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Spatial Concentration in The Irish Pharmaceutical Industry: The Role of Government Intervention and Agglomeration Economies

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Abstract

This paper examines the spatial pattern of the pharmaceutical industry in Ireland and in particular the drivers accounting for spatial concentration in the industry.[1] Spatial concentration indexes indicate a particularly high level of spatial concentration in one of the industry's sub-sectors, namely, drug substance production. This high level of concentration has been attributed to the operation of agglomeration advantages, notably localisation economies. Based on interview data and secondary sources, a detailed investigation of the spatial dynamics and location factors involved suggests that these advantages have played, at most, a relatively limited role and that the concentration of the industry in and near the two particular urban centres in question has largely been driven by government intervention, notably environmental and regional planning policy and the related spatially selective provision of well-serviced industrial sites and infrastructure.

INTRODUCTION

The tendency of economic activity in general, and industrial activity in particular, to concentrate in particular localities or regions has long attracted the attention of economists and geographers. The debate about the forms and determinants of such spatial concentration has recently been reignited (see Martin, 1999; McCann 1995; Parr, 2002; Phelps and Ozawa, 2003). Important subjects of this debate include the extent to which observed concentrations are driven by agglomeration factors and the respective roles of the various agglomerations factors.

Evidence from the literature shows that agglomeration advantages, including technological spillovers, are an important driver behind many instances of industrial spatial concentration. At the same time, one should also allow for the possibility that, in certain situations, agglomeration advantages may play only a limited role in the industrial concentration process (see McCann, 1995; Malmberg *et al*., 2000). In certain contexts, an explanation of observed spatial concentration requires that we rescue some of the insights of early location theory, notably those related to the role of location factors and state intervention in the process of spatial concentration.

The proposition of this paper is that, in certain geographical/sectoral contexts, government intervention (notably in the form of spatial/regional planning policy), rather than agglomeration advantages, constitutes the most important driver behind local/regional industrial concentration. The agglomeration economies at play are limited or mainly take the form of urbanisation economies, notably those related to a local pool of labour. As is argued below, such concentrations are most likely to occur in the following contexts: countries whose governments take a relatively active role in regional planning and the related planning of industrial sites; late developing countries with limited research and development and innovation activity; and

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industrial sectors characterised by large-scale manufacturing plants that require extensive and well-serviced industrial sites.

This proposition will be supported via a study of the spatial dynamics of the pharmaceutical industry in Ireland. Nearly all employment in the industry is concentrated in foreign-owned manufacturing plants, which have been attracted to Ireland primarily by the low rate of corporation tax (currently 12.5%). As such, corporation tax has been the primary factor driving the concentration of such plants in Ireland at a national level. The focus of this paper, however, is on spatial concentration at the local/regional scale.

Existing studies of spatial clusters in the pharmaceutical industry in core economies such as the USA, the United Kingdom, Germany and Switzerland generally show or suggest that localisation economies, notably technological spillovers, have played an important role in the process of spatial concentration (e.g. Gray and Parker, 1998; Boasson and MacPherson, 2001; Schreuder 1998; see also Cooke (2003) in relation to the growing biopharmaceutical/biotechnology sub-sector). Technological spillover advantages arguably pertain more to the R&D and innovation functions than to the manufacturing activities in those concentrations. While spatial clustering is also a distinctive feature of the Irish pharmaceutical industry, such R&D/innovation functions are largely absent in the Irish case. The purpose of this paper is to analyse the locational patterns portrayed by the pharmaceutical industry in Ireland and the key influences underlying the observed patterns. This analysis demonstrates how, in the Irish case, very different factors have been driving the process of spatial concentration compared with those which operate in the core industrial economies.

The paper begins with a theoretical discussion of the concepts of spatial concentration and agglomeration. This is followed by an outline of the development of the pharmaceutical industry in Ireland since its inception in the 1950s, separating out the various sub-sectors that make up the industry. The next section is methodological, focusing, firstly, on data issues encountered in the research and, secondly, on the spatial concentration measures utilised in the analysis. The paper then proceeds with a description of the spatial distribution of the industry, focusing on two of its main sub-sectors. It will be shown that the overall level of spatial concentration of the industry is entirely due to the spatial concentration of one of the sub-sectors – the manufacture of drug substances. The paper continues with a more detailed investigation of the spatial dynamics of the drug substance sub-sector, distinguishing between two periods: before and after the mid-1980s. The paper ends with some concluding comments.

THE CONCEPTS OF CONCENTRATION AND AGGLOMERATION

Marshall (1890) is generally credited for laying the foundations for much of the current theorizing about the advantages of industrial spatial concentration. However, arguably it was Weber (1909) that developed the first real theory of spatial concentration as part of his broader theory of the location of industries. He showed how industrial concentration is driven by two forces: the operation of general location factors, such as labour costs and transport costs, and additional advantages derived from the concentration of firms at one place - agglomeration factors, These

agglomeration advantages basically rested on the concept of external economies of scale, developed by Marshall.

Weber's ideas were subsequently developed and refined by neoclassical location theorists, notably those contributing to geography's quantitative revolution of the 1950s and 1960s. The period since the second half of the 1980s has been characterised by a renewed interest in spatial concentration and agglomeration involving an increasingly diverse range of theoretical perspectives, including standard agglomeration theory, transaction costs, flexible specialisation, innovative milieux and institutional and evolutionary economics (Benneworth and Henry, 2004). This variety of approaches instigated an intense debate regarding the forms and determinants of spatial concentration and the operative processes involved (see Phelps and Ozawa, 2003; Parr, 2002; McCann 1995; Martin, 1999; Cumbers and McKinnon, 2004). Two important foci of this debate have related to:

(1) The specific agglomeration factors that are responsible for particular observed concentrations
(2) The extent to which agglomeration economies are responsible for observed spatial concentrations of industrial activity.

A discussion of the first of these foci benefits from an overview of the range of possible agglomeration advantages. Marshall's original contributions are still useful for grouping the agglomeration advantages identified in recent literature. His observations on the subject of agglomeration[2](Marshall, 1890; 1919; 1930) tend to be summarised into a triad of external economies – a pooled market for workers with specialised skills, a growing number of increasingly specialised input suppliers and technological spillovers.

The local pool of labour can provide an efficiency gain for both workers and firms by maximising job-matching opportunities and thus reducing search costs (Gordon and McCann, 2000). As regards input relations, a localised industry can support more suppliers, which increases the level of specialisation and efficiency of the supply base, which, in turn, presents an efficiency gain for the customers (Harrison, 1992). The actual driver for geographical proximity between firms is the desire to reduce the costs of transactions across space (Krugman, 1991). This may involve transport/logistics costs and/or the cost of intentional information exchange between the two firms (van Egeraat and Jacobson, 2005 and 2006).

The third advantage that is commonly distilled from Marshall's work, technological spillovers, involves informational or knowledge externalities which result from the concentration of (both vertically and horizontally) related firms, facilitating processes of learning and innovation in the locality (Malmberg and Maskell, 1997 and 2002). Technological spillovers are believed to be intensified by proximity in "untraded interdependencies" (Storper, 1995) and independent of the degree of intentional interaction. Knowledge tends to become embedded in the local milieu (Malmberg, 1996) – "the mysteries of trade (…) are in the air" (Marshall, 1898, p.350). Unintentional interaction (Oerlemans and Meeus, 2005) within a group of firms involves the acts of observation and comparison by firms (Malmberg and Maskell,

[2] Marshall applied the term *localisation.*

2002) which are facilitated by non-geographical forms of proximity, notably social, cultural and institutional proximity (although these other forms of proximity can indirectly be augmented by geographical proximity) (Boschma, 2005).

Hoover (1937) made an important contribution to the theory of agglomeration economies by dividing such economies into two distinct types: localisation and urbanisation economies. Localisation economies, as identified by Marshall (1890), are advantages that firms in a single industry (or set of closely related industries) gain from being located in the same location while urbanisation economies are advantages gained by all firms, regardless of sector, from being located together. Urbanisation economies are partially based on economies of scope. They can be regarded as a more general form of the localisation economies discussed above. For example, instead of a pooled market for workers with specialised skills, in the case of urbanisation economies all firms benefit from a pooled market for workers in general. In reality, it is not always easy to distinguish between localisation or urbanisation economies, which is partly dependent on the level of sectoral aggregation applied (McCann, 1995; Parr 2002; Glasmeier, 2000; Phelps, 1991).

One of the main criticisms of agglomeration theory is its ineffectiveness in explaining or predicting the empirical reality of industrial concentrations (Malmberg and Maskell, 2002). It is often unclear which particular agglomeration factors are responsible for observed concentrations. Emphasising cost-reduction in inter-firm transactions is no longer regarded as being helpful given the fact that in many cases of agglomeration most firms have few local backward linkages (Phelps, 1991; McCann, 1995). Partly as a result of this, the focus of analysis has shifted to technological spillovers and related social, cultural and institutional issues (Martin, 1999; Malmberg and Maskell, 2002). The problem is that such technological spillovers are difficult to identify and measure. In the absence of cost-reduction factors, spatial concentrations are often assumed to be shaped by hypothetical local spillovers (McCann, 1995; Malmberg and Maskell, 2002) For an example in the context of the Irish pharmaceutical industry, see Krugman (1997). However, technological spillovers as defined in this paper are unlikely to play a significant role in some industrial concentrations, for example concentrations of manufacturing plants with limited involvement in innovation and research & development. In the absence of inter-firm transactions, the efficiency gains related to the pool of labour may well be the only significant agglomeration advantage operative in such concentrations.

In addition, the search for an explanation of agglomerations of a single industry or clusters of closely related industries tends to focus on localisation economies rather than urbanisation economies. However, many of such single industry agglomerations tend to occur in large urban areas such as San Francisco, Los Angeles and London, and it has been suggested that at least some single industry agglomerations may reflect general urbanisation economies available in such urban areas, rather than localisation economies (Simmie, 2004, Gordon and McCann, 2000). These advantages may take the forms of efficiency gains due to a pooled market for workers and a varied set of input and service suppliers, benefiting a whole range of sectors operating in the urban economy.

The second, related, debate concerns the extent to which agglomeration economies are responsible for observed spatial concentrations. The literature provides evidence

for the fact that agglomeration economies are an important driver behind many instances of industrial concentration. At the same time, one should not loose sight of the possibility that in certain industrial concentrations agglomeration economies only play a limited role (see also McCann, 1995; Malmberg *et al*., 2000).

In this regard, it is helpful to reintroduce some of the insights of location theory. Traditional location theory already showed that operation of general location factors, such as labour costs and transport costs, can lead firms to concentrate at material sites, transshipment points, cheap labour locations and major markets in order to exploit the comparative advantage offered by these points (Dicken and Lloyd, 1990). McCann (1995) also makes the point that industrial concentration may be driven by location-specific factor efficiency costs, without the operation of agglomeration economies. Firms can for example be attracted to a particular area due to the prior presence of a large pool of skilled or unskilled unemployed workers there. Where the existing factor efficiency is not caused by the existing level of concentration, one should not explain this concentration in terms of agglomeration economies.

In a similar vein as Weber, Marshall distinguished between *causes* and *advantages* of localisation (Marshall, 1898). The causes are basically the initial trigger or reason for the development of an industry at a particular locality. The advantages are what we can interpret as the actual localisation economies that lead to the further expansion of the concentration. Marshall identified various causes for the initial concentration of industry, including physical conditions and the demand related to the 'patronage of court'.

Important *causes* for concentration today are related to government intervention. Environmental regulation, industrial policies, spatial planning and related spending by state and local government authorities/agencies can greatly influence firms in their choice for a location and in some cases directly lead to industrial concentration. Some of these factors are mediated through government's role in the supply-side of the market for industrial sites, which, along with the locational preferences of manufacturing firms, partly determines the pattern of industrial location (Van de Krabben and Boekema, 1994; Louw *et al*. 2004; Lambooy *et al*. 1997). This role can take the form of promoting the development of well-serviced industrial sites at certain locations (e.g. through financial/fiscal incentives or the direct provision of well-serviced industrial sites) and/or that of blocking industrial activities from other locations (physical planning and environmental regulations). In some cases such government intervention can lead to a concentration of industrial sites in a limited number of locations and thus be a very important *cause* for industrial concentration.

In some cases such industrial concentration may give rise to agglomeration advantages that instigate a process of further concentration. However, in certain cases agglomeration advantages may remain very limited and, rather than merely constituting the *initial* trigger for a concentration, government intervention remains the most important driver for further industrial concentration.

There are probably not many industrial concentrations where agglomeration economies are totally absent (Parr, 2002). Notably, most industrial concentrations in the vicinity of urban areas are bound to benefit from at least some level of urbanisation economies in the form of educational institutions, labour market pooling

and infrastructure. However, these may have little impact on the process of spatial concentration or only act as 'reinforcing agglomeration economies' (Parr, 2003). This refers to situations where agglomeration economies are at work, but the concentration is not dependent on these agglomeration economies. In many cases therefore, the real question is not whether agglomeration economies are present or operative, but rather concerns the relative strength of agglomeration economies and whether they are an important factor in (further) industrial concentration.

In relation to urbanisation economies it is also important to consider that they may not be responsible for driving spatial concentration in *particular* localities. This is because a range of urbanisation economies (although not all) is available in all urban centres of a similar size. Therefore, although urbanisation economies may be responsible for the concentration of industry in urban centres, they do not always serve as an explanation for the concentration in *particular* urban centres.

The proposition in this article is that, in certain geographical/sectoral contexts, government intervention and general location factors, rather than agglomeration economies, remain the most important driver behind observed industrial concentrations. The agglomeration economies at play are limited and/or mainly take the form of urbanisation economies, notably those related to a local pool of labour.

Such concentrations are most likely to occur in sectors that are characterised by large-scale manufacturing plants requiring large and well-serviced industrial sites with high utility requirements. In addition, certain country-specific characteristics may be influential. First, different countries have different traditions with respect to the role of governments in spatial and industrial planning (Lambooy *et al.*) and countries where governments take a relatively active role in industrial and regional planning are more likely to develop such instances of industrial concentration. In such countries, industrial and regional policies and the actions of government agencies can have a great impact on the spatial distribution of industry, leading to what might be called 'government-led' spatial concentration as opposed to market-driven agglomeration. Secondly, the branch-plant type industrial structure of some late-developing countries means that many industrial sectors are characterised by limited innovation and R&D activity. Technological spillovers are unlikely to play a significant role in industrial agglomeration where this is the case.

The pharmaceutical industry in Ireland provides a case where all these conditions operate simultaneously. As part of its attempt to catch up with the industrialised world after independence was achieved in 1922, the Irish Government has had an active involvement in industrial development and regional economic planning. Since the 1960s industrial development has relied strongly on inward foreign direct investment which provided the government with some leverage over the location decisions of companies. One of the sub-sectors of the pharmaceutical industry is a prime example of a sector characterised by large-scale manufacturing plants, high infrastructural and utility requirements and increasingly strict environmental regulations.

THE HISTORY OF THE PHARMACEUTICAL INDUSTRY IN IRELAND

The pharmaceutical industry includes a range of related sub-sectors including finished drug products, drug substances, other (non-drug substance) intermediate inputs and

diagnostics. Drug substances, also referred to as active pharmaceutical ingredients (APIs), are the most important ingredients of a drug product, being responsible for its pharmacological effect. They can be manufactured by chemical synthesis, extraction, cell culture/fermentation or by recovery from natural sources. (A detailed definition of the pharmaceutical industry and the demarcation of its boundaries is provided by [*Author*] (2006)).

Until the 1960s there was virtually no pharmaceutical industry in Ireland (Galvin, 1998). The post-independence autarkic economic development policies, including the Control of Manufacturers Act (designed to keep the ownership of industry in native hands), offered little incentive for foreign companies to invest in Ireland (White, 2000b), while the manufacturing of most pharmaceutical products was too sophisticated and required too much capital for indigenous players. The increasing shift towards more outward-looking economic policies (focused strongly on the stimulation of exports through the attraction of inward investment) from the end of the 1950s (O'Malley, 1989) led quickly to the first substantial investments by foreign companies. These companies were primarily attracted by the zero rate of corporation tax on profits derived from exports As such, the low corporation tax rate has been the primary factor driving the concentration of plants in Ireland at the national level.

The pharmaceutical industry in Ireland really took off in the 1970s. In 1970 the Industrial Development Authority (IDA), the state agency responsible for attracting inward investment, adopted a focused strategy of searching out emerging growth sectors and targeting potential foreign investors via an aggressive direct marketing approach (White, 2000a). The fine chemicals industry (including pharmaceuticals) was identified as one of the target sectors (Childs, 1996). The IDA succeeded in attracting a substantial number of foreign (notably US) companies in the sector, employment in which grew strongly, from just over 1,300 in 1972 to 4,750 in 1979 (see Figure 1). Most growth was accounted for by the drug substance and drug product sub-sectors. Very few companies focused on the production of other intermediates, with only two employing over 50 staff in 1979 – a situation that would change little in subsequent periods. *[Insert figure 1 about here]*

After a brief period of stagnation during the recessionary early 1980s, pharmaceutical manufacturing employment grew continuously from about 4,500 in 1985 to nearly 19,500 in 2003, by which time pharmaceuticals had become one of Ireland's leading industrial sectors. By far the strongest growth occurred in drug products, although the drug substance sub-sector experienced strong growth also, particularly in the second half of the 1990s. The growth in drug products manufacturing has been related to the increasing harmonisation of regulatory regimes and reduction of other non-tariff barriers against international trade in pharmaceutical products (*Irish Times*, July 2, 2004). One sub-sector that has experienced strong growth since the second half of the 1990s is diagnostics. The growth of employment in the pharmaceutical industry has involved both expansions of existing companies and the arrival of new companies.

Indigenous companies have played a relatively insignificant role in the sector's growth. During the 1960s there was only a handful of indigenous companies which were mainly involved in the formulation of over-the-counter (OTC) drug products. Since then, there has been a number of indigenous start-ups, most of them engaged in the formulation of veterinary pharmaceuticals or OTC human drug products. More

recently, a small number of companies also began manufacturing diagnostic products. Nevertheless, in 2003 foreign companies accounted for 93 per cent of total pharmaceuticals employment and virtually all employment in the drug substance sub-sector. Indigenous operations remained relatively small with only seven indigenous companies employing more than 50 staff (see Table 1). *[Insert Table 1 about here]*

DATA AND METHODOLOGY

The analysis of spatial concentration and its drivers is based on both qualitative and quantitative research exercises. The qualitative research involved semi-structured, face-to-face, interviews with senior staff at twelve major pharmaceutical plants in the period 2005-2006.[3] Part of these interviews dealt with the decision-making involved in selecting the plants' locations and the relevance of various agglomeration factors in the decision-making process. In addition to the company interviews, the research included 12 interviews with current and retired staff at relevant institutions, notably the Industrial Development Agency, Cork County Council (within whose boundaries one of the main concentrations of pharmaceuticals plants is located) and the Environmental Protection Agency. The qualitative micro-level data and contextual information derived from these interviews was used to make logical deductions regarding the relevance of the various agglomeration factors.

The quantitative exercise involved the computation of spatial concentration indicators for the pharmaceuticals industry from the annual Forfás Employment Survey of manufacturing operations in Ireland, currently conducted by Forfás (the National Policy Advisory Board for Enterprise, Trade, Science, Technology and Innovation). The survey is conducted at operations level. An operation in the data set is generally a separately incorporated unit of a firm or corporation, corresponding to a set of functions on a particular site.[4] Individual firms can have several operations in Ireland and operations can consist of several plants, producing different products. The individual operations were used as a unit of analysis in this paper. The survey provides, for each year from 1972 on, data on the location, employment and activity of each manufacturing operation in Ireland. Activity is categorised in the survey returns using the 4-digit NACE classification.

The definition of the pharmaceutical industry employed in this paper does not precisely correspond to the 4-digit NACE codes. The following activities were included: drug substances (part of NACE 2441), drug products (NACE 2442), diagnostics (part of NACE 2466 and part of NACE 3310) and other intermediate chemicals (part of NACE 2441). First inspection of the data set showed that many operations were incorrectly coded and substantial recoding was carried out on the basis of information obtained through Internet-based research combined with short telephone interviews.[5] A separate category was included for a small number of operations that produced both drug substances and drug products. The final data set

[3] As part of a larger research project, a total of 53 staff members were interviewed, including general managers, materials managers, personal managers and managers of R&D. The material presented in this paper is based mainly on information obtained during the interviews with general managers and R&D managers.

[4] There are exceptions. For example, in some cases, the research and development unit of an operation is separately incorporated from the manufacturing unit.

[5] For a more detailed report of definitional and recoding issues see [Author, (2006)].

includes a total of 122 pharmaceutical manufacturing operations, 95 of which were in operation in 2003 (Table 1).

This data set was used to compute measures of spatial concentration in the pharmaceutical industry and its various sub-sectors. The geographic unit of analysis used was the administrative county; county boroughs were combined with the counties in which they are located, giving a total of 26 observation units. The level of spatial concentration of an industry can be analysed very basically by inspecting the geographical distribution of employment across spatial units. The proportion of employment in the top region or top two regions can function as a simple measure of spatial concentration. A high proportion of employment in the top regions is suggestive of the operation of agglomeration economies, although this still needs to be demonstrated. This paper presents the geographical distribution of pharmaceutical employment across 26 counties.

Many measures of geographical concentration aim to compare the geographic pattern of employment or plants for one sector with the pattern of an aggregate (for example, all industry). Such measures are often interpreted as an indication of the operation of localisation economies. This paper uses the index proposed by Maurel and Sedellot (1999) (henceforth referred to as the MS index). The index, γ, controls for differences in industrial concentration (distribution of employment over the plants in an industry) and provides a measure of spatial concentration of an industry (suggestive of localisation economies) beyond what would be expected on the basis of industrial concentration. The mathematical derivation of the MS index is shown in Appendix 1. Maurel and Sedillot (1999) adopt the following classification of concentration levels: a low degree of concentration ($\gamma < 0.02$); moderately concentrated ($0.02 < \gamma < 0.05$); very concentrated ($\gamma > 0.05$).

THE SPATIAL DISTRIBUTION OF THE IRISH PHARMACEUTICAL INDUSTRY

Figure 2 presents the spatial distribution of employment in the pharmaceutical industry in Ireland. The overall picture is one of modest concentration. There are two main concentrations, one in county Cork county and one in Dublin county. In 2003 the two counties accounted for 45 per cent of all employment in the industry. Outside these two regions there are sizeable secondary concentrations in five other counties. Still, a significant number of operations, accounting for 17 per cent of employment, are scattered around the country outside these concentrations. The simple figures regarding the spatial distribution of pharmaceutical employment are reflected in the MS-index, often used as an indication of the operation of localisation economies. The value of γ for the total pharmaceutical industry in 2003 was 0.03 - on the low side in the 'moderately concentrated' category. *[Insert figure 2 about here]*

A more detailed examination of the industry reveals strongly contrasting spatial patterns for the two main sub-sectors. The drug substance or API sub-sector (see Figures 3 and 4) is characterised by a large grouping of operations in Cork, a secondary grouping in Dublin and a relatively small number of isolated operations outside these two counties. County Cork accounts for nearly half of total employment while Dublin accounts for another quarter. The MS index for the sub-sector in 2003 is 0.20, indicating a very high level of spatial concentration. In contrast, drug products operations are far less spatially concentrated (see Figures 5 and 6). The largest

grouping of drug products operations is in County Dublin, but smaller groupings can be found in Mayo, Waterford, and Cork. As regards employment, four counties each account for between 13 and 19 per cent of the total. Interestingly, Cork plays only a modest role, both in terms of number of plants and employment. The MS index computed for the sub-sector in 2003 is -0.02, indicating a very low level of spatial concentration. *[Insert figures 3, 4, 5 and 6 about here]*

Figure 7 shows the trends, over time, for the MS index for all pharmaceutical employment and for employment in the drug substance and drug products sub-sectors. The drug substance sub-sector has been characterised by a high and rising MS index for most of the period since 1972. After a period characterised by a relatively low MS index during the 1970s, the sub-sector became 'very concentrated' ($\gamma > 0.05$) by 1980 and for the next two decades the index shows a rising trend, reaching the very high value of 0.25 in 2001. Since reaching this peak the value has dropped somewhat. In contrast, the drug products sub-sector has always been characterised by a low level of concentration. The MS index was very low during the early 1970s. From 1975 the index rose to a peak in 1984 – but since then has shown a downward trend, falling below zero in 1992. *[Insert figure 7 about here]*

THE SPATIAL DYNAMICS OF THE DRUG SUBSTANCE SUB SECTOR: CAUSES OF CONCENTRATION AND THE ROLE OF AGGLOMERATION ECONOMIES

The high and rising level of spatial concentration in the drug substance sub-sector might suggest the operation of agglomeration economies, and especially localisation economies. The remainder of this paper will investigate the determinants of this high level of spatial concentration against the background of a more detailed history of drug substance plant location in two periods: before and after the mid-1980s. These two periods portray significant differences in the location patterns of new plants.

The period to the mid-1980s – concentration in Cork Harbour

Table 2 lists the new drug substance operations established on new sites in the period up to 1986. Three drug substance plants were established in the 1960s, all of them in the Dublin region. However, despite this head start, the period of rapid growth of drug substance manufacturing activity in Ireland in the 1970s largely bypassed Dublin. Until the mid 1970s, in terms of number of operations, the spatial pattern of the sub-sector was rather dispersed. Apart from Dublin and the area around Cork City, a number of companies had established plants on isolated sites in small rural towns on or near the banks of rivers that were used to discharge the wastewater. It was only in the second half of the 1970s that Cork really started to establish itself as the centre of drug substance production in Ireland. By the mid-1980s there were ten drug substance operations in County Cork. The figures do not fully express the dynamics in the area. During the period a number of companies expanded their operations via new plants. Other companies acquired existing operations or sites (indicated in brackets), often significantly expanding the operations in the process. The data on new operations are reflected in Figure 8, which charts the changing distribution of employment. Dublin's share of total drug substance employment fell from 54 per cent in 1972 to 14 per cent in 1986 while over the same period Cork's share rose from 36 to 47 per cent. *[Insert Table 2 about here] [Insert figure 8 about here]*

The main ‘causes’ (as defined by Marshall) for this spatial concentration in Cork are related to government intervention, notably environmental regulation, spatial planning, regional policy, and related investment in serviced industrial sites. In the early 1970s the IDA identified the pharmaceuticals industry as one of its target sectors. Generally, foreign companies were primarily attracted to Ireland because of tax incentives and they were relatively easy to persuade to locate where the IDA wanted them to locate (O’Farrell, 1975). However, pharmaceutical plants had specific locational requirements. Pharmaceutical production facilities - in particular large drug substance plants - required sites that were serviced, to a relatively high specification, with effluent disposal facilities, fresh water, and electricity. Water is important for two reasons. First, drug substance production produced chemically contaminated wastewater, which eventually needed to be discharged to surface water. Secondly, the production process often required large amounts of fresh water. In general the fresh water requirements far outstripped the existing capacities available in most municipalities (Leonard, 1988). In fact, one of the early movers, Pfizer in Cork Harbour, needed to drill a series of wells to augment the public water supply (Clarke *et al*., 2003).

As part of its strategy, the IDA invested in the necessary infrastructure, concentrating most of its limited resources in Cork Harbour, adjacent to Cork City. In the second half of the 1970s, the IDA purchased large land banks in the harbour area, notably at Little Island and Ringaskiddy. It invested in the required drainage infrastructure, including a major marine outfall for discharge of effluent in Ringaskiddy. In addition, during the late 1970s/early 1980s, Cork County Council created the largest capacity of processed water in the country through the Harbour and City Water Supply Scheme. In later years, the Electricity Supply Board installed the required power supply (Childs, 1996).

The rapid build-up of suitable physical infrastructure and the availability of sizeable industrial sites, often with outline planning permission already in place, made Cork Harbour a relatively attractive location for new drug substance projects (Gallagher, 2003). In addition, having made substantial investments, the IDA was eager to sell the land in Cork Harbour. Whenever a company was interested in setting up a drug substance plant in Ireland, the IDA would strongly promote its sites in Cork Harbour (see also Breathnach, 1982; Meyler and Stobl, 2000). Spatial concentration was further driven by the practice of ‘reference selling’ - another element of the IDA’s promotion strategy. Potential investors in Ireland were usually invited to visit existing flagship companies in their sector. Pfizer in Cork Harbour functioned as the flagship company for the pharmaceutical industry. Because of its location it also served to specifically promote Cork harbour to potential investors in large-scale processing projects.

Thus, in the ten-year period between 1975 and 1986, six of the ten new drug substance operations on new sites in Ireland were established in Cork Harbour, and by the mid 1980s, the area had firmly established itself as the centre of the pharmaceutical industry in Ireland.

The question remains, as to why the IDA concentrated so much of its limited resources in Cork Harbour? One of the main reasons was regional planning. During

the 1960s and early 1970s, spatial and industrial policy became increasingly characterised by an attempt to encourage a shift of manufacturing employment out of Dublin, the traditional core area of the national economy. The Buchanan Report (Buchanan and Partners, 1968) advocated a policy of concentrated deconcentration in a select number of growth centres, notably Cork and Limerick-Shannon.[6] The industrial policy was to be implemented by the IDA through its regional industrial plans.

Partly in response to this, in 1972 the Cork Harbour Commissioners, in close co-operation with the IDA and Cork planning authorities, proposed the Cork Harbour Development Plan, involving a major upgrading of the port, including the development of large industrial zones. On Little Island, priority was afforded to a range of small and medium-sized enterprises, including pharmaceutical companies. Ringaskiddy was to be specifically developed for deep-water industries requiring large volumes of water and adequate facilities for large-scale effluent disposal (Brunt, 1980, 1998 and 2005).

Another reason for concentrating limited resources in Cork Harbour is related to environmental regulations and public concerns, although Cork Harbour would not have been the only possible location on the basis of this factor. Some physical planning and environmental controls on industry had been in place since the introduction of the Local Government (Planning and Development) Act in 1963. This included the control of wastewater effluent discharged in natural water bodies. Although the standards were still relatively relaxed, by the end of the 1960s, local governments were already driving quite tough bargains with pharmaceutical plants about the level of chemical effluent (Leonard, 1988). For drug substance plants located on the banks of inland rivers with limited assimilative capacity[7], this created a need for intensive on-site treatment of wastewater. This reduced the relative attractiveness of such sites, especially in small urban centres with limited municipal sewage treatment capacity. On the other hand, it increased the suitability of locations near tidal rivers, estuaries or the sea. Large assimilative capacity was one of the most important location factors for the first two pharmaceutical companies which located in Cork Harbour in the early 1970s (Pfizer and Penn Chemicals). In fact, it is argued that Pfizer would probably not have invested in Cork Harbour at all if it had not been allowed to discharge untreated wastewater in the Harbour (Leonard, 1988).

In addition, concern among the general public as well as local and central government about the potential pollution caused by pharmaceutical and other chemical plants rose very quickly during the 1970s (Leonard, 1988). This was partly driven by severe odour problems caused by some of the first established drug substance plants. In response, between 1970 and 1978, the IDA started to carefully select sites that would minimise the environmental impact of new pharmaceutical projects. With respect to wastewater discharge, in principle there were many suitable locations in Ireland that offered sufficient assimilative capacity. However, intensifying public concern and stricter planning regulations made the establishment of isolated large-scale chemical synthesis plants in rural settings increasingly difficult. Eli Lilly was the last company

[6] Subsequent official policy statements emphasised a greater dispersal of development throughout the country (Drudy, 1991) but Cork remained a focus for industrial development.

[7] Assimilative capacity is the capacity of a natural body of water to receive wastewaters or toxic materials without deleterious effects.

to get planning permission for such a development (at Kinsale in 1978) and, given the strong scrutiny by both general public and planning bodies, was fortunate to get it (Leonard, 1988). Instead, the aim was to guide plants that produced large amounts of effluent into two areas, partly selected because of their great assimilative capacity i.e. Cork Harbour and the Shannon Estuary (Leonard, 1988). Initially, in the mid-1970s, two new drug substance plants located in the Shannon area. However, with the establishment of new, well-serviced, industrial estates in Cork Harbour in the second half of the decade, this area became the prime location for new drug substance plants.

It has been suggested that the concentration of drug substance plants in Cork Harbour was the result of Cork County Council planning department being particularly undemanding of companies where it came to pollution control – the "pollution haven hypothesis" (Leonard, 1988). This research found very little support for this idea. In fact, Cork County Council was one of the stricter local authorities in Ireland. (See *Author*, 2006), for a more extensive treatment of this issue.)

Let us now consider to what extent the rapid concentration of drug substance plants in Cork was driven by the operation of agglomeration economies, and especially localisation economies – i.e. a growing number of increasingly specialised input suppliers, technological spillovers and a pooled market for workers with specialised skills. As regards specialised input suppliers, if this were an important factor in the concentration of drug substance plants in Cork, one would expect a co-location of buyers and suppliers. Drug substance plants use a range of material inputs, but virtually none of these are manufactured in Cork - or Ireland for that matter (Company interviews. See also Brennan, 2004). Similarly, none of the interviewed drug substance plants sell their output to drug product plants in Ireland. In addition, drug products plants are strongly under-represented in Cork. Local specialised input-output relations can therefore not have been a factor in the concentration of drug substance plants in Cork Harbour.

As regards technological spillovers, like most plants operating in Ireland during the 1970s and 1980s, the drug substance plants had a strong branch-plant character, with limited functionality other than bulk manufacturing. Technology was generally directly transferred from the strategic plants in the home countries. Headquarter and product/process development functions were absent. This makes it unlikely that there were any technological externalities embedded in the local milieu, facilitating processes of learning and innovation. Such externalities certainly will not have been a driver for the further concentration of drug substance plants in Cork Harbour.

Finally, it is unlikely that the concentration process was driven by a market for workers with specialised skills in Cork. Most of the pharmaceutical workers in the 1970s and early 1980s were operatives, with relatively limited skill-levels and generally no third-level education. Plants employed a limited amount of engineers and chemists, but these needed to be *qualified* as opposed to *specialised*. Cork did provide a number of more general labour-related advantages. It had an industrial history and a number of companies employed engineering skills, notably the Ford Motor factory. In addition, Cork had a well-developed third-level education infrastructure, including a school of chemistry. Finally, as the second city in Ireland, Cork provided a large pool of general labour, much of which was unemployed after significant job-losses in the early 1980s (Brunt, 2005). These were undoubtedly important attractions for drug

product plants, as they were for a range of other industries. However, along with Cork City's well-developed urban services, these were mostly urbanisation, rather than localisation, economies.

It is difficult to determine the precise strength of these urbanisation economies during this period. However, they must have been relatively modest since they clearly were of insufficient strength to offset the disadvantages of spatial concentration which emerged when a number of drug substance plants in Cork Harbour in the late 1970s and 1980s (as in other locations in Ireland) were responsible for persistent pollution problems, notably air pollution (Leonard, 1988). In an environment of rising public concern and protests, some companies preferred to dissociate themselves from these problems by locating on isolated sites in more rural locations. At least two companies - Elli Lilly in 1978 and Merrell Dow in 1987 - declined to locate in Cork Harbour for this reason. Whatever their size, these urbanisation economies cannot, on their own, serve as an explanation for the location and concentration of drug substance plants in Cork, since similar economies were available in a range of other urban centres.

The period since the mid-1980s – shift to Dublin

The geography of the drug substance sub-sector has changed significantly in the period since the mid-1980s. The main change has been the rising significance of Dublin as a location for drug substance plants. This change is best captured by the location pattern of *new* drug substance sites since 1987. Table 3 presents the locations of sizeable new drug substance operations (employing more than 20 employees) on new sites between 1987-2006. With eight new drug substance sites, Dublin accounted for half of such sites in Ireland. Although Cork Harbour continued to receive new plants on new sites, it was less successful, particularly in the 15-year period from 1987-2003, when it accounted for only two of the 13 new plants established on new sites in Ireland.

[Insert Table 3 about here]

These developments are not fully reflected in the data for investment and employment for the drug substances sub-sector. This is because, as in the period before the mid-1980s, many existing companies made significant repeat investments in Ireland, generally expanding on existing sites throughout the country. In addition some newly arriving companies purchased existing drug substance sites. As regards the distribution of employment, it is only in the early 2000s that we see a significant decrease in Cork's share (from 56 per cent in 2001 to 49 per cent in 2003) and an increase in Dublin's share (from 14 per cent in 2002 to 26 per cent in 2003). The reduction in Cork's share is reflected in a reduction of the MS index (see Figure 7), indicating a lower level of spatial concentration in the sub-sector. However, the share of the top two counties (Cork and Dublin) actually rose, from 61 per cent in 1986 to 74 per cent in 2003 (see Figure 8).

The relative shift in drug substances employment from Cork to Dublin was – again - strongly influenced by government intervention, notably changing regional planning policies and the related location of new well-serviced industrial sites. The 1970s policy of industrial dispersal and encouragement of a shift of manufacturing employment away from Dublin was progressively relaxed in the 1980s (White,

2000a). This was partly a response to the fact that, during the 1970s and 1980s, the East Region (containing Dublin) experienced serious industrial decline and its share of manufacturing employment shrank significantly (Drudy, 1991). Thus, during the 1980s and 1990s local authorities, in conjunction with the IDA, developed a number of well-serviced industrial estates in County Dublin, along the M50 orbital motorway.

The attraction of such readily-available, large, well-serviced industrial sites has increased in the period since the mid-1980s. Increasingly stringent regulations and controls are shortening the effective period of patent protection in the pharmaceutical industry (Pisano, 1997), making the time it takes to establish a new manufacturing plant of strategic importance. In addition, the fermentation processes used in the expanding biopharmaceutical sub-sector have very high utility requirements, particularly power and wastewater disposal facilities. A good example of infrastructure influencing plant location involves the Wyeth Biopharmaceuticals plant in Dublin. Initially, the company considered locating this large biopharmaceutical facility near its existing drug products plant in Newbridge, a mid-size town some 50km southwest of Dublin. However, the campus was eventually located in Dublin because adequate wastewater treatment services were not immediately available in Newbridge (*Kildare Nationalist*, April 7, 2000).

Thus, since 1987 a new concentration of drug substance plants emerged in Dublin while the existing concentration in Cork expanded in absolute terms, particularly since 2003. We can again consider the extent to which these concentrations were driven by the operation of agglomeration economies, especially localisation economies.

As regards specialised input suppliers, the corporate interviews show that, as in the previous period, virtually none of the raw materials used by drug substance plants are manufactured in Dublin or Cork. The growth of the pharmaceutical industry did help to attract a substantial number of process engineering and construction management companies to both cities in the 1980s and 1990s (see also Kearny, 2003). Most interviewees in Cork and Dublin perceived this concentration of engineering companies at their doorstep as beneficial. However, most of these companies service a range of other sectors, including other chemical sectors and food processing. Therefore, to the extent that the concentration of engineering companies does present an advantage, it is largely an urbanisation economy. It is unlikely that it was a very important factor in companies' decisions to locate in Cork or Dublin since pharmaceutical plants in more isolated areas do not experience notable disadvantage due to distance from the offices of these service firms. Engineering companies tend to provide efficient services nationwide. As an interviewee at a more isolated plant mentioned: "We have no issue with engineering companies. They are always very quick". In a sense, the advantages operate on the Irish national scale, rather than the local scale.

With respect to technological spillovers, although these are difficult to measure, the interviews provided little support for the idea that these have played a substantial role in the spatial concentration of the drug substance industry since the mid-1980s. This is probably partly due to the fact that for a long time the industry remained truncated, with virtually no R&D or headquarter functions. It was only at the late-1990s that a

number of companies started to add late-stage process development functions to their Irish operations.

The interviews provided very little evidence of genuine technological spillovers operating via untraded interdependencies and unintentional information exchange and facilitating innovation within the local industry. There is a degree of contact between local companies and local institutions concerning local infrastructure and production climate in general, notably in Cork. However, according to the interviewees this contact does not act as medium for technological spillovers facilitating innovation within the local industry. Even *intentional* interaction regarding technology is limited, dyadic and often not locally/regionally bounded. The research found very little evidence of technological interaction between pharma companies in Ireland, never mind between companies in individual clusters. Collaborative research projects between companies and local universities have been rare, although there have been a handful of examples in recent years. Even then, some of these projects involve universities and companies located in different regions. A local IDA representative considered the extent of local technological spillovers within the largest spatial concentration of plants in Ireland (in Cork) in the following way:

> Certainly, from a spatial point of view, it [the drug substance sector in Cork] is a cluster. But if you look at the broader definition of a cluster, as defined in terms of the interaction between the companies, with the broader environment, a greater level of interaction with the community ... I think there is a long way to go yet before you can describe it as a full cluster.

Finally, in relation to the relevance of a market for workers with specialised skills, the skill-levels in the drug-substance plants have risen sharply compared to the period before the mid-1980s. This is partly because of the introduction of more sophisticated process technologies. Another reason lies in the expansion or establishment of new functions, notably quality control/assurance and process research and development, particularly since the end of the 1990s. As an example, 59 per cent of the staff at a recently established drug substance plant have third-level education while 4 per cent have a Ph.D. At the process research and development unit of the plant, all staff have third-level education and 23 per cent have a Ph.D. Apart from a general rise in skill levels, a substantial share of the required skills are also increasingly specialised in the particular needs of the drug substance sub-sector.

Interviewees invariably stated that the supply of suitably qualified labour has become a very important location factor. To an extent, the existing concentration of drug substance plants in Cork and Dublin was perceived as an advantage in this respect, but nearly all interviewees related the supply of qualified labour more generally to the location of third level institutions and the quality of life in the major urban centres of Ireland. In relation to the third level institutions, one IDA executive remarked: “All the colleges and universities in the country are supplying the people who work in the area. So the pharma sector is a national industry, particularly for the third-level institutions. It does not matter which university, your skill is to the same level”. Asked which role the local technical skills base had played in its decision to locate in Cork Harbour, the manager of a plant established since 1987 replied: “For [our company] it was important that we had a university at our doorstep, good technical colleges for want of another word, for the supply of qualified staff. (…) So long as they have a Regional Technical College it is okay. It does not have to be in Cork”.

As mentioned above, most companies now have some interaction with local third-level institutions regarding course content. It is likely that this interaction has had a positive influence on the numbers and specific skills of local graduates. On the other hand, the companies have had contact with non-local universities as well and some of the companies are represented in national-level forums, influencing the skill levels in Ireland as a whole.

As regards quality of life, interviewees noted that qualified and specialised labour is very mobile and most companies recruit on a national and international basis (Cf. Leibovitz (2004) in relation to the biotechnology industry in Scotland). The targeted highly qualified people tend to have relatively high expectations regarding quality of life and availability of services, which often translates in a preference for a location in or near the major population centres (see also Malecki, 1979). For both reasons companies prefer locations in or near these centres. At least two plants that were located further away from the main urban centres in Ireland appear to have experienced greater difficulties attracting qualified staff and one general manager stated that he would not locate in a similar area again for this reason. A number of interviewees believed that the attractiveness of Dublin is recently being offset by the rising house prices and cost of living in that city. It is believed that this is now having a deterring effect on investments in Dublin and may be one of the reasons behind the recent resurgence of investment in Cork harbour.

Thus, without completely dismissing the recent emergence of limited localisation economies, to the extent that drug substance plants were attracted to Dublin and Cork because of the location of third-level institutions and the quality of life that the two cities offered as major population centres, the market for qualified and specialised workers should again be interpreted mainly as an urbanisation economy. Again, these kinds of urbanisation economies were available in other urban centres as well. In this respect, other suitable urban centres mentioned during the interviews included Galway, Limerick, and Waterford. Thus, although both factors probably confer great advantages on Dublin and Cork, it is questionable whether they represent an important part of the explanation for the concentration of the sub-sector in these *particular* cities.

As regards the future, interviewees at seven drug substance plants were asked to identify the three most important locational considerations if they currently had to decide on a location within Ireland. Two factors stood out in the replies. All interviewees regarded the availability of skills as an important factor. This factor was generally mentioned in conjunction with the proximity to a third-level institute. Five interviewees also mentioned the importance of well-serviced sites and utilities. This factor was less important for the two other plants because of their relatively small scale of operations. Given the fact that there are several urban centres that can satisfy the skills requirement, the factor that is likely to most strongly influence the location of drug substance plants, and their possible concentration in certain areas, therefore, is the availability of well-serviced sites. In support of this contention, a senior manager of a recently-established large-scale drug substance plant remarked:

> I would say the infrastructural issues are most important because, you know, we have a big facility … If you can't support the facility you have a major problem. Obviously the skills base then would be a significant additional factor. (…) With the caveat that you

> could meet these requirements, mainly the infrastructural ones … there is no reason why you could not locate in some of these other centres [other then Dublin and Cork]. But again, with the caveat of meeting all of the infrastructural requirements, mainly utilities.

Regional planning policies and the concomitant investment in industrial sites and infrastructure are therefore likely to play an important role in the future spatial distribution of the sub-sector. In this respect the new National Spatial Strategy (NSS) 2002-2020 (Government of Ireland, 2002) aims to achieve a greater balance of socio-economic growth between regions, partly through the concentration of development in nine national 'gateway' centres of critical mass. Under the Strategic Development Zone mechanism provided for in the Planning and Development Act 2000, streamlined planning processes will apply to locations in, or close to, these gateway centres (Government of Ireland, 2000). This mechanism is designed to speed up the planning process for specific developments that are of economic importance to the State.

The IDA has embraced the NSS (see Dorgan, 2004) and supports it via its FDI promotion strategy, including the distribution of 'strategic sites' (see also O'Kane, 2005). These sites are being specifically developed to support large and medium-scale manufacturing activities with large utility requirements, especially pharmaceutical plants. Apart from Ringaskiddy (in Cork Harbour) and Dublin, the newer strategic sites are all located in the vicinity of coastal 'gateways': Galway, Dundalk, Limerick/Shannon and Waterford (See Figure 9). The IDA has already secured advance planning permission for a 400-acre biopharmaceutical campus at the Galway strategic site (Beesley, 2006). These developments, if successful, are likely to lead to a reduction of the high levels of spatial concentration on a national scale, as measured by the MS index. *[Insert figure 9 about here]*

The findings presented in this paper suggest that, as long as Ireland's general attractiveness to new pharmaceutical projects is retained, the IDA should have relatively little difficulty in 'directing' companies to well-serviced strategic sites near sizeable urban centres other than Dublin and Cork. The problem is that, as of 2005, some of the strategic sites outside Cork and Dublin still lacked important elements. For example, although plans are in place to construct a new effluent treatment plant to serve the strategic site near Waterford, at the time of writing this has still to materialise, while the Dundalk site requires an upgrading of its power supply. "Ringaskiddy and Grange Castle [in Dublin] are probably the only two places where you could walk into tomorrow and say 'I take that 50 acres there'" (Interview retired IDA staff, December 2005). At the same time new strategic sites continue to be developed in the existing concentrations (Beesley, 2006).

CONCLUSION

This paper has shown how, unlike other sub-sectors of the pharmaceutical industry, the drug substance sub-sector in Ireland has been spatially concentrated since its inception in the early 1960s. During the 1970s and the first half of the 1980s, Cork Harbour established itself as by far the single most important centre of drug substance production in Ireland. The period since the mid-1980s has been characterised by a

relative shift to Dublin, although the drug substance sub-sector in Cork has continued to expand. Today, the sub-sector is heavily concentrated in these two locations.

This high level of concentration is sometimes attributed to the operation of agglomeration economies, notably Marshal's triad of localisation economies. This paper suggests that the concentration of the drug substance industry in the two particular urban centres has largely been driven by government interventions, especially environmental and regional planning policy and the related spatially selective provision of well-serviced industrial sites and infrastructure.

This is not to say that companies in the two locations do not benefit from agglomeration economies. Agglomeration economies have been at play, particularly since the mid-1980s. However, they are mainly of the urbanisation type, relating particularly to the availability of labour supplies, although limited localisation economies have recently been developing in the form of engineering services, tailored college courses and the supply of specialised qualified labour. Although urbanisation economies have been a factor in the concentration of the industry near two urban centres, the fact that these economies have also been available in several other urban centres means that they cannot serve as an explanation for the particular concentration of the drug substance plants in Cork and Dublin.

The limited role of localisation economies is partly underlined by the development of the second concentration of drug substance plants in Dublin since the mid-1980s. Under a less restrictive spatial planning regime, the provision of suitable sites and utilities in Dublin instigated a substantial shift in the location of new drug substance plants.

The evidence presented in this paper does not challenge the large body of work that demonstrates the salience of localisation economies, notably technological spillovers, in the process of spatial concentration in general. In fact, as mentioned earlier in this paper, existing studies suggest that such factors play an important role in the process of spatial concentration in the pharmaceutical industry in core economies. Rather, the case of the Irish pharmaceutical industry serves to show that, in certain sectoral/geographical contexts, government intervention, along with some more mundane urbanisation economies, can be the most important driver behind the spatial concentration process. Possible areas for generalisation include: other countries where governments take a relatively active role in regional planning and the related planning of industrial sites; late developing countries with a strong branch-plant character or, at least, relatively limited research and development and innovation activity (e.g. Costa Rica and Malaysia, Singapore); and industrial sectors characterised by large-scale manufacturing plants requiring large and well-serviced industrial sites with high utility requirements (e.g. the petrochemical sector).

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APPENDIX 1

Many measures of geographical concentration aim to compare the geographic pattern of employment or plants for one sector with the pattern of an aggregate. Krugman (1991) proposed a variant of the Gini coefficient as a measure of spatial concentration (suggestive of localisation economies). One of the problems with this measure is that it is very sensitive to differences in the size-distribution of the plants. Where employment is concentrated in a small number of plants located in a limited number of regions, the index always indicates a relatively high level of spatial concentration. The index of Maurel and Sedellot (1999) specifically addresses this problem. The index controls for differences in industrial concentration (distribution of employment over the plants in an industry) and provides a measure of spatial concentration (suggestive of localisation economies) beyond what would be expected on the basis of industrial concentration. The formula for the index is:

$$\gamma = \frac{G - H}{1 - H}$$

The first component in the equation is a measure of raw geographic concentration, where:

$$G = \frac{\sum_{i=1}^{M} s_i^2 - \sum_{i=1}^{M} x_i^2}{1 - \sum_{i=1}^{M} x_i^2}$$

s_i is the proportion of sector employment located in geographic area i and x_i is the proportion of aggregate industrial employment in area i. M denotes the number of geographic areas.

Control for the size distribution of plants is obtained by adjustment for the Herfindahl index[8] of industrial concentration (in terms of the distribution of employment across plants), where:

$$H = \sum_{j=1}^{N} z_j^2$$

z_j is the share of plant j in total sector employment and N denotes the number of plants in the sector. The result of this adjustment is that a sector will not be regarded as spatially concentrated only because its employment is concentrated in a small number of plants.

The index is sensitive to the level of sectoral aggregation and the geographic unit of analysis applied. Maurel and Sedilot find that an increase in the size of geographic unit leads to higher concentration levels while an increase in the level of sectoral aggregation (from 4-digit to 2-digit French NAF level) leads to a lower index. Maurel and Sedillot used the above classification for an analysis of concentration of industry in France at the level of 95 departments and 4-digit NAF. A broadly comparable level of aggregation is applied in this paper involving the 26 counties in Ireland and the 4-digit NACE classification.

[8] The Herfindahl index is a measure of industry concentration, generally used as an indicator of competition among firms. It is defined as the sum of the squares of the market shares of each individual firm. It can range from 0 (a very large amount of small firms) to 1 (a single firm).

Table 1: Number of operations and employees in pharmaceutical industry - 2003

	Foreign		Indigenous		Total	
	Operations	**Employees**	**Operations**	**Employees**	**Operations**	**Employees**
Drug substance	30	6379	1	26	31	6405
Drug product	32	9082	13	886	45	9968
Both substance and product.	5	1772	1	20	6	1792
Other Interm.	2	109	2	58	4	167
Diagnostics	5	732	4	411	9	1143
Total	74	18074	21	1401	95	19475

Source: Based on Forfás Employment Survey

Table 2: Location of new drug substance operations on new sites* - 1972-1986

First job year	Company	Location
1961	Loftus Bryan Chemicals (new API operation established by Schering Plough in 1981)	Rathdrum, Co. Wicklow
1964	Squibb Linson (now Bristol-Meyer Squibb)	Dublin
1967	Hedleys Labs	Dublin
1972	Pfizer Ringaskiddy	Cork Harbour
1972	Chembiotic (New API operation established by Schering-Plough** in 1983)	Brinny, Co. Cork
1972	Klinge Pharma	Killorglin, Co. Kerry
1974	Penn Chemicals (New API operation established by SmithKline in 1976)	Cork Harbour
1974	Merck Sharpe and Dohme	Clonmel, Co. Tipperary
1974	Syntex (now Roche)	Clarecastle, Co. Clare
1975	Galeo (later Pharmacia; now Pfizer Inchera)	Cork Harbour
1977	SIFA (now Schwarz)	Shannon, Co. Clare
1978	Irish Fher (now Cambrex)	Cork Harbour
1979	Plaistow (now Pfizer Little Island)	Cork Harbour
1980	Eli Lilly	Kinsale Co. Cork
1981	Pilmar (New API operation established by Janssen Pharmaceuticals; now Johnson & Johnson)	Cork Harbour
1981	Newport Synthesis	Dublin
1983	Iropharm (now Honeywell)	Arklow, Co. Wicklow
1985	Angus (New API facility established by Warner Lambert in 1997; now Pfizer)	Cork Harbour
1986	Wexport Pharmaceuticals	Cork Harbour

*Note: *New drug substance operations established on existing drug substance sites are indicated in brackets.*

***Denotes operation producing both drug substances and drug products*

Table 3: New drug substance operations with more than 20 employees established on new sites - 1987-2006

First job year	Company	Location
1987	Yamanouchi	Dublin
1988	Servier*	Arklow, Co. Wicklow
1989	Kinerton	Dublin
1990	Fort Dodge*	Sligo
1990	Sandoz (now Novartis Ringaskiddy)	Cork Harbour
1992	Helsinn Chemicals	Dublin
1992	Tyco Healthcare	Dublin
1998	Rottapharm*	Dublin
1998	Cascade Biochem	Cork Harbour
2000	Bristol Myers Squibb	Dublin
2000	Wyeth Biopharma	Dublin
2002	Abbott Ireland Pharma	Sligo
2003	Takeda Chemical	Dublin
2003	Recordati	Cork Harbour
2004	Centocor Biologics	Cork Harbour
2006	Amgen	Carrigtwohill

*Note: *Denotes both drug substance and formulation plant*

Figure 1: Employment pharmacuetical sub-sectors - 1972-1993

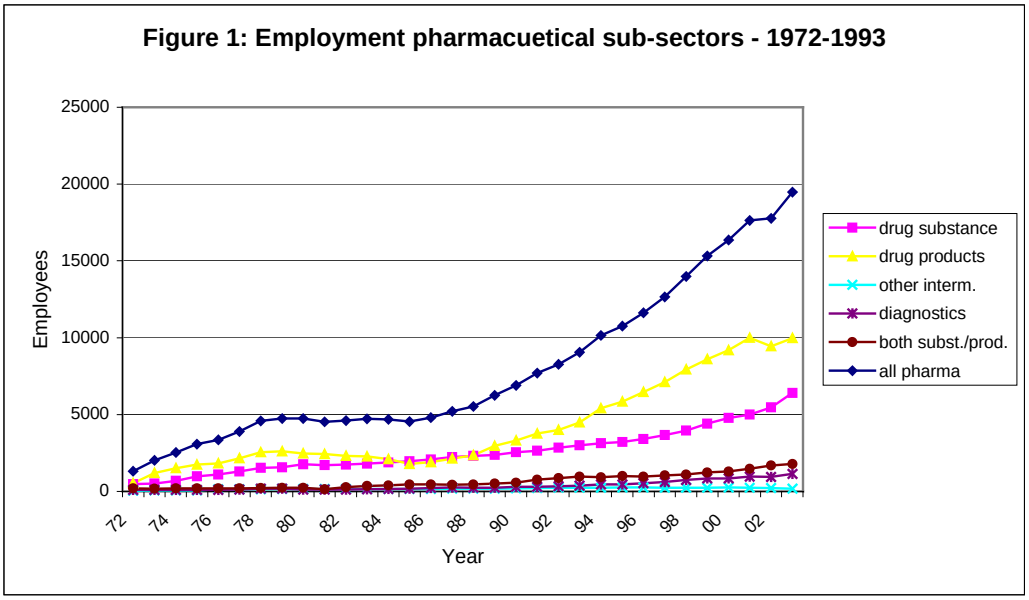
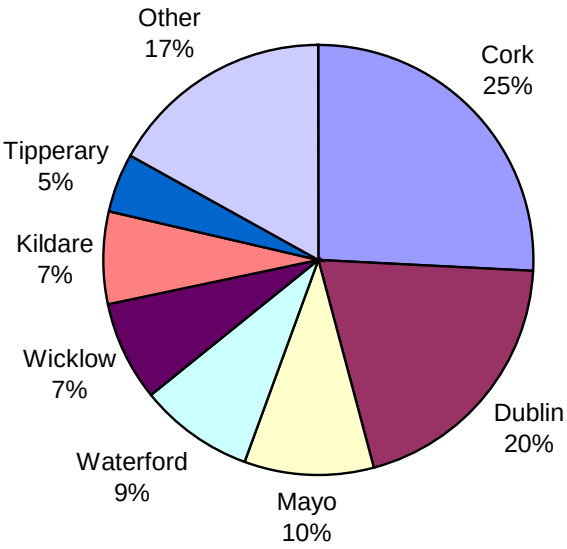
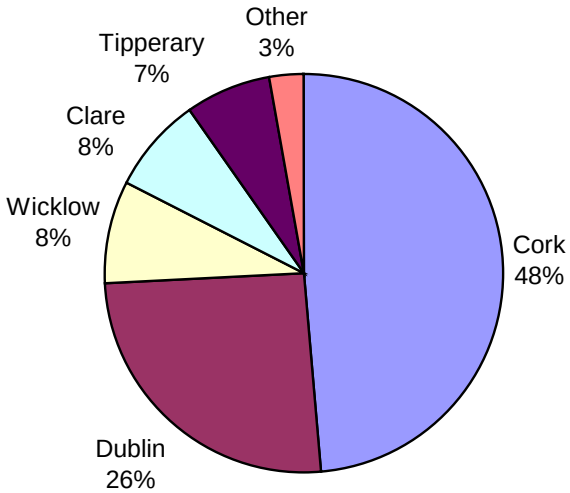


Figure 2: Employment pharmaceutical industry by county, 2003



Source: *Forfas employment survey*

Figure 4: Employment in drug substance operations by county, 2003*



Source: *Forfas employment survey*
**Excluding employment in operations involved in both drug product and drug substance production*

Figure 3: Location of drug substance operations, 2003

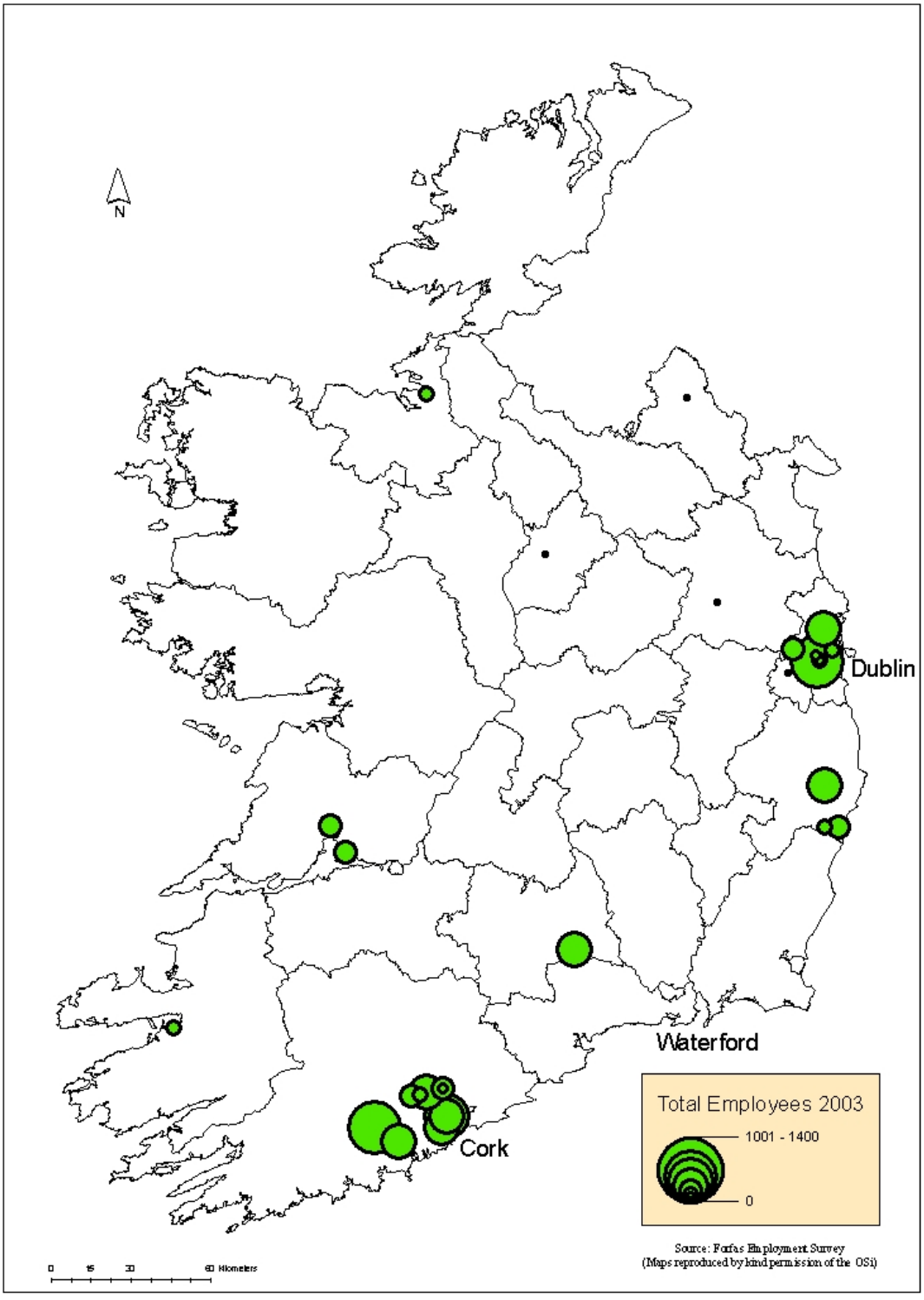


Figure 5: Location of drug product operations, 2003

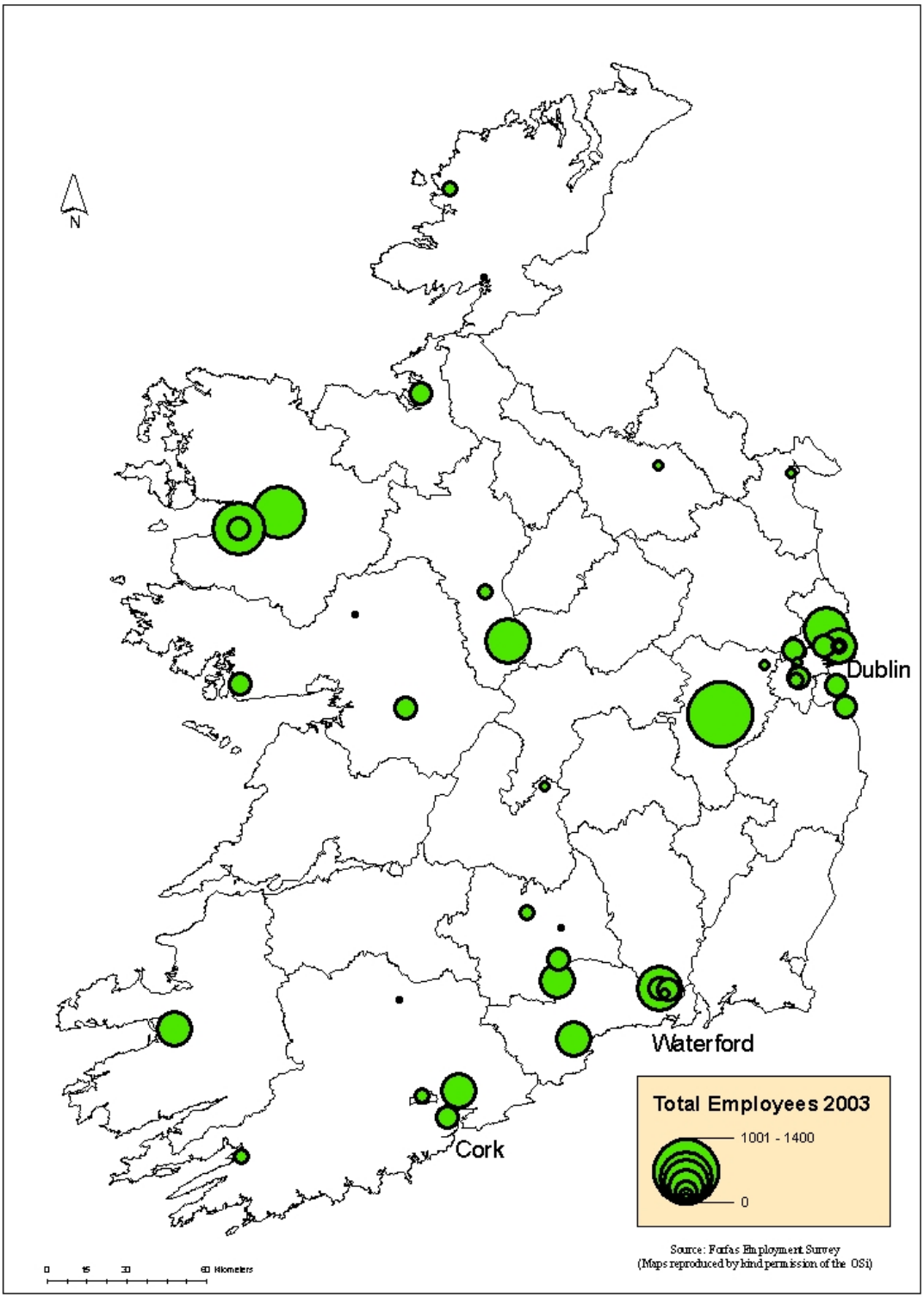
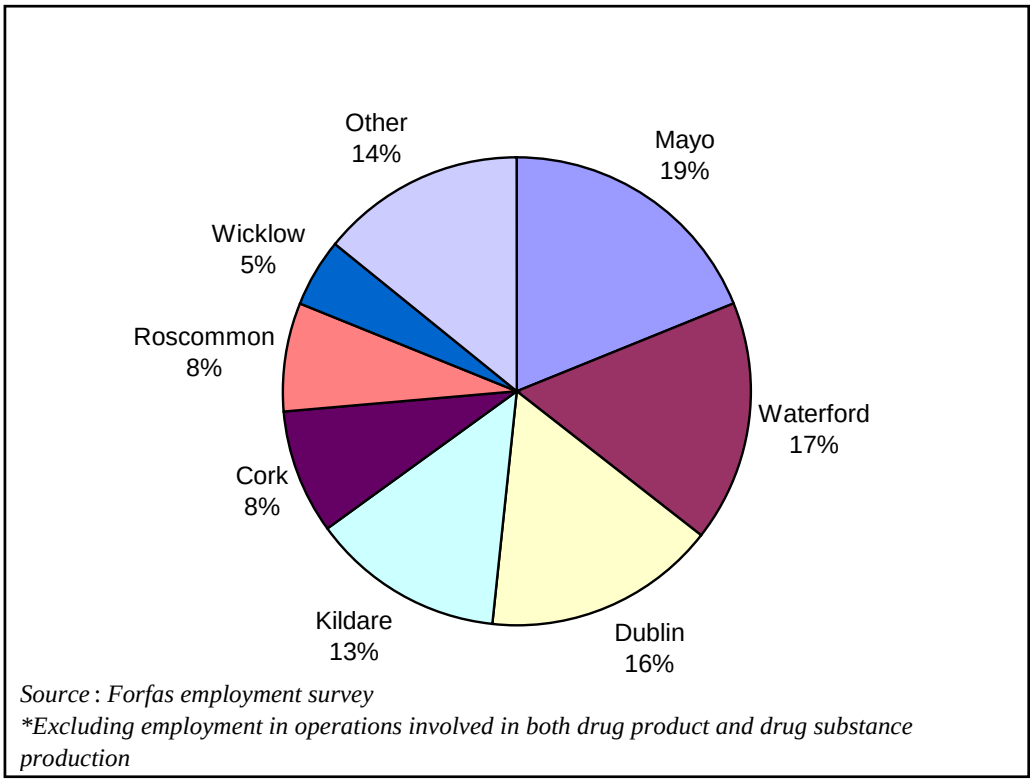
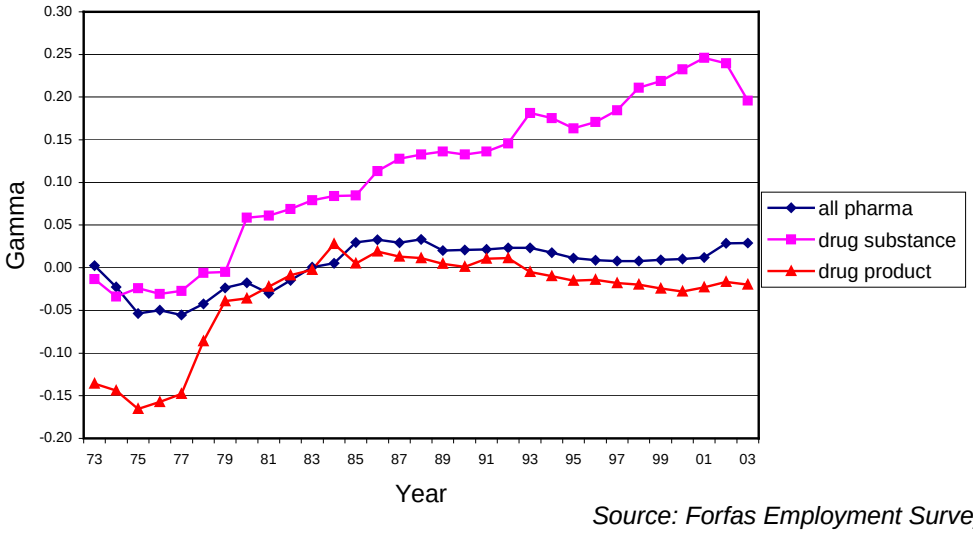


Figure 6: Employment in drug product operations by county, 2003*



Source: *Forfas employment survey*
**Excluding employment in operations involved in both drug product and drug substance production*

Figure 7: MS-index pharmaceutical sub-sectors, 1973-2003



Source: Forfas Employment Survey

Figure 8: Share of Cork and Dublin in drug substance employment, 1973-2003

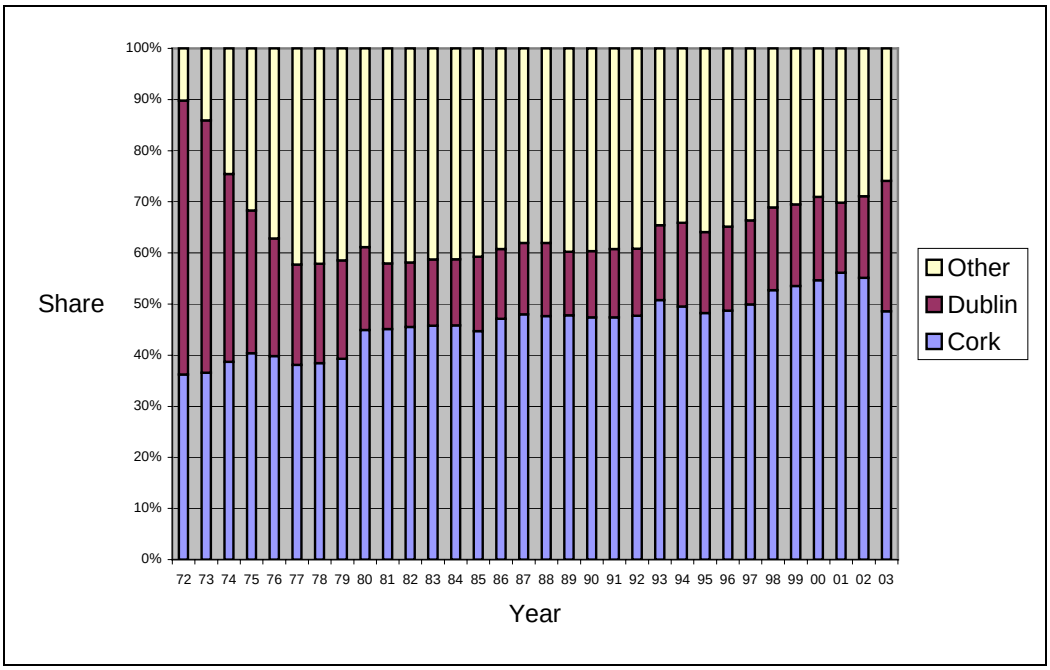


Figure 9: Locations of strategic sites, 2006