INNOVATION IN THE INDUSTRIAL HEARTLAND - ILLAWARRA CASE STUDY

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ABSTRACT Innovation is linked with both regional growth and the capacity of industrialised countries to compete in global markets. Regional innovation in industrial regions can result in either the emergence of new growth industries or the restructuring of older industries based on their knowledge-intensive sectors. This paper uses data from surveys of inventors and manufacturing firms in the Illawarra region of NSW, Australia, to analyse the role of innovation in Australian industrial regions. It also provides a simple regression analysis of the survey results highlighting those economic and organisational factors that are significantly related to regional R & D activity. It was found that current innovation patterns were more typical of a traditional industrial region with relatively low levels of innovation in its economic base industries. However, there was evidence that new innovative growth sectors were emerging and that creative milieu factors were important determinants of the level of innovation in the Illawarra.

1. INTRODUCTION

The relationship between innovation and spatial economic development is one salient polemic in current regional analysis. The USA and European Union have shown a renewed capacity to compete in global markets for advanced technology and high quality design-intensive products. That their internationally successful industries were often geographically concentrated in particular regions has led to a resurgence of interest in the spatial dimension of economic restructuring and in attempts to identify particular characteristics of regional economies which support the development of such industries (Porter, 1990; Storper, 1995; Cooke *et al*, 1997, 1999).

Identification of specific regional institutions, business organisational features and practices or public policies which lead to the development of internationally competitive industries has been elusive, with different factors identified in some studies while others have often found no significant differences among regional types. Initially, attention focused on the formation of specific industrial clusters in industrial districts. These clusters involved strong vertical input-output relationships among local firms plus strong local horizontal relationships between firms in these sectors and suppliers of producer inputs (Piore and Sabel, 1984). However, clustering and industrial districts have proven to be special cases with many innovative regions having neither industry specialisation nor strong commercial relationships among local firms (Storper, 1995). By the mid 1980s, attention focused on cultural factors or 'creative milieux' which fortunately developed in particular areas and acted as a nurturing bed for technological

innovation, new product development, social capital enhancement, entrepreneurship and export marketing activities, which together have generated successful new industries (Aydalot and Keeble, 1988; Storper, 1993; Camagni, 1995; Morgan, 1997).

The regional features identified as forming this creative local environment have included the availability of essential factors of production including professional and technically skilled workers, flexible suppliers able to assist in the development of new components and machinery for technically advanced products and specialist service firms able to support the rapid commercialisation and global marketing of these new products. Ready access to major international transport facilities are also important determinants of location for such firms. In advanced technology and design-intensive products, access to the 'knowledge base' of these industries is essential for innovation. The knowledge base for each industry consists of public and private research laboratories, specialist universities and institutes of technology and / or design which educate and employ scientists, engineers and designers, develop new products and generations of products and train key employees able to transfer this new knowledge into commercial organisations. Another essential feature of this milieu is that innovative firms need to be located close to these institutions and connected into global information networks which link them into other parts of this knowledge base. Further, innovative firms need close connections with their customers and partners to facilitate 'face to face' contacts in product development and marketing to assist in customising and improving their products as the market evolves (O'Farrell and Hitchens, 1988; Todtling, 1992; Simmie, 1998).

Innovative milieux have been identified in regions such as the industrial districts of central and north-east Italy (Pyke and Sengenberger, 1992) and in the high technology corridors of 'Silicon Valley' in California and Route 128 near Boston Massachusetts (Saxenian, 1996). However, these conditions are most often found in areas within or close to metropolitan cities, such as North Sydney in NSW (Hodgkinson, 1997), Ile-de- France in Paris (Storper, 1993), Tokyo-Osaka in Japan (Fujita and Hill, 1993), South-east England (Henry *et al*, 1996; Keeble, 1997), Haifa in Israel (Shefer and Frenkel, 1998) and Vienna in Austria (Todtling, 1992). It is also argued that firms in these metropolitan regions are more exposed to international competition which forces them to adopt the technological and organisational changes necessary to survive in global markets, relative to firms in more protected peripheral markets (O'Farrell *et al*, 1992).

The emergence of new regions based on the growth of innovative industries raises the question of what is happening in those older regions which formed the heartland of industrial development in past systems of large scale mass production and which have been under severe competitive pressure from imports since the mid 1970s. Technological and organisational changes associated with international competition may be adopted by regional firms allowing them to also successfully compete in new technology and design-intensive industries. Such changes include the refocusing of R & D towards small scale software development, the increased

technical research capacities found in many regional Universities, the extension of sophisticated communication and corporate information systems to regional centres, the intensification of clusters and knowledge bases associated with specific regional industries and the devolution of decision-making to operational units within multidivisional firms (Ettlinger, 1992, Capello, 1994). Thus, it is possible that industrial regions can be revitalised if new sectors develop to replace declining industries or if restructuring activities within these older industries allow them to re-emerge in internationally competitive.

This study provides an analysis of the type of innovative activity occurring in the Illawarra region of NSW, one of Australia's industrial heartland regions, using data obtained from surveys of inventors and manufacturers undertaken in 1997. It particularly seeks to identify whether the observed activity in this region is more typical of the traditional view of older industrial regions where innovation is concentrated on process improvements in the base regional industries as a means of retaining their position in an overall declining market. Alternatively, there may be evidence that innovative activity is converging towards that typical of the new growth regions with high levels of product innovation, the emergence of new industries or revitalised sectors within the older industries, and the development of a regional environment which both supports innovation and links local firms into broader international markets. An understanding of the potential of the Australian industrial heartland to adapt to the innovative conditions associated with international markets provides a framework in which policies can be developed to support the positive elements of regional restructuring in such regions.

2. INNOVATION IN INDUSTRIAL HEARTLAND REGIONS

Technological innovation is important for regional development. Regions where firms are able to generate, adapt and adopt new technologies have competitive advantages in terms of cost and quality over those that cannot. Process innovations result in a continuous improvement in the productivity of regional industries. Product innovations provide the foundation for new local industries and allow regional firms to expand their markets by continually introducing new varieties of products to meet specific client needs. The extent to which regions benefit from innovation lies not only in the number of innovations arising in that area but also whether the environment is supportive to the commercialisation of those inventions by local entrepreneurs (Thwaites and Wynarczyk, 1996).

Todtling (1990, 1992) developed a useful typology of regions which highlights the relationships between innovation and different sets of organisational and location features. His 'old industrial area' featured relatively low levels of product innovation either as original invention or as continuous modifications, but with frequent introductions of process innovations. Firms in these regions were exposed to strong international market competition, both from the newly industrialised countries if involved in standardised mass production markets or from the advanced industrial regions in relation to technology-intensive product markets. As a result, these firms introduced new technology and undertook organisational

restructuring. However, they still had low levels of R & D and marketing activity. This reflected situations where many firms acted as sub-contractors to dominant firms and / or were owned outside the region which mitigated against their independently developing and introducing new products. This provides a relatively typical depiction of the innovative activities expected in traditional industrial regions.

It contrasts with the situation in new growth regions which had high levels of local collaborative activity and firms undertake significant levels of R & D and marketing activities. Innovative firms had relatively certain markets arising out of their long-standing relationships with customers and suppliers within that region. They were also involved in cooperative relationships with other local firms, regional universities, research institutions and external partners. Further they had high levels of participation in public innovation programs. Consequently, factors associated with the creative milieu were present within these regions, ie. well developed university and research facilities, highly skilled labour force, good communication and transport infrastructure and well developed producer service firms.

There is a similar set of contrasting features in Storper and Salais' (1997) 'Industrial World' compared with their 'Intellectual World'. In the industrial world, firms produce generic standardised products using mass production technologies. They compete predominantly on the basis of price in markets where demand fluctuates uncertainly. Consequently the emphasis is on introducing significant new process technologies which will reduce production costs. In the intellectual world, firms undertake large investment in R & D derived from their participation in the scientific and technical knowledge base. Research is project based and undertaken by locally based teams who are linked, via communications networks, into the world-wide professional and scientific community. Innovation in these firms is product orientated often involving changes to the qualities of or developing new uses for existing products as well as original product invention.

However, some studies have found evidence of significant new employment growth in industrial regions based on both technological and organisational innovations, which have resulted in the revitalisation of their traditional industrial base. The Great Lakes region of the U.S.A. has experienced re-industrialisation with a resurgence of industrial growth in its traditional steel and automobile industries based on knowledge-intensive processes which featured high levels of innovation and sophisticated production technologies in association with the development of high quality, high value-added product sectors (Florida, 1995; The Economist, 1997). The mining, steel and chemical industries of the Ruhr region in Germany, after a substantial downturn in industrial activity, have recently experienced a significant improvement in economic performance based on restructured traditional industries plus new environmental industry firms which have emerged from the knowledge base originally established within these traditional industries (Rehfeld, 1995; Kunzman, 1995). These and other studies of older industrial areas suggest that innovation and regional revitalisation can be

associated with traditional industries as well as with new high technology sectors. Nevertheless, the existence of a supportive regional environment for innovation remains an essential element in this path to regional development (Cooke, 1995).

A number of other studies have identified an increase in innovative activity in non-metropolitan regions. Vaessen and Wever (1993) argue that active entrepreneurs in peripheral regions in the Netherlands, by overcoming the constraints in these environments, could emerge as tough competitors in international markets. Vaessen and Keeble (1995) found the level of innovation among growing small and medium firms in peripheral regions in the UK was equal to that found in regions located close to London. It concluded 'that though suffering from a relatively unfavourable environment for innovation activity, peripheral firms can, if they grow, in due course overcome these comparative disadvantages and achieved high if not higher innovation rates than their more favourably located counterparts' (p. 502).

Keeble (1997) in his analysis of small and medium firms in the U.K. found no statistically significant differences in the level of innovation between regions, when innovation was broadly defined to include service and manufacturing innovations, process and product innovations and continuous improvement as well as original (new to the industry) innovations. Industrial heartland regions had the highest levels of process innovation. Further, their level of original product innovation was just below that of the leading regions and they had higher levels of continuous product innovation. This study did not provide an explanation for the apparent improvement in innovative activity outside core regions in the U.K. but does demonstrate that both original as well as continuous improvement and product as well as process innovation can occur in industrial regions.

However, not all studies of innovation in non-core regions provide such encouraging results. An earlier study, Keeble and Bryson (1995), found the highest level of innovative activities occurred in high growth regions in the 'outer' southern part of Britain, particularly for new product innovation and adaptation of new production processes. Harris and Trainor's (1995) study of manufacturing in Northern Ireland showed that R & D and a percentage of sales was relatively low and that basic research was predominantly confined to locally-owned firms while branch plant operations tended to transfer in technologies. Most innovation was in processes rather than products and aimed at lowering costs and improving efficiency. Phelps (1995) found that the level of process and workforce innovation in the electronics industry of South Wales was equivalent to that of the core region of Hampshire-Berkshire but the level of product innovation was significantly lower. Suarez-Villa and Fischer (1995) found that despite a dispersion of productive activities to peripheral regions, R & D remained concentrated in the metropolitan region within the Austrian electronics industry. These results are consistent with the type of activity expected in Todtling's and Storper and Salamis' typology of industrial regions.

There are thus contrasting views on the relationship between innovation and regional development in industrial regions. One perspective focuses on the

capacity of such regions to generate new technology firms, either in product areas totally unrelated to its original industrial base or emerging from that base but using this knowledge to generate new growth industries. The other perspective suggests that through a thorough restructuring of the traditional base industries to incorporate new technologies and organisational forms, regional firms can emerge as successful international competitors and maintain this position by undertaking continuous technological and product innovation. In this paper, data obtained from the Illawarra surveys will be used to examine which of these perspectives appears to explain innovation in one of Australia's industrial heartland regions.

3. SURVEY DESIGN

The Illawarra region occupies 8,485 sq. km consisting of a long, narrow coastal strip and bordering tablelands south of Sydney, NSW, Australia. The population was estimated at 372,860 people in June 1996 of whom 183,500 live in the City of Wollongong and 76,000 in the City of Shoalhaven. Population grew at 1.3% p.a. in the region as a whole between 1991 and 1996 (ABS, 1998).

Wollongong is traditionally considered a heavy industrial area, being the main location for BHP's Port Kembla integrated steelworks and associated rolling and coating works, coal mines and coke works. The Port Kembla area contains a concentration of associated transport, metal fabrication, chemical and other industrial activities. The industrial base also includes a significant clothing sector, which was encouraged during the 1960s with capital subsidies from the State Government to provide employment for female workers. The southern part of the Illawarra contains a concentration of wood, paper and wood products industries as well as some substantial food processing firms. Hence, there are two major industrial groupings in the region, the first based around metal products in the north and a second based on wood and paper products in the south (Hodgkinson, 1998).

Wollongong has a substantial regional University, which is now one of the largest employers in the region. This University has developed research expertise in a number of science and engineering areas, which are relevant to the development of new technology in the region. The urban services function of the City of Wollongong has also grown significantly in recent years and is able to supply a relatively sophisticated range of support services to local industry. The region, despite its heavy industrial image, also provides an extremely attractive natural environment with a plentiful supply of beachside and rural home sites. Spectacular coastal scenery can be found at Kiama, Jervis Bay and Ulladulla on the south coast. Quality natural environments are available in Moreton and Royal National Parks, along the Southern Highlands escarpment and on the Tablelands itself. Thus the region contains a sufficiently large population, industrial base, urban centre, University and quality of life factors to suggest it could support a creative milieu within an old industrial region. This makes it an ideal area in which to investigate aspects of the alternative paths of innovation found in industrial heartland regions in the 1990s.

A survey of inventors in the Illawarra was conducted in February 1997, involving clients of the Illawarra Innovation Advisory Service. This service was established at the Wollongong City Council Business Information Services' library by the NSW Department of State and Regional Development as a pilot project to provide advice to individual innovators in the region. This survey was a first attempt to evaluate the economic significance of inventors in the Illawarra. The service provided a list of 73 known innovators. However, problems contacting many of these people reduced the actual survey to 32 useable responses. Consequently, most of this analysis will be based on a subsequent survey of manufacturers.

The sample for the manufacturers survey was selected from the 1992 Register of Manufacturing Industry, Illawarra Region, updated from the 1996 telephone books. The sample selection process involved a stratified selection based on three geographical districts - Wollongong Statistical District (Wollongong, Shellharbour and Kiama), Shoalhaven, and Wingecarribee. Within each district, the sample was selected on the basis of ASIC industry codes, such that those industry sectors with the largest proportion of firms had a relatively large representation in the sample. In addition, the sample selection process was designed to favour larger firms (greater than 20 employees) as these have been identified in the literature as being more likely to undertake research and development or innovation. Subject to these constraints, the selection process was random. The sample selected relative to population is shown in Appendix I. The response rate for this survey was 44.4%, or 36.4% of all small firms sampled and 64.8% of all large firms sampled. This was considered a reasonable response from a mail survey. The response was reasonably well distributed across sectors. Survey responses were weighted by sector to allow for variations in the response rate. Nevertheless, data limitations have affected the amount of detailed analysis, which could be undertaken from this database.

The data was initially analysed using chi-squared tests to identify significant variations in the incidence of R & D (based on four types of activity: basic research, prototype development, commercialisation and adaptation) by a range of factors identified in the literature as likely to be significant in industrial regions. Firms which identified as not undertaking R & D were also queried as to whether they undertook any self-development of products or processes, as a further measure of regional continuous improvement activity. Further analysis to identify the relative significance of these factors on regional innovation activity was undertaken using multivariate PROBIT regressions.

4. SURVEY RESULTS - INNOVATION IN INDUSTRIAL AREAS

4.1 The Relative Significance of Product versus Process Innovation

It was argued above that innovation could provide the basis for new industrial activities in old industrial areas and so create diverse employment opportunities to replace those being lost from technological change and import competition in its

traditional economic base. Restructuring in BHP Steel has resulted in the loss of almost 12,000 jobs from its Port Kembla works since 1984. The results from the inventors survey indicate that most invention has occurred in areas other than the traditional regional industries, particularly in transport (14%), recreation (21%) and construction (21%). Invention was also relatively strong in information technology / computers (8%), engineering ie. fabricated metal products and transport equipment (4%) and other manufacturing (11%), while 12% occurred in miscellaneous product areas. The majority of these innovations were products aimed at the final consumer. If these inventions could be successfully commercialised in the Illawarra Region, they would make a substantial contribution to the broadening of the local economic base and to employment opportunities in the region.

However, a different situation emerged from the manufacturers survey. Most of these firms' innovations were orientated towards improving the production processes of other firms in the region ie. improving the productivity of the existing economic base. Innovations reported by respondents to the survey are shown in Appendix II. The incidence of innovation by industry among manufacturing firms is shown in Table 1. A total of 25.8% of firms undertook recognised technological innovation activity (which includes basic and applied research, commercialisation of innovations and adaptation activities). This is lower than the Australian average of 33.7% (ABS, 1995). However, 56.8% of firms undertook self-development of new technologies and processes and 54.3% self-developed new products. Thus an extra 29% of firms had some internal development work, or continuous improvement of existing processes and products, which they did not formally classify as R & D.

Table 1. Incidence of Innovation by Industry Sector (%)

ASIC Sector	Undertake R & D	Self-Develop Processes	Self-Develop Products
Food, beverages, etc	---	100.0	100.0
Textiles	40.0	66.7	100.0
Clothing and footwear	60.0	60.0	60.0
Wood products, furniture	10.7	100.0	80.0
Paper products, printing	13.0	42.9	71.4
Chemicals, coal products	66.7	33.3	33.3
Clay, concrete, cement	20.0	40.0	40.0
Basic metals	80.0	80.0	40.0
Fabricated metals	17.9	41.7	45.8
Transport equipment	---	100.0	100.0
Elect, equipment and machinery	80.0	100.0	77.8
Miscellaneous goods	---	75.0	75.0
No activity	74.2	20.7	23.9

The results from the manufacturing survey indicate that innovations in manufacturing firms were strongly process focused and that R & D was relatively strong in the larger firms in the traditional industries ie. basic metals, chemical and coal products and clothing and footwear, but not in fabricated metals or transport equipment. It was also low in the regional industries of Southern Illawarra, ie. wood products, furniture, paper products and printing, clay, concrete and cement and food processing. However, sectors which reported a low occurrence of R & D often reported a high incidence of the more broadly defined self-developed product and process innovation suggesting that some form of development work still occurred within many of these operations. The electrical equipment and machinery industry had high levels of R & D and could potentially develop into a new growth sector within the region.

Most studies indicate that R & D is more likely to occur in large firms, although this varies with the capital intensity of the industry sector (Dosi, 1988; Freeman and Soete, 1997). As shown in Table 2, the proportion of Illawarra firms undertaking R & D rose with size. Compared with the Australian average, the Illawarra had lower proportions of firms in all employment size categories, which undertook formally defined R & D.

The majority of small and large firms self-developed their technology and new product items, bearing in mind that these responses may include some small-scale development and adaptation work outside the usual definitions of innovation, as 'new to the market'. Large firms also acquired new products and technologies from their parents. Medium-sized firms were less likely to self-develop technologies and products, more often acquiring them via licensing. They also had a relatively high proportion which acquired no new technology or product lines.

Firms which self-developed their new technologies or products or obtained them by license mainly had head offices in the Illawarra while those which obtained it from parents mainly had their head office in Sydney. Firms which did not source new technologies were mainly owned and controlled from the Illawarra and were prevalent in the paper products and printing and fabricated metals sectors, both significant elements of the traditional economic base of the region. Firms in food and beverages were particularly likely to obtain their technologies and products from parents. Licensing of technology was prevalent in the clay products, concrete and cement sector (which also tended to obtain their new products under license) and electrical equipment and machinery sector.

Table 2. Incidence of Innovation by Size of Firm (%)

	Undertake R & D	
Employment Size	**Illawarra**	**Australia**[1]
1 to 20	17.9	25.0 – 41.3
21 to 99	26.5	50.7 – 60.9
100 and over	60.9	74.8 – 90.3

[1] Data sourced from ABS 8116.0 (1995), *Innovation in Australian Manufacturing*.

Illawarra manufacturing firms, which undertook some R&D, had an average R & D to sales ratio of 5.07% in 1995/96. Thirty-two per cent of firms had a ratio of 1% or below, 42% had a ratio between 1.25% and 5%, and 26% had a ratio more than 5% to a maximum of 40%. This compared well with an average of 3.96% in 1993/94 for Australian innovative firms (ABS, 1995), although the Illawarra figure may be slightly inflated due to differences in definitions. There were significant differences in the type of R & D activities in the Illawarra by size of firm, as shown in Table 3.

While small firms had generally low levels of R & D, they had a relatively high incidence of basic research and prototype development activities indicating that original innovations were prevalent in small firms. The incidence of commercialisation activity did not vary significantly by firm size. However, adaptation activities were significantly more likely to occur in larger firms.

Illawarra-owned firms were more likely to undertake R & D than those owned in Sydney. There was also a much higher incidence of R & D occurring in branches whose head offices were outside NSW or overseas compared with those with head offices in Sydney. This suggests that innovative activity in the Illawarra is being overshadowed by its proximity to Sydney for firms with branches in both regions. However, the variation in self-development of new products and processes by head office location was much less pronounced indicating that some form of continuous product or process development occurred in many firms with head offices in Sydney.

The pattern of innovation among Illawarra manufacturers thus falls into two groups. One group comprises small local firms undertaking basic and applied research and product development outside the traditional regional metals industries. Much of this involved the development of new machinery and equipment and chemical products destined for use in these traditional sectors. Nevertheless, some activity also occurred in the new information technology, energy efficiency and other high technology sectors (Hodgkinson, 1998). The second group comprises larger, subsidiary operations mainly in the traditional

Table 3. Incidence of Innovation by Type of R & D by Firm Size (%)

	Employment Size			Total	Total
Activity	**1-20**	**21-99**	**100+**	**R & D Firms**	**All Firms**
Any R&D***	17.9	26.5	60.9	100.0	25.8
Basic research*	21.7	4.3	13.0	39.1	9.6
Develop prototype	23.4	12.8	6.4	42.6	10.7
Commercial	37.0	23.9	19.6	80.4	20.2
Adaptation**	8.7	17.4	17.4	43.5	10.8

*** Significant at 97.5% confidence level
** Significant at 95% confidence level
* Significant at 90% confidence level

industrial sectors which have a higher incidence of commercialisation and adaptation activities, supported by some basic research activity.

4.2 R & D and Firm Performance

R & D expenditures do not necessarily translate into high sales and employment growth. This depends on the relative efficiency of that activity which is often dependent on the capacity of the regional environment to support the commercialisation of innovation (Vaessen and Keeble, 1995).

R & D and Sales Growth

The average value of sales of Illawarra manufacturing firms in the Illawarra in 1995/96 was $24,994,075. This was well above the Australian average due to the presence of BHP, Australia's largest manufacturer, in the region. Average sales of firms which undertook R & D was just over $84 million, or $23.9M excluding BHP, compared with an average of $12.3M (1993-94) for Australian innovative firms. Illawarra firms, which did not undertake R&D, had average sales of $905,000 compared to an Australian average of $1,571,500 (ABS, 1995). Sales grew on average by 15% over the past five years for Illawarra manufacturers, 17.3% for innovators and 13.7% for non-innovative firms. A detailed analysis of the relationship between sales growth and R & D is shown in Table 4.

Firms, which undertook R&D most commonly, had low sales growth (1% to 10%), although a significant proportion had achieved relatively high sales growth (11% to 51+%). However, R & D firms also often had negative sales growth. The relationship between R & D and positive sales growth was strongest in relation to adaptation activities. Firms which undertook adaptation of products and processes were less likely to have negative sales growth and more likely to have either low or very high sales (51%+) growth.

Table 4. Sales Growth by Type of R & D Activity Undertaken by Firm (%)

Sales Growth Over Past 5 Years	Any** R & D	Basic* Research	Prototype Develop.	Commercialisation	Adaptation**
Negative	20.5	0.0	16.7	24.2	0.0
None	2.6	5.9	0.0	0.0	5.9
1% - 10%	43.6	52.9	50.0	39.4	58.8
11% - 50%	20.5	29.4	22.2	21.2	17.6
51% or more	12.8	11.8	11.1	15.2	17.6

Notes: ** Significant differences at 95% confidence level
* Significant differences at 90% confidence level.

There was a weaker relationship between basic research and commercialisation activities and sales growth. Firms which undertook basic research were less likely to have negative sales growth and more likely to have low or moderate sales growth (1% to 50%). Commercial activities were however often associated with negative sales growth. Innovative firms which undertook applied (prototype) research were likely to have negative or low sales growth. Innovative firms most commonly achieved a moderate sales growth of between 1% and 10% over the past five years.

Thus, while there is some relationship between undertaking R & D and sales growth, no strong or consistent pattern is revealed. Adaptation activities, most commonly associated with larger firms, had the best correlation with good sales performance. Commercial activities were associated with both negative and good sales growth. Basic and prototype research was most commonly associated with low sales growth, while prototype research was also associated with negative sales growth. In the Australian data, a more consistent relationship between undertaking innovation and high levels of sales growth was revealed (ABS, 1995). Hence, undertaking R & D did not guarantee improved sales performance in the Illawarra.

R & D and Exports

It is also suggested that the degree of openness of a region can have a significant impact on the level of innovation. High levels of import competition force firms to innovate to maintain their share of the market and this leads to exports (Porter, 1990; O'Farrell *et al*, 1992). As reported in Markey, *et al* (1999), firms in the Illawarra region faced a slightly lower level of competition than the Australian average. However, Illawarra firms which faced stronger market competition are more likely to undertake technological and organisational change. There was a highly significant relationship (99.5% confidence level) between undertaking R & D and higher levels of export sales as shown in Table 5. On average Illawarra manufacturers exported 6% of their output. Firms, which undertook R&D, exported 18.2% of sales (17.7% excluding BHP), while non-R & D firms exported only 1.6% of sales. Thus, R & D activity tended to be strongly related to export activity in the Illawarra. A similar relationship was found in Australia as a whole (ABS, 1995). This finding is consistent with other studies, which analysed the relationship between regional R & D and exports (Harris and Trainor, 1995; Vaessen and Keeble, 1995).

Firms, which undertook R&D, were less likely to have no exports than firms, which had no R & D. These R & D firms most commonly had exports equivalent to 1% to 5% of sales. High levels of exports were more commonly associated with commercialisation and adaptation activities. However, basic research and prototype activity were also associated with high exports, indicating that some firms were able to obtain commercial benefits from original innovation activity.

Table 5. Level of Overseas Sales by R & D Activity (%)

% of Exports to Total Sales	% of Firms					
	With R & D ****	Basic Research ***	Prototype ***	Commercialisation ****	Adaptation ****	No R & D ****
NIL	32.0	36.4	45.5	31.6	33.3	85.7
1% - 5%	38.0	36.4	27.3	31.6	33.3	7.1
6% - 10%	4.0	0.0	0.0	5.3	0.0	1.8
11% - 20%	0.0	0.0	0.0	0.0	0.0	3.6
21% - 30%	8.0	0.0	0.0	5.3	8.3	0.0
31% - 40%	8.0	18.2	18.2	10.6	8.3	1.8
> 40%	12.0	9.1	9.1	15.9	16.7	0.0

**** *Significant at 99.5% confidence level*
*** *Significant at 97.5% confidence level*

Table 6. Employment Growth by Type of R & D Activity (% of Firms)

Employment Growth Over Past 5 Years	Any R & D		Commercialisation*		Adaptation*	
	Yes	No	Yes	No	Yes	No
Negative	30.2	9.2	20.0	75.0	36.8	20.0
None	23.3	46.2	25.7	12.5	21.1	28.0
1% - 10%	2.3	11.8	2.9	0.0	5.3	0.0
11% - 50%	37.2	20.2	42.9	12.5	26.3	44.0
51+%	7.0	12.6	8.6	0.0	10.5	8.0

Notes: *Significant at 95% Confidence level

R & D and Employment

Illawarra manufacturing firms were relatively large, having an average employment size of 87 workers in 1995/96 and employment growth averaging 42.5% over the past five years. Average employment in firms, which undertook R&D, was 266, and 88 if BHP is excluded, and 25.5 in firms, which had no R & D. However, there is no positive relationship between undertaking R & D and employment growth. Of the 6.5% of firms in the sample, which had increased employment by over 100% in the past 5 years, all did not undertake R & D and a higher proportion of those, which had negative employment growth, undertook R & D.

Commercialisation of innovations was the only sub-set of R & D activity, which had a significant positive relationship with employment change. As shown in Table 6, there is a strong relationship between not undertaking commercial development of innovations and experiencing negative employment growth and

between undertaking commercial development and achieving moderate to high employment growth (11% or more).

Overall, these data on the relationship between innovation and firm performance indicate that the Illawarra region is not gaining significant income or employment benefits from much of its innovation activities. However, innovation was strongly associated with exports. This relationship held across all R & D activities. The main performance benefits arise from the commercialisation and adaptation activities which tend to be associated with larger, subsidiary operations. Basic and applied research in smaller firms is not resulting in demonstrable sales or employment growth, although exceptions did occur. Indeed firms which do not undertake R & D (but may take some self-development activities) have different but not necessarily worse performance in sales and employment growth, than those, which do. Thus small firms undertaking original innovation appear to be affected by the same poor innovative environment identified in the inventors survey, suggesting the lack of a creative milieu in the region is affecting their capacity to successfully commercialise their research outputs.

4.3 Organisational Factors

The creative milieu consists of relationships between firms and with research institutions that assist in the development and marketing of innovations. It also involves general satisfaction with the economic environment of the region and the range of services and programs available to support innovative activities. Most firms rated their current location and facilities in the Illawarra as either ideal or adequate. Firms which undertook R & D rated their current location as inadequate for some current or future activities more frequently than firms which did not (at 97.5% confidence level). However, they represented only 13.3% of all innovative firms suggesting that, overall, they found their current locations in the Illawarra were relatively satisfactory.

Cluster (input-output) relationships, sub-contracting and collaborative activities have been identified as having a significant positive influence on R & D activity as part of a local creative milieu (Suarez-Villa and Fischer, 1995; Baptista and Swann, 1998; Shefer and Frenkel, 1998). Fifty-seven per cent of all respondents indicated that they had significant client-supplier relationships in the Illawarra. However, only 15.6% indicated that they undertook joint activities with other firms in the Illawarra. There were no significant differences between firms which undertook R & D and those which did not in whether they had client-supplier relationships. However, there was a significant difference (at 97.5% confidence level) between R & D and non-R & D firms in terms of whether they undertook joint activities with other local firms. Joint activities were undertaken by 27.3% of R & D firms compared with 11.9% of non-R & D firms.

Table 7. Joint Activities by Whether Firm Undertook R & D (% of Firms)

Joint Activity	R & D Firms	Non-R & D Firms
Production	37.9	37.9
Technology Development	20.1	7.1
Product Development	30.8	14.8
Marketing	3.6	18.9
Exporting	21.3	0.0
Total	41.5	58.5

R & D firms were more likely to be involved in joint technology development, joint product development and joint exporting than non-R & D firms. Non-R & D firms undertaking joint technology development reflected a situation where most of the development work was undertaken by their partner. Both R & D and non-R & D firms were equally involved in joint production activities while non-R & D firms were more likely to be involved in joint marketing activities.

Firms were also asked what location factors they would find attractive in a location designated as a science / technology park. Firms generally found ready access to suppliers of industrial equipment or components, proximity to suppliers, specialist business support services and proximity to other firms in their industrial sector the most attractive location features. There were no significant differences in these responses between R & D and non-R & D firms. These responses reflect the relative importance of localisation economies or access to suppliers and service providers to a firm's location decision.

R & D firms were significantly more attracted to locations which could offer a variety of site sizes and structures including smaller, lower cost buildings and sites and also locations which could offer more expensive but physically attractive landscaped surroundings and visible, prestigious buildings, centralised conference facilities, etc. They were also significantly more attracted to locations which offered ready access to University researchers or private research institutions providing specialist laboratory facilities, consulting expertise and trained graduates in their areas of activities, as suggested by the creative milieu explanation of regional innovation.

Thirty-seven per cent of firms that undertook R & D had had contact with the University of Wollongong compared with 17.9% which did not, as shown in Table 8. Firms that undertook R & D predominantly had contacts with the University involving assistance in product development and / or research. Non-R & D firms' contacts predominantly involved the supply of goods and services.

Fifty-nine per cent of firms identified at least one area where the University of Wollongong undertakes research in collaboration with businesses as being relevant to their activities. As might be expected from the industrial structure of the region, steel products was the most relevant area for firms in general followed by

Table 8. Contacts with the University of Wollongong (%)

Type of Contact	R & D Firms	Non-R & D Firms	All Firms
Product Development	92.5	4.1	33.3
Supply of Goods	0.0	37.0	28.6
Supply of Services	0.0	34.2	19.0
Training	15.0	13.7	14.3
Supply of Technology	7.5	4.1	9.5
Research	22.5	0.0	9.5
Educational Visits	0.0	15.1	9.5

Note: Percentages add to more than 100% as multiple responses were allowed.

engineering. However, environmental issues and software design areas were also quite relevant. R & D firms registered a higher degree of relevance than non-R & D firms particularly in the areas of industrial automation, electrical engineering, energy efficiency, managerial and organisational change, economic development in south east Asia and bulk materials handling. The only area where R & D firms registered less relevance than firms in general was in steel products, supporting the finding that firms in the fabricated metals industry had relatively low R & D activity in the Illawarra.

Overall, these results support the creative milieu hypothesis that access to business support services, clients and suppliers, partners, infrastructure, the knowledge base and a pool of trained workers are important in encouraging innovation, entrepreneurship and the commercial development of new products and processes within a region. However, it also indicates that such a creative milieu is largely absent from the Illawarra region. While inventors encountered a number of problems affecting their innovation process, only 18% of R & D manufacturers identified barriers to innovation in this region, supporting Vaessèn and Weber's (1993) argument that surviving innovators in peripheral regions adapted to the local environment. There was also a relatively low usage of government programs with only 28% of R & D manufacturers having received some support for their innovative activities. This predominantly involved the tax write-off schemes. Other studies indicate that access to government support can greatly increase research activity in older industrial regions (Harris and Trainor, 1995).

5. THE DETERMINANTS OF R & D

In order to identify which of the above factors were significantly related to whether a firm undertook R & D in the Illawarra, the data from the Manufacturers survey was analysed using the Probit regression procedure. Owning to data limitations and the high variability in some relevant variables, e.g., turnover and sales growth, only a limited number of potential factors could be analysed. These were divided into two models. Model I analysed economic factors, ie. whether the

firm was located in one of the region's economic base industries (Base), the age of firm in the Illawarra (Years), whether it was locally owned (Local), its proportion of exports to turnover (Salesover), and total employment (Employ). Model II analysed organisational factors, ie. whether it had input-output relationships with other local firms (Busrelat), whether it undertook any joint activities with other local firms (Jointact), whether it had technical contacts with the University of Wollongong (Techcont), and whether it rated its current location as ideal or adequate for current and future activities (Currloc). The probit coefficients (with 't' values in brackets) are shown in Table 9.

All the economic factors other than local ownership were significantly related either negatively or positively to a firm undertaking R & D. Firms within the region's major economic sectors (metal manufacturing or wood and paper products) were significantly less likely to undertake R & D than those not in these groupings. This result reflects the low level of R & D in metal fabrication and wood and paper products identified in Table 1, and the relatively high level in electrical equipment and machinery. This result is contrary to the expected outcome that R & D would be higher in industries which had a strong presence in the region. The age of the firm was also negatively correlated with undertaking R & D. However, this result was expected in that younger firms are generally considered to be more innovative than older ones. There was a strong positive correlation between exports and undertaking R & D, as anticipated by the results in Table 5. The propensity to undertake R & D also increased with employment size. Again this result is consistent with the expected outcome that larger firms are more likely to undertake R & D.

Most of the economic factors were not significant for the decision to undertake basic research. However there was a highly significant negative correlation between being in one of the region's major economic sectors and basic research activity. These results indicate that original research tends to stochastic, as was individual invention, but that firms in the regional base industries have low levels of original research activity. The most risky form of research, prototype development, was also significantly negatively associated with regional base industries and age, but positively associated with employment size. Activities to commercialise innovations were also negatively associated with regional base industries and age, but less significantly so. There was a highly significant positive association between commercial innovation and exports. Few economic factors were associated with whether a firm undertook adaptation activities, with only employment size having a weak positive relationship. Overall, these results indicate that innovative activity is not a direct outcome from the traditional industries of the region but rather occurs in new sectors or in spin-off activities arising from the knowledge base of those industries.

A similar analysis was undertaken to determine which factors influenced the decision of firms to undertake continuous process or product development or to self-develop processes or products. Few economic factors proved significant. The

Table 9. Determinants of R & D in the Illawarra Region - Probit Estimates

	Any R & D	Basic Res.	Prototype	Commercial	Adaptation	Continuous Process	Continuous Product	Self-Develop Process	Self-Develop Products
MODEL I: Economic Factors									
Intercept	.08253	-.52122	-.09638	-.16636	-.64627	1.26876	2.03882	.87927	1.06611
	(0.152)	(-0.768)	(-0.159)	(-0.325)	(-1.103)	(2.134)	(2.995)	(0.426)	(2.094)
Base	-.67448	-1.58281	-.90982	-.46715	-.45535	-.48599	-.40085	-.29937	-.15978
	(-1.920**)	(-2.993***)	(-2.074**)	(-1.321*)	(-1.102)	(-1.291*)	(-1.147)	(-0.918)	(-0.497)
Years	-.01539	-.01484	-.03380	-.01445	-.00116	-.00535	-.01097	-.00133	-.00589
	(-1.559*)	(-1.036)	(-2.053**)	(-1.404*)	(-0.112)	(-0.460)	(-1.070)	-0.918)	(-0.653)
Local	-.37651	.28195	-.00737	-.28994	-.59387	-.20407	-1.12534	.03898	-.64519
	(-0.846)	(0.506)	(-0.015)	(-0.681)	(-1.255)	(-0.418)	(-1.969**)	(0.097)	(-1.503*)
Salesover	.03957	.00253	.01095	.04176	.01069	.04294	.00459	.02377	.00376
	(2.024**)	(0.188)	(0.809)	(2.461***)	(0.902)	(1.100)	(0.318)	(1.252)	(0.298)
Employ	.00458	.00162	.00056	.00035	.00323	.00010	.00014	.00018	.00016
	(1.897**)	(0.667)	(1.667**)	(0.36113)	(1.584*)	(0.099)	(0.310)	(0.314)	(0.440)
MODEL II: Organisational Factors									
Intercept	-.99988	-1.16984	-1.98121	-.92365	-1.86267	.77349	.32466	.20434	.27279
	(-2.272)	(-2.274)	(-3.253)	(-2.030)	(-3.256)	(1.791)	(1.220)	(0.512)	(0.674)
Busrelat	-.40412	-.27455	-1.35963	-.58629	.15615	.43049	.33649	.01227	-.02155
	(-1.223)	(-0.702)	(-2.396***)	(-1.678**)	(0.390)	(1.289*)	(1.070)	(0.040)	(-0.072)
Jointact	.55108	.54633	1.36731	.69457	.25647	.72028	.93777	.46286	.53108
	(1.297*)	(1.160)	(2.279**)	(1.603*)	(0.531)	(1.274)	(1.639*)	(1.088)	(1.268)
Techcont	1.239	.70765	.80292	.88487	1.408	.61802	.22879	.50810	.19353
	(2.708**)	(1.483*)	(1.531*)	(1.963**)	(3.013***)	(1.034)	(0.462)	(1.050)	(0.428)
Currloc	.21133	-.03277	.44220	.10613	.17122	-.18951	-.10582	.02850	-.00745
	(1.169)	(-0.151)	(1.811**)	(0.573)	(0.807)	(-1.034)	(-0.596)	(0.170)	(-0.045)

* t value significant at 90% probability
** t value significant at 95% probability
*** t value significant at 99% probability

strongest result was a negative association between local ownership and undertaking continuous product development and self-developing their product changes. There was also a relatively weak negative association between undertaking continuous process development and being in a regional base industry, paralleling the results for undertaking R & D.

From model II, organisational factors tended to be less significantly associated with the decision to undertake R & D than economic factors. Being involved in collaborative activities and, more significantly, having technical contracts with the University were the most important factors. Contact with the University was the only organisational factor associated with undertaking basic research. Organisational factors were more strongly associated with undertaking prototype development. There was a highly significant negative association between having input-output relationships with other firms and prototype development, paralleling the result from regional base industries. This might suggest that being in relatively secure supply or sub-contracting relationships with other (possibly larger) firms in the region is inhibiting new product and process development. However, there was a strong positive association between being involved in joint or collaborative activities with other firms and undertaking R & D. Having technical contracts with the University and being satisfied with their current location also had a positive influence on prototype development. Thus a number of factors consistent with the concept of a creative milieu had a significant influence on firms undertaking applied research or prototype development of their innovations.

Organisational factors also had a significant influence on whether firms engaged in commercial development of their innovations. Again, client-supplier relationships were negative. Collaborative relationships between local firms and technical contracts with the University had a significant positive effect on undertaking commercialisation activities. Both these factors are important elements within a regional creative milieu and are particularly important for small, high technology firms. On the other hand, adaptation activities were less related to organisational factors, with only technical contracts with the University having a (highly significant) positive association with this form of R & D.

Continuous improvement and self-development activities had very little significant association with organisational factors. Continuous process development had a weakly significant positive association with that firm being involved in client-supplier relationships with other local firms. Continuous product development had a weakly significant positive association with that firm being involved in collaborative or joint relationships with other local firms. Overall, however, this form of activity, although strongly evident in the region was not associated with factors identified as part of an innovative regional environment.

6. CONCLUSION - FROM HARDY INDIVIDUAL TO A CREATIVE MILIEU

Two perceptions on the relationships between innovation and economic development in industrial regions were identified in the literature review. It is perhaps not surprising given the difficulties noted earlier in finding definitive relationships between regional variables and growth, that the Illawarra case study provided evidence of both.

In many ways, the Illawarra region had a relatively traditional 'old industrial region' pattern of innovative activity. There are relatively high levels of continuous improvement and self-development activities in both process and product innovations which occurs across all regional industries, testimony to the high level of technical skills in the region. However, the percentage of firms undertaking R & D or innovation involving the introduction of new or substantially improved products or processes, is lower than the national average. This appears to reflect the low levels of basic research and applied research activities in the regional base industries in the Illawarra, with most research in these industries occurring in larger, subsidiary operations and orientated toward development (commercialisation and adaptation) activities. Local firms operating in client-supplier or sub-contracting relationships within these industry groupings had low levels of R & D. Generally, the Illawarra appears to have a difficult regional environment for both individual inventors and innovative small manufacturers to establish viable commercial operations. The image of innovators as Vaessen's hardy entrepreneurs, succeeding through individual efforts to overcome an unfavourable environment comes through this study.

However, elements of the more favourable scenario were also identified. While most of the innovations developed by firms covered in this survey involved process improvements aimed at the existing economic base industries, there was evidence that these activities contained the seeds for potential industrial revitalisation in the region. The innovative firms were much more likely to be classified to different industry categories to those in the traditional cluster or economic base industries of the region, although the initial impetus for innovation was often to improve processes within those industries. There was very strong evidence of a significant association between innovation and exports suggesting that these small innovative firms were quickly looking to external markets for sales rather than relying on the local market. Further, there were strong associations between undertaking basic research and prototype development and these firms having contacts with the local regional University and undertaking collaborative activities. These results indicate that two factors identified in other studies, ie. links into international markets and the existence of a supportive creative milieu are associated with spin-off and new product innovation in Australian industrial regions. However, creative milieu factors were relatively scarce in the Illawarra, implying that one cause of the low levels of R & D could be the lack of a supportive regional environment for innovation.

This study indicates that there is a need to provide more support to innovators in industrial regions to assist them in the commercial aspects of developing markets for their innovations and that stronger public policies are required to encourage an innovative culture in such regions. Regional innovation policies need to be firm specific and focused on encouraging more firms to increase their R & D effort particularly in the traditional industrial sectors, and to support individuals starting up firms in new industrial sectors. Improved innovation levels could give an increased dynamism to existing industry and broaden the economic structure of the region by adding new globally orientated firms. In this way, we may see Australian industrial heartland regions emulating the success stories found overseas with the emergence of new industry sectors and the restructuring of the older declining industries to focus on their higher skilled, knowledge-based sectors.

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