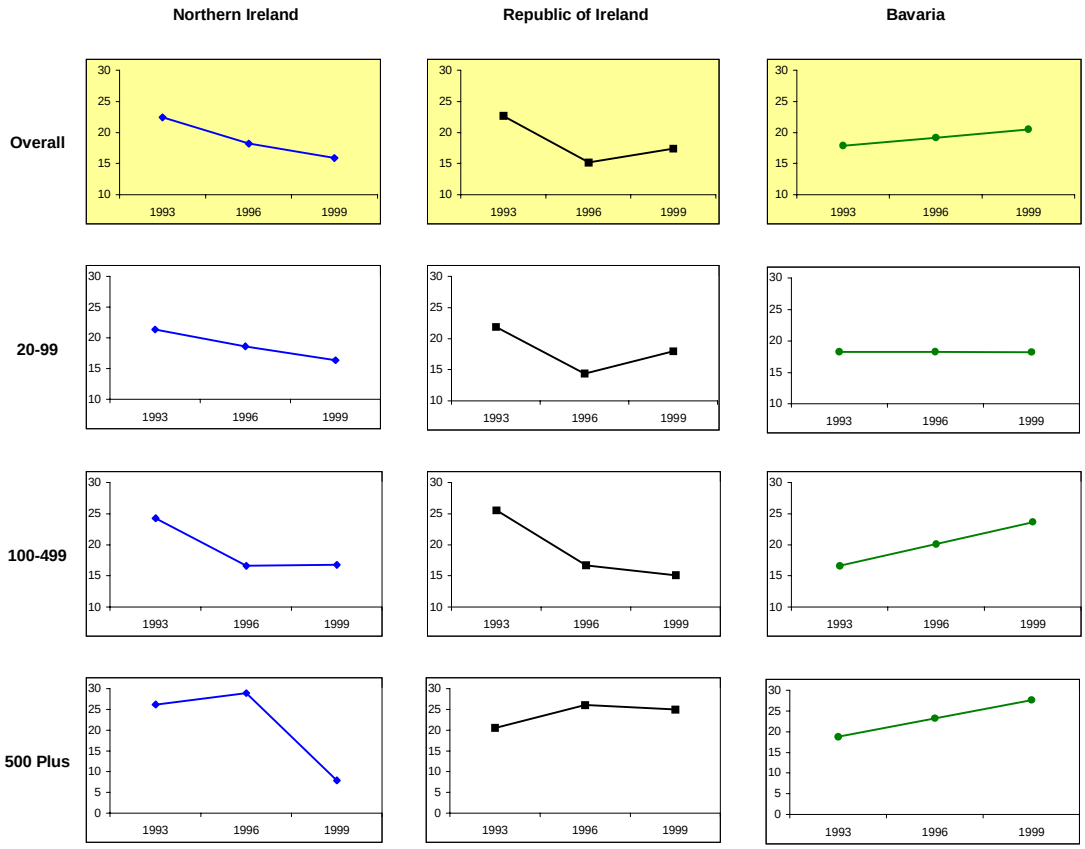


Figure 10: Percentage of Sales that are new Products



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