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Abstract. Regional industrial policy emphasizes the notion of building on existing concentrations of competitive firms. A range of measures to identify such concentrations has been put forward in the literature. These however do not identify *substantial* concentrations which have the best potential for further development, tend to concentrate on scale measured by employment and are applied using data for pre-specified administrative boundaries. This paper presents a new concentration index that identifies *substantial* concentrations and utilizes information on both the number and scale of plants. It also proposes a method for generating relevant industry-specific spatial units.

JEL classification: C43; R12

Key words: Geographical concentration; industrial specialization; agglomeration; methodology

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1 INTRODUCTION

Since the 1970s regional industrial policy has been inspired by a range of territorial production concepts including Italianate 'Neo-Marshallian industrial districts' (Brusco, 1989), Porterian 'clusters' (Porter, 1990), regional sectoral 'systems of innovation' (Malerba, 2003; Asheim and Gertler, 2005) and, more recently, regional 'business ecosystems'. These concepts rest on insights from multiple disciplines and theoretical approaches, including classical location and agglomeration theory, institutional economics, socio-economic approaches and evolutionary economic geography. These territorial production concepts tend to incorporate a sectoral dimension in that they point to the benefits of geographically concentrated groupings of firms in the same or related industries.

Geographical concentration of competitive firms in specific industries is generally believed to provide advantages to the firms involved, as well as setting in motion cumulative processes that will lead to the further development of these concentrations in specific areas. At the same time, the growing competitiveness of these existing concentrations will impede the development of similar industries in other areas. Regional industrial policy therefore often emphasizes the notion of building on existing concentrations of competitive firms.

The identification of existing concentration is often based on geographical concentration and industrial specialisation indices. Geographical industrial concentration can be defined as the extent to which employment in a particular industry is concentrated in a small number of localities or regions. Commonly used measures include the locational Gini, the Herfindahl-Hirschman index, the MS index (Maurel and Sedillot, 1999) and the decomposable Theil index (Bickenbach et al. 2012). These indices provide measures of the overall level of geographical concentration of an industry. They provide, however, no direct insight into the importance of individual concentrations. For this measures of regional industrial specialization such as the Krugman Dissimilarity Index, the Gini Coefficient and the Herfindahl-Hirschman Index for Specialisation or the simple location quotient are commonly utilised.

The measures for geographical concentration and industrial specialisation have a number of significant drawbacks when used to inform regional industrial policy making and planning. Firstly, neither the measures for geographical industrial concentration nor the measures for industrial specialisation provide a direct insight into the relative size or importance of individual concentrations.

Arguably, regional industrial policy making inspired by cluster thinking should focus on *substantial* concentrations. These are the concentrations which have the best potential for further development. A second shortcoming common to these measures is that they only use employment and do not account for the number of firms, which is, at least equally important where regional industrial policy making is partly based on an appreciation of the beneficial effects of interaction amongst multiple firms. Thirdly, most indices do not take account of the size distribution of the concentrations. Finally, the extent of the spatial units is usually pre-specified to concord with administrative boundaries. As industry concentrations may incorporate parts of different administrative units, restricting the analysis to predefined administrative units is not appropriate. Utilising administrative units also risks being subject to the so-called modifiable area unit problem, where the results are sensitive to the choice of spatial unit.

This paper contributes to the literature by proposing a new concentration index that identifies *substantial* concentrations, and a new methodology for generating relevant, industry-specific, spatial units. The measure incorporates both the number of plants and the scale of activity measured by employment in a concentration. Furthermore, the methodology allows for the identification of concentrations that spill across administrative boundaries by utilizing commuting based labour fields.

The new measure is illustrated using detailed plant level data for Ireland. This data identifies the location of plants using XY coordinates and their size is measured as total employment. A number of previous papers have considered the geographic concentration in Ireland. Morgenroth (2008) considered specialization of NUTS 3 regions over time. The analysis in this paper shows that the spatial extent of significant concentrations does not match well with that NUTS 3 administrative boundaries. At the micro-spatial scale, analysis has focused on the differences of location patterns across sectors and the degree to which sectors prefer urban locations (Morgenroth, 2009). However this analysis did not focus on groups of spatial units that could encompass substantial concentrations, which is the focus of this paper. The detailed geography of individual sectors has also been explored (e.g. Van Egeraat and Curran, 2013). Here we illustrate the methodology for a number of sectors.

The paper begins by first discussing the advantages and drivers of geographical industrial concentration. This is followed by a discussion of the existing measures of geographical concentration and industrial specialisation and their drawbacks. It continues with an exposition of the proposed index and methodology. The next two sections demonstrate demonstrate the benefits of the methodology by applying it to Republic of Ireland data. The final summarizes and draws conclusions for regional industrial policy-making.

2 GEOGRAPHICAL CONCENTRATION: ADVANTAGES AND DRIVERS

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 social scientists. The debate regarding the determinants of such spatial concentration and the processes involved is evolving (see McCann 1995; Martin, 1999; Parr, 2002; Phelps and Ozawa, 2003; Brown and Rigby, 2010; Boschma and Fornahl, 2011, Van Egeraat and Curran, 2013) but, for the purposes of this paper, Marshall's original contributions are still useful for grouping the advantages identified in recent literature. His observations on the advantages of industrial geographical concentration (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 latter have become an important focus of attention, believed to underpin processes of learning and innovation (Malmberg and Maskell, 1997 and 2002).

In the context of open innovation models (Chesbrough, 2003) inter-organisational knowledge flow is becoming an increasingly important factor. Such knowledge flow is facilitated by inter-firm networks and proximity. Proximity is deemed particularly important for tacit knowledge flow and untraded knowledge externalities. Such untraded externalities are believed to be intensified by common informal rules and conventions that, to an extent, are locally bounded. As a result, knowledge tends to become embedded in the local milieu (Malmberg, 1996). Ultimately, proximity and agglomeration accelerate the diffusion of information and knowledge which leads to innovation through the development of new products, services and business models. Superior innovation performance creates a halo effect which attracts organisations and individuals to the area, setting in motion processes of cumulative causation.

Hoover (1937) refined the concept 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 gain from being located in the same location while urbanisation economies are advantages gained by all firms, regardless of sector, from being located together. Recently, Asheim, *et al*. (2011) has coined the concept of 'related variety', which in a sense links localisation and urbanisation economies. Here the advantages that firms in an industry gain from being located in the same location also benefit firms in a set of related industries (as opposed to firms in a single industry or all firms in the region).

It is important to note that not all instances of geographical concentration are necessarily driven by agglomeration economies. In this regard, in the absence of evidence for local backward linkages with specialised input suppliers or a pooled market of skilled labour, spatial concentrations are often assumed to be shaped by local spillovers. However, the existence of these spillovers is not always established (Van Egeraat and Curran, 2013; McCann, 1995; 2002; Orsenigo, 2006, Phelps, 1991). In many cases of concentration, agglomeration economies may only play a limited role in driving the concentration process (see McCann, 1995; Malmberg *et al*., 2000). In reality 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, 2002).

This latter point is important from an industrial policy perspective in that the existence of a geographical industrial concentration does not mean that beneficial advantages and processes are in operation. Whether such concentrations should be a target for industrial policy or whether such processes could be stimulated always requires more detailed investigation

3 GEOGRAPHICAL CONCENTRATION AND INDUSTRIAL SPECIALISATION

A large corpus of work has developed in the construction and empirical application of measures of geographical industrial concentration and related concepts. Geographical industrial concentration can be defined as the extent to which employment in a particular industry is concentrated in a small number of localities or regions. Commonly used measures include the locational Gini, the Herfindahl-Hirschman index and the Maurel and Sedillot index. All measures of geographical concentration aim to compare the geographical pattern of employment with the pattern of an aggregate, either a reference region or a uniform distribution.

Krugman (1991) proposed the locational Gini, a variant of the Gini coefficient, as a measure of spatial industrial concentration. This indicator compares the degree of concentration of an industry to that of a reference region, often the country as a whole. This relative measure takes values between 0 and 1. 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 indicates a relatively high level of spatial concentration.

The Herfindahl-Hirschman index is an absolute measure that compares the distribution of employment in a particular industry with that of a uniform distribution. The value of the index increases with the degree of concentration reaching 1 when all employment is concentrated in one region. The difference between this absolute measure and relative measures lies in the reference structures used. The two types of measures will take different values in cases where total employment is very unequally distributed across regions. Campos (2012) illustrates this with reference to the water supply industry. Because employment in water supply is relatively evenly spread across all regions, its Herfindahl-Hirschman index is low. However, because total employment is often not uniformly distributed, water supply has an average locational Gini.

These basic measures have formed the basis for more sophisticated measures of concentration. Ellison and Glaeser (1997) addressed the problem of sensitive to differences in the size distribution of the plants by incorporating the Herfindahl index defined across plants within an industry[1]. This index was further modified by Maurel and Sedellot (1999) and Devereux et al. (2004). The MS index controls for differences in the size distribution of plants and provides a relative measure of spatial concentration beyond what would be

[1] 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).

expected on the basis of concentration of employment (in terms of the distribution of employment across plants).

The formula for the MS index is:

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

The first component, *G*, is a measure of raw geographic concentration, where:

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

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 firms is obtained by adjustment for the Herfindahl index of industrial concentration (measured as the distribution of employment across plants), where:

$$H = \sum_{j=1}^{N} z_j^2 \tag{3}$$

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. Maurel and Sedillot (1999) adopt the following classification of concentration levels: a low degree of concentration (γ < 0.02); moderately concentrated (0.02 < γ < 0.05); very concentrated *(*γ> 0.05).

All three indices provide measures of the overall level of geographical concentration of an industry. They provide, however, no direct insight into the importance of individual concentrations. For this, policy making tends to rely on measures of regional industrial specialisation.

Extant literature presents a range of measures of dissimilarity and specialisation (Prothero, 2012). Dissimilarity and similarity indices measure how similar/dissimilar a region's industrial structure is relative to that of a reference area. Popular indices in this regard include the Krugman Dissimilarity Index, the Gini Coefficient and the Herfindahl-Hirschman Index for Specialisation. Such indices allow for some inference in relation to specialisation, in that areas with high dissimilarity values are likely to have industrial specialisations.

The actual level of specialisation in specific industries in specific regions can be measured with the Location Quotient, which measures whether the share of employment in an industry in a particular area is disproportionate relative to its share in total national employment. Formally it is defined as the share of sector *i* in the employment in spatial unit *j* relative to the share of sector *i* in national employment:

$$LQ_i = \frac{S_{ij}}{S_j} \quad \textbf{(4)}$$

Where $S_{ij} = \frac{e_{ij}}{E_j}$ and e refers to employment.

A location quotient with a value greater than 1.0 occurs if a specific industry makes up a higher share of employee jobs in a specific area than that industry does nationally, indicating that the area has a relative specialisation in that industry.

Industries with a high location quotient in a region are often deemed to be geographically concentrated. However, although related, geographical industrial concentration and regional industrial specialisation should not be conflated. Even if a specific region has a relative specialisation in a specific industry, this industry can, nationally, be characterised by a low geographical concentration index, and vice versa. The confusion lies in the difference between 'a geographically concentrated industry' and 'an industrial concentration'.

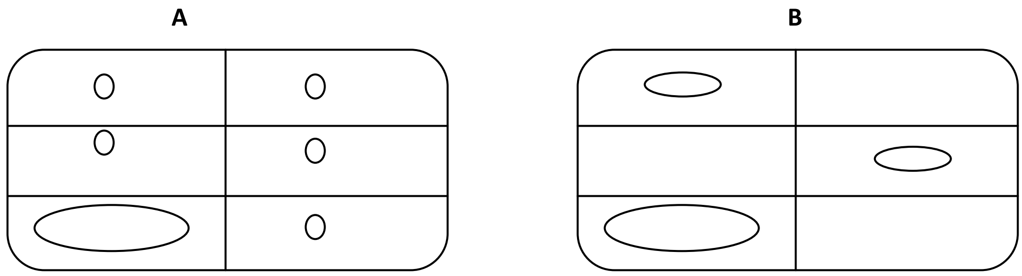
When we define an industrial concentration as an industry in a region with a location quotient greater than 1.0, we need to be very cautious when interpreting the results for policy making purposes. This is because a high location quotient does not necessarily point to a substantial number of employees in an industry. In fact, a small absolute number of industry employees in a region with a small number of total employees relative to the national total employees can lead to a high location quotient. In contrast, a great absolute number of industry employees in a region with a large number of total employees relative to the national total employees can lead to a low location quotient, with the danger that this group is not picked up for policy making purposes.

The measures for geographical concentration and industrial specialisation described above have a number of significant drawbacks when used to inform regional industrial policy making and planning. Firstly, neither the measures for geographical industrial concentration nor the measures for industrial specialisation provide a direct insight into the relative size or importance of individual concentrations. Arguably, regional industrial policy making inspired by cluster thinking should focus on *substantial* concentrations. These are the concentrations which have the best potential for further development.

A second shortcoming common to these measures is that they only use employment and do not account for the number of firms, which is, at least equally important where regional industrial policy making is partly based on an appreciation of the beneficial effects of interaction amongst multiple firms. A focus on employment can even lead to the identification of 'one firm concentrations' based on the presence of a single very large firm (in terms of employment), while spatial units with many small firms in a particular sector may not be identified as concentrations. As discussed, this issue is addressed by the MS index but the MS index does not provide direct insight into the importance of individual concentrations.

Thirdly, most indices do not take account of the size distribution of the concentrations. The consequence is illustrated in Figure 1. This depicts a situation where both total employment and employment in the spatial unit with the highest concentration are equal. In situation A there is one clear industry concentration in one spatial unit and the rest of the employment is fragmented over the rest of the spatial units. In situation B the industry overall is more concentrated in a smaller number of spatial units, which could be based on industry specific characteristics (for example the size distribution of firms in an industry). Most indices do not differentiate between these two situations but, arguably, the largest concentration is relatively more substantial in situation A than in situation B.

Figure 1. Illustration of industry concentration



Finally, the extent of the spatial units is usually pre-specified to concord with administrative boundaries. As Martin (2012, 13-14) has observed: “The regions and localities we study are rarely functionally meaningful economic entities, but instead are often demarcated - for data collection, administrative or political reasons - along somewhat arbitrary lines.”

As industry concentrations may incorporate parts of different administrative units, restricting the analysis to predefined administrative units is not appropriate. Utilising administrative units also risks being subject to the so-called modifiable area unit problem, where the results are sensitive to the choice of spatial unit.

4 A MEASURE FOR IDENTIFYING SUBSTANTIAL GEOGRAPHIC CONCENTRATIONS

In order to address the shortcomings of existing measures, we propose a Concentration Index (CI index) that can be used to identify *substantial* industrial concentrations. The absolute measure proposed here is not based on specialisation but on disproportionately large shares of the national sector in specific areas. Furthermore, the index takes account of employment in conjunction with the number of firms, as well as the size distribution of the concentrations. Finally, we address the problem related to working with pre-specified administrative boundaries. This begins with a description of the CI index using administrative boundaries. This is followed by outlining a methodology for dealing with the problems arising from administrative boundaries.

The starting point for this measure is that an industry is defined to be overrepresented in a spatial unit when the share of industry employment and number of firms is larger than expected on the basis of a uniform distribution of employment and firms over the total country. The index applies a cut-off equal to twice the share of employment and number of firms expected from a uniform distribution.

$$c = \left[\frac{2}{N}\right] \tag{5}$$

Here*,* c represents the cut-off and N is the total number of counties in a country. The problem here is that physical sizes of the spatial units can differ.[2] This means that a uniform distribution of industry employment over the surface of the country would not result in equal employment in every county. A simple solution for this problem is to use the share of a spatial unit's surface relative to the country surface and multiply that by two as a spatial unit specific cut-off. If the boundaries of spatial units were drawn randomly, this approach would be an optimal solution to account for differences in spatial unit size. However, administrative boundaries are typically drawn with respect to historical settlement patterns with less populated areas having larger spatial units. Consequently, the physical size of a spatial unit is included in the formula:

(6)

[2] Flegg and Webber (1997), in the context of using location quotients in order to derive regional input-output tables, point out that the size of the spatial units needs to be accounted for.

$$c_j = \left[\frac{2}{N}\right]^{\frac{1}{1/\left(\frac{a_j}{a}-\frac{1}{N}\right)}}$$

The relative size is incorporated in the power of the formula *c*, in which *a* is the surface area and *j* is the specific spatial unit. The cut-off is equal to the previous case if the size of spatial units is exactly the average size. When the spatial unit is smaller, the cut-off is lower and vice versa. Table 1 presents the effect on the cut-off for some physically small and large counties in Ireland, the subject of empirical illustration discussed in the next section.

Table 1. Two lowest and highest cut-offs based on area size

County	C_j
Louth	6.90%
Carlow	6.92%
Galway	8.36%
Cork	8.75%

As stated, the indicator uses both employment and number of firms to determine whether an industry in concentrated in a specific region.

$$CI_{ij} = \left(\frac{E_{ij}}{c_j E_i}\right)\left(\frac{F_{ij}}{c_j F_i}\right) \quad \textbf{(7)}$$

CI represents the concentration indicator, *E* is the employment, *F* the number of firms and *i* the specific industry. The separate terms for employment and number of firms are multiplied with each other. If the employment and the number of firms in an industry in a county are equal to the total national industry employment and number of firms multiplied by the cut-off value, the score of the *CI* is equal to one. The multiplication of the two parts makes it possible for an industry concentration to be identified even when one of the parts of the formula has a value lower than one.

A specific element that we want to take into account is the size distribution of the concentrations as discussed in Section 3. A relatively high level of spatial concentration of an industry should decrease the chance for any concentration to be identified as a substantial concentration based on the CI index. This requires the cut-off to reflect the spatial concentration of the industry, which is achieved by utilising an adapted version of the Herfindahl-Hirschman index[3].

$$RCE_i = \sum_j^N \left(\frac{E_{ij}}{E_i}\right)^2 \qquad\qquad RCF_i = \sum_j^N \left(\frac{F_{ij}}{F_i}\right)^2 \tag{8}$$

RCE is the spatial industry concentration for employment and *RCF* is the spatial concentration for firms, which is in both cases a value between zero and one. As with the Herfindahl index, the value is based on the sum of squared shares. However, in our analysis we use the industry employment per spatial unit rather than the firm level industry employment. An outcome of one would mean that all industry employment is concentrated in one spatial unit and if the employment is equally distributed over the country the value would approximate zero.

$$ce_{ij} = c_j(1 + RCE_i) \qquad\qquad cf_{ij} = c_j(1 + RCF_i) \tag{9}$$

ce is the cut-off value for employment in which the *RCE* is used as an multiplier and the *cf* is the cut-off value for firms based in the *RCF*. The result is that *ce and cf* will be doubled if the spatial concentration of an industry is one and that it is equal to *c* if it is equal to zero. Inserting the cut-offs for employment and number of firms in the equation yields the following expression:

$$CI_{ij} = \left(\frac{E_{ij}}{ce_{ij}E_i}\right)\left(\frac{F_{ij}}{cf_{ij}F_i}\right) \tag{10}$$

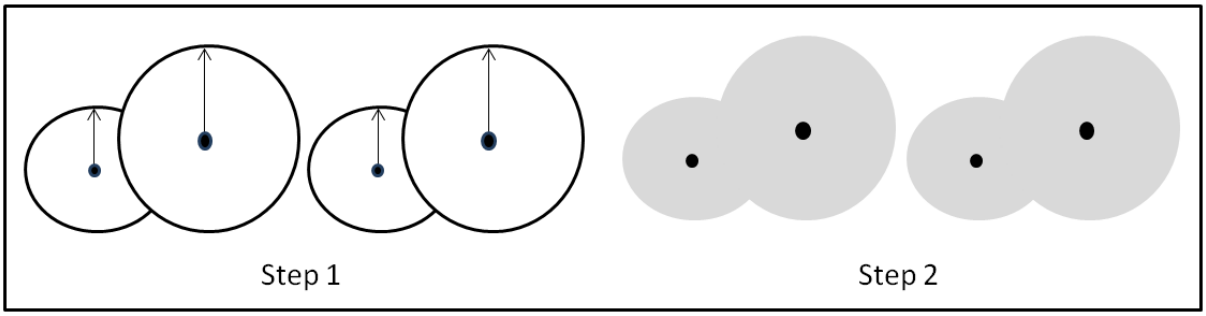
This CI index can be applied to pre-defined administrative units such as counties or regions. However, for reasons outlined, this is not optimal. Therefore a methodology is developed to determine discrete areas that better reflect the geographical shape of industry concentrations[4]. The shape of the areas is determined by the geographical configuration of individual industries and area-specific travel to work flows. The areas are composed of

[3] The inclusion of the adapted form to the Herfindahl-Hirschman index, implicitly further controls for the size distribution of firms.
[4] Other measures incorporating endogenous spatial scale make use of spatial weights matrices which impose a researcher determined spatial structure. See Ariba, G. (2001) and Lafourcade, and Mion (2007).

merged labour fields of plants. The underlying logic is that firms that draw part of their workers from the same area are potentially part of an integrated grouping.

The method involves a number of steps (see Figure 2). The first step is to identify the spatial extent of the labour fields of individual plants in an industry. The size of the labour field is determined by the travel to work area of the electoral district in which the firm is located, based on travel to work data from the CSO POWSCAR dataset, the details of which are provided in the next section. The size of the labour field is calculated as the average travel to work distance of the workers in a specific electoral district and, therefore, varies from area to area. The second step involves merging overlapping labour fields resulting in discrete areas. These areas vary in spatial extent, numbers of firms and employment, and they are industry specific. The CI Index is then applied to the new set of areas to identify substantial concentrations.

Figure 2. Creating discrete areas of overlapping labour fields



One drawback of the methodology is that the resulting output of discrete areas complicates the calculation of the comprehensive CI index as outlined above. The logical adaptation of the CI index would be to use the number of concentrations instead of the number of counties in the formula. One of the complications with this lies in the large difference in the number of concentrations between industries. This results in strongly diverging cut-offs. This is not resolved and for this reason we retain a cut-off derived from county data. The control for county size can be removed, simplifying the formula for the CI index. Another drawback of the methodology is that small, insignificant, plants can link two or more, otherwise discrete, areas. To resolve this, the smallest 1% of the firms is removed from the data set for the identification of discrete areas (but reintroduced for the calculation of the CI index).

5 DATA

The new measure and methodology are applied to data for the Republic of Ireland. While other studies have used total employment as their basic yardstick for identifying geographical industry concentrations, the analysis here focuses specifically on employment in firms which are in receipt of assistance by one of the four Irish government agencies involved in enterprise promotion and development – the Industrial Development Agency, Enterprise Ireland, Údarás na Gaeltachta and Shannon Development. Hereinafter, these firms are referred to as "agency-assisted" firms.

Employment and other data for agency-assisted firms are derived from an annual survey conducted by Forfás, the Irish government's industrial policy advisory agency.[5] For 2012 the Forfás Employment Survey data covers over 8,000 firms with almost 270,000 full time employees. These firms accounted for one sixth of all employment in manufacturing and services. While the coverage is comprehensive particularly in manufacturing, there are some sectors where the coverage in the Forfás data is relatively sparse. Agency-assisted manufacturing firms comprised about 80 per cent of all manufacturing employment and 90 per cent of total merchandise exports (1). Assisted services firms, while representing only seven per cent of total services employment, accounted for around 70 per cent of all services exports. Assisted firms, therefore, account for the bulk of national exports. Overall, therefore, assisted firms can be regarded as acting as key drivers of economic development at both national and regional levels.

The database provides the following firm-level information: number of employees; address and county; electoral division in which located; NACE (Nomenclature Statistique des Activites Economiques) revision 2 code. An important feature of the data set is that it provides addresses of individual firms which can be geo-coded. The resulting point data are an essential input for the proposed methodology to address the problem related to working with pre-specified administrative boundaries. The commuting data used to establish the labour fields of individual plants was taken from the Place of Work, School or College - Census of Anonymised Records (POWSCAR) Census 2011. Another notable advantage of the Forfás data set is that it records the place of work of employees, in contrast to the place of living, as is the case with the Population Census data. This is an important issue in the light of the high level of Irish inter-county commuting.

The methodology outlined above has been applied at the 2-digit NACE level of industrial aggregation. Primary industries have been excluded from the analysis. A small number of additional industries have been distinguished and added to the 2-digit NACE classification including Medical Devices and Software. These have been included because of their size and importance to the Irish economy. Their inclusion has also been driven by heuristic considerations in that extant literature provides considerable empirical knowledge about the geography of these industries in Ireland to which the output of the proposed index and methodology can be compared. The three industry groups have been constructed by combining selected 3-digit NACE categories. Very small industries, in terms of employment and firms, have been combined into a residual group of Other Manufacturing and Services.

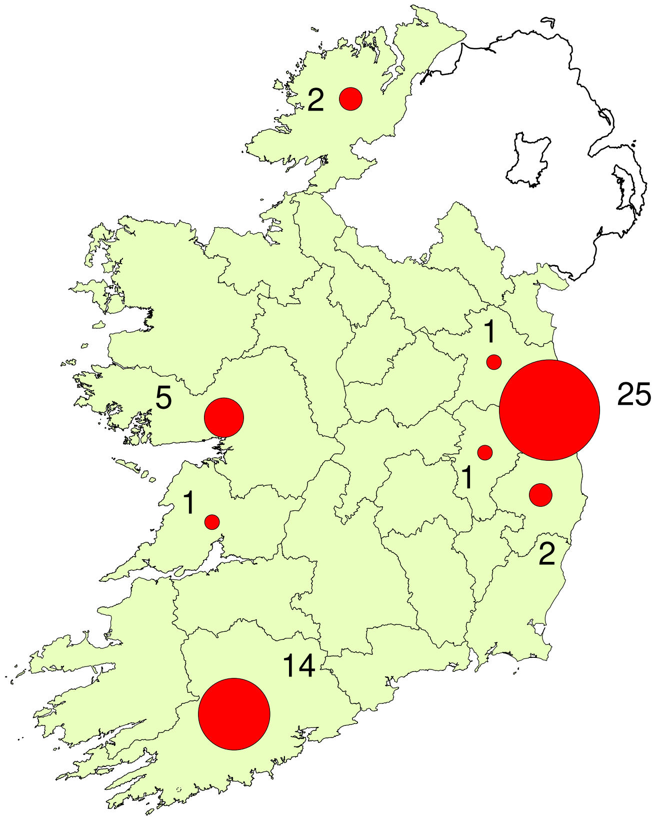
[5] The authors would like to thank Forfás, now the Strategic Policy Division within the Department of Jobs, Enterprise and innovation, for allowing the researchers access to this data.

6 SUBSTANTIAL CONCENTRATIONS IN THE REPUBLIC OF IRELAND

This section examines the merits of the CI index in the empirical context of the Republic of Ireland. The analysis begins with a general discussion of the number of substantial industry concentrations identified and their location. This is followed by a more detailed analysis of its application to three industries: Medical Devices, Pharmaceuticals and Software.

Applying the CI index using pre-specified administrative county boundaries produces a total of 51 substantial concentrations. Figure 3 shows how these concentrations are co-located in a small number of counties: 25 in Dublin; 14 in Cork and 5 in Galway. These are among the counties in Ireland with large urban centres and employment concentrations. In contrast, all other counties have very few concentrations, with 18 counties having no concentration at all. This result was expected since counties with relatively small numbers of firms and/or employment overall, are unlikely to have substantial numbers of firms and/or employment in individual industries. Conversely, counties with relatively large numbers or firms and/or employment overall, are bound to have substantial numbers of firms and/or employment in individual industries. The main anomaly here is County Limerick which, despite of being among the four main employment concentrations in the country, has no substantial geographic industry concentration. The output generated by the CI index is significantly different from that of an analysis based on location quotients where, per definition, each area will be specialised in at least one industry and, generally, a number of industries.

Figure 3. Number of substantial industry concentrations per county (based on CI index applied at county level)



Figures 4 to 6 illustrate the application of the CI index and method on three specific industries: Medical Devices, Pharmaceuticals and Software. The output is contrasted with the output of a simple location quotients analysis. For each sector the figures present the concentrations based on the location quotient analysis (left map), the substantial concentrations based on the CI index applied at the county level (centre map) and the substantial concentrations based on the CI index at the level of overlapping labour fields (right map). Starting with Medical Devices, the location quotient analysis suggests quite extensive areas of concentration, covering nearly half the country, though not including Counties Dublin and Cork, the counties with the two main urban centres. Applying the CI index at the county level reduces the number of counties with substantial concentrations to two, now including County Cork which was not picked up as a concentration by the location quotient analysis. The concentrations are rather coarsely defined, covering the entire area of two counties. The overlapping labour field methodology not only refines the geographical extent of the identified concentrations but also detects other concentrations around

Limerick, Athlone and Dublin. This map closely expresses the empirical reality described in extant literature (Curran and Van Egeraat, 2014; Giblin 2008).

Moving to the Pharmaceutical industry we also observe diverging sets of industry concentrations yielded by the competing measures. Here, the location quotient analysis suggests quite extensive areas of concentration, covering one third of the country, though not including County Dublin. Applying the CI index at the county level reduces the number of substantial concentrations to Counties Dublin and Cork. Once again, the overlapping labour field methodology not only refines the geographical extent of the concentrations but also identifies an additional discrete substantial pharmaceutical concentration around Waterford. This method provides a precise depiction of the empirical reality of two discrete substantial pharmaceutical concentrations in the south of Ireland, one focused on drug substance chemical synthesis (around Cork) and one on drug product manufacturing (around Waterford) (see Van Egeraat and Curran, 2014).

The analyses of the Software industry again support the benefits of the labour field version of the CI methodology. The location quotient analysis suggests concentrations in County Dublin and County Leitrim in the north-west, the least populous country of the country bereft of any significant urban concentration. County Leitrim's software industry 'concentration' consists of two firms employing about 450 workers. In contrast, the grouping of over one hundred software firms in Cork, employing over 7300 workers is not detected. This is resolved by the application of the CI index at the county level which identifies two substantial concentrations, Cork and Dublin, the counties with the two main urban centres. The overlapping labour field is again more refined but also suggests that the substantial concentration around Dublin is spatially more extensive, stretching into Dublin's hinterland.

The output for all industries is summarised in Table 2. The analysis reveals striking differences across industries with respect to their spatial configuration, with some substantial concentrations encompassing the entire country while others are regional or local. Arguably, concentrations covering most of the country should not be referred to as concentrations. In fact these are ubiquitous industries, the opposite of geographically concentrated industries. These include the more traditional industries including: Food Products; Wood and Wood Products; Other Non-metallic Mineral Products; and Fabricated Metal Products.

Figure 4. Application of three methodologies to Medical Devices industry

significantly.

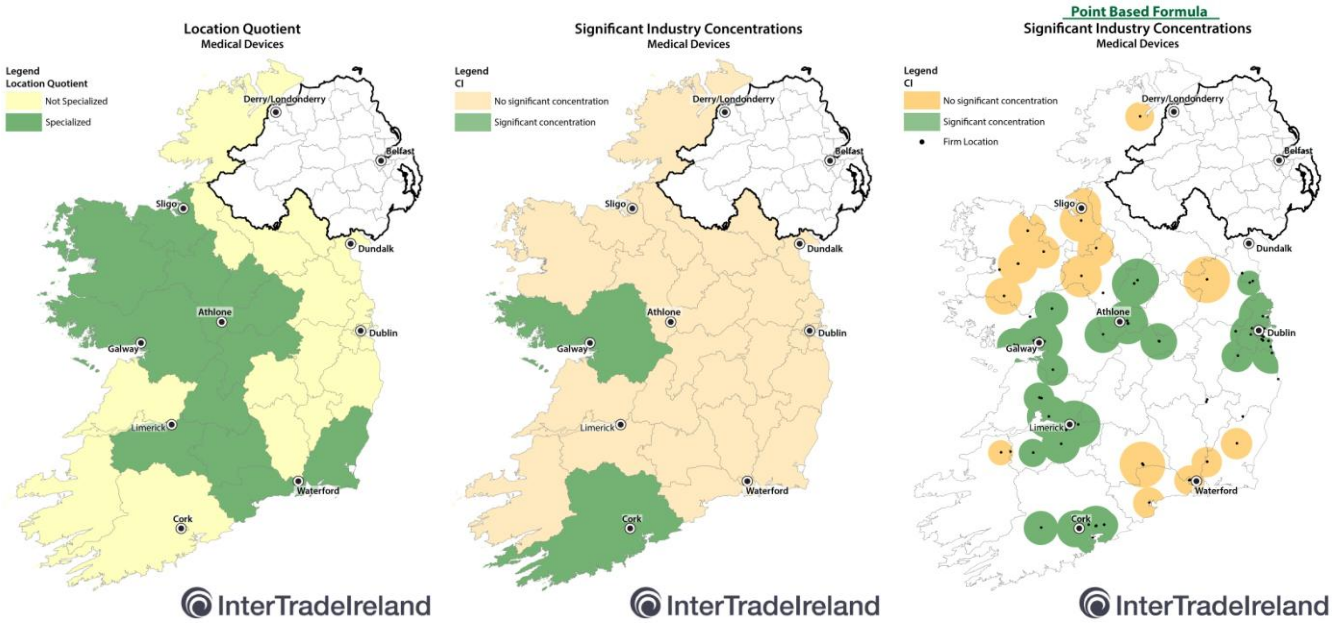


Figure 5. Application of three methodologies to Pharmaceuticals industry

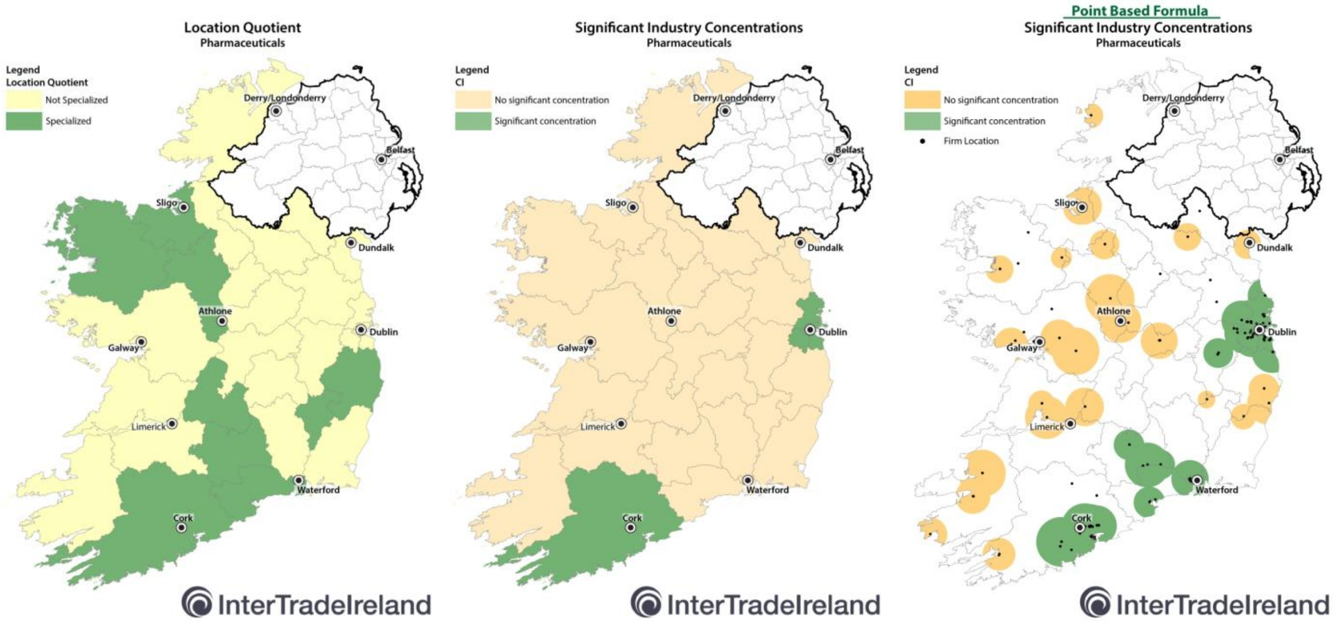
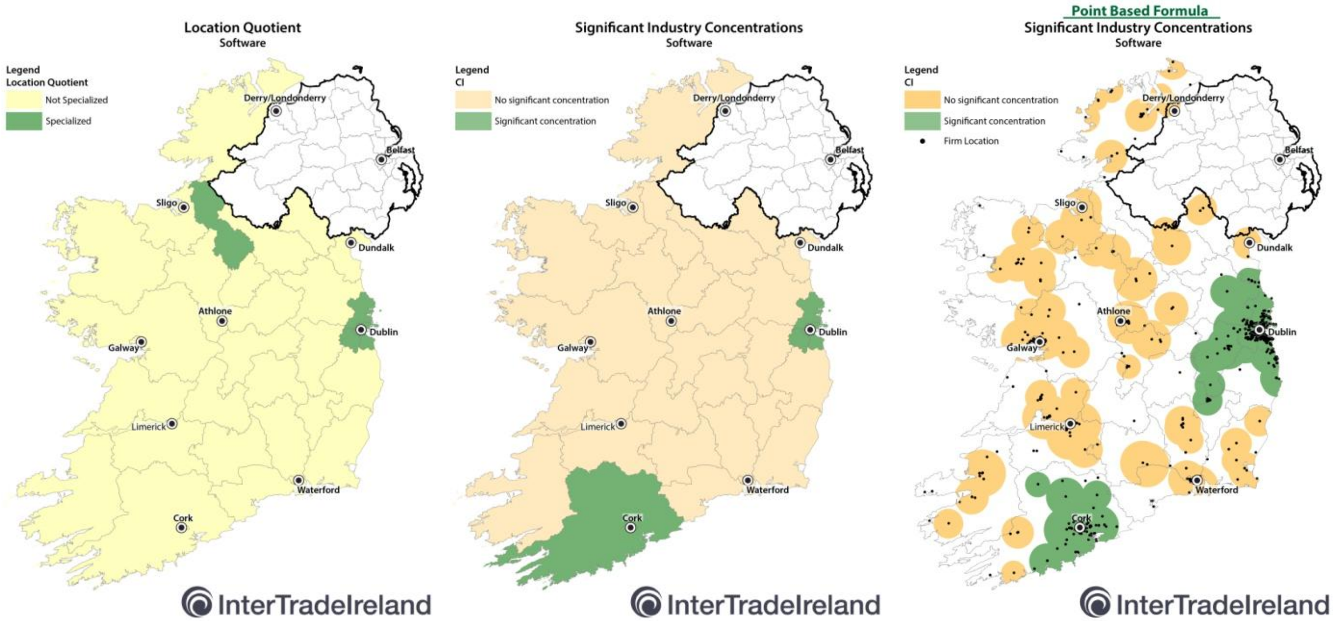


Figure 6. Application of three methodologies to Software industry



Most other industries are characterised by three or less substantial concentrations with a substantial number of single-concentration industries. All non-ubiquitous industries have a concentration encompassing Dublin. In relation to the three other main employment centres, Cork is included in substantial concentrations of four industries, Limerick in three, and Galway in two. The anomaly of Limerick, observed in the context of applying the CI index at the county level, is therefore resolved when using the labour field methodology.

Overall, the labour field methodology results in a total of 31 substantial concentrations, a reduction of 20 compared to the CI index applied to the county level. 29 of these concentrations encompass at least one of the main employment centres in the country. This is an even smaller share than was observed in the context of the CI index applied at county level. However, due to the fact that concentrations are now crossing county boundaries, a greater number of counties are, at least partially, incorporated in substantial concentrations. The fact remains, however, that many area and counties are not linked to any substantial industry concentrations (ignoring ubiquitous industries). These tend to be peripheral locations with no substantial employment centres, such as Counties Donegal, Mayo, Kerry and Leitrim as well as the peripheral areas of Counties Cork and Galway, predominantly in the west of Ireland.

Table 2. Substantial industry concentrations (based on CI index and labour field methodology)

Industry	**Detail**	**Number**
Manufacturing of food products	Ubiquitous	0
Manufacturing of Beverages	Dublin	1
Manufacturing of textiles	Dublin/Mid-East region, reaching into Dundalk	1
Manufacturing of wearing apparel	Dublin/Mid-East region	1
Manufacturing of wood and wood products, except furniture	Very extensive - Leinster province/ West/Midlands	0
Manufacture of paper and paper products	Dublin reaching into the Mid-East region	1
Printing and reproduction of recorded media	Dublin	1
Manufacture of chemicals and chemical products	Dublin reaching into Midlands; Cork; Limerick	3
Manufacture of basic pharmaceutical products and pharmaceutical preparations	Dublin; Cork and Waterford/South East	3
Manufacture of rubber and plastic products	Midlands plus Monaghan, Dublin/Mid-East coast	2
Manufacture of other non-metallic mineral products	Almost ubiquitous except for the West and South	0
Manufacture of fabricated metal products, except machinery and equipment	Almost ubiquitous	0
Manufacture of electrical equipment	Dublin; Limerick	2
Manufacture of motor vehicles, trailers and semi-trailers	Greater Dublin	1
Manufacture of furniture	East coast including Monaghan down to Waterford and Midlands region	1
Manufacturing of Medical Devices	Dublin; Midlands; The West; Cork	4
Repair and installation of machinery and equipment	No single substantial concentration	0
Publishing activities	Greater Dublin	1
Motion picture, video and television programme production, sound recording and music publishing activities	Dublin stretching into Wicklow; Galway	2
Computer programming, consultancy and related activities	Extensive concentrations Dublin/Mid-East; Cork	2
Information service activities	Dublin	1
Financial services activities, except insurance and pension funding	Dublin	1
Activities of head offices; management consultancy activities	Dublin, stretching into Kildare	1
Architectural and engineering activities; technical testing and analysis	Dublin reaching south to Carlow and into the Midlands region	1
Office administration, office support and other business support activities	Dublin, reaching into the Mid-East region	1

7 CONCLUSION

Geographical concentration of competitive firms in specific industries is generally believed to provide advantages to the firms involved and to set in motion cumulative processes that will lead to the further development of these concentrations in specific areas. At the same time, the growing competitiveness of these existing concentrations will impede the development of similar industries in other areas. Regional industrial policy therefore tends to include the notion of building on existing concentrations of competitive firms.

The identification of existing concentrations is often based on geographical concentration and industrial specialisation indices that do not provide a direct insight into the relative size or importance of individual concentrations. Arguably, regional industrial policy making inspired by cluster thinking should focus on *substantial* concentrations. These are the concentrations which have the best potential for further development. Further shortcomings of existing indices include the fact that they tend not to account for the number of firms in a concentration, as well as their restriction of the analysis to pre-defined administrative units.

As existing measures are inadequate, this article proposes a new Concentration Index that can be used to identify *substantial* industrial concentrations. It has a number of features:

- It is not based on specialisation but on disproportionately large shares of the national sector in specific areas.
- It takes account of the scale of employment in conjunction with the number of firms.
- It takes account of the size distribution of concentrations
- It does not work with pre-specified administrative boundaries but, instead creates industry-specific discrete areas, based on area-specific commuting fields of the labour force.

The measure and methodology were applied to recent data for the Republic of Ireland. The analysis supports the benefits of the index and methodology over existing indices. The measure only identifies substantial industrial concentrations. Compared to the output of traditional indices, the measure produces fewer concentrations that are more suitable targets for industrial policy. Most of these concentrations encompass the main employment centres of the country. However, the output is not simply a reflection of the general employment distribution. The analysis highlights important differences across sectors and identifies concentrations of differing spatial extent.

The analysis clearly demonstrates the advantage of the overlapping labour fields methodology over working with pre-specified administrative boundaries. It shows how many concentrations extend into neighbouring counties. For some non-core counties and areas, this identifies opportunities and targets for policy making that could have been ignored when using more traditional indices. It also underscores the importance of coordinating industrial policy at the regional level. The fact remains, however, that many peripheral areas and counties are not linked to any substantial industry concentrations. This is equally informative for policy making. It suggests that cluster type, or smart specialisation type, industrial policies are less suitable or less effective in such areas. This does not mean that there are no opportunities for industrial development. Some of the ubiquitous industries provide opportunities for development. Or industrial policy may 'simply' focus on creating key framework conditions that support industries in general.

The proposed CI index and methodology have two drawbacks that may be the subject of further study. Firstly, the index and methodology may not be directly transferable to other contexts with different settlement and sectoral structures (size distribution of firms). In the context of Ireland and the specific dataset used, the methodology of overlapping labour fields does not present sufficiently discrete labour fields. To resolve this, the smallest 1% of firms is removed from the data set. In other countries, depending on the settlement and sectoral structure, a smaller or larger percentage of firms may need to be removed. The other drawback, related to the overlapping labour field methodology, is that the output complicates the calculation of the comprehensive CI index. The pragmatic solution adopted means that the CI index loses some of its sophistication.

Finally, as with all indices, the CI index and methodology merely identifies substantial geographical industrial concentrations. Such concentrations may be suggestive of the existence of agglomeration economies and beneficial clustering processes that industrial policy may link into. However the workings of such economies and processes will have to be established in detailed industry analysis.

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