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Clustering in Ireland: development cycle considerations

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ABSTRACT

Motivated by ongoing research into the cluster concept that considers dynamic features of economic development and the cluster life cycle, differences between traded clusters and local activity across different spatial scales are examined for Ireland. Using recent cluster definitions for Europe, this paper presents clustering patterns within the Irish economy from 2008 to 2012. We report on data requirements when applying the benchmark cluster definitions to Irish data. Integrating small, open economy features with life-cycle concerns, we focus on specific clusters in Ireland, along with their export performance, noting that appropriate cluster boundaries are neither regional nor national. Analyses indicate that while Ireland hosts a number of internationally competitive clusters, foreign-owned firms remain substantially more productive than indigenous enterprises. We identify the geographical location of these prominent clusters at the NUTS-3 regional level and highlight the role of regional features for differences in adaptive cycles of clusters. We identify a substantial portion (60%) of Irish regional wage variation relates to the different cluster mixes across regions.

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INTRODUCTION

Interest in clusters and cluster-based policies in Ireland dates back to the Culliton Report (Culliton, 1992), which highlighted the importance of a competitive business environment to the development of enterprise and recommended the promotion of clusters focused 'on niches in national competitive advantage' (Doyle & Fanning, 2007, p. 268). The Culliton Report's policy recommendations were heavily informed by Porter's (1990) definition and measurement of clusters.[1] Clusters were described as 'geographic concentrations of interconnected companies and institutions in a particular field' (Porter, 1998, p. 78). Porter (1990) identified the potential of clusters within a framework of locational competitive advantage as providing mechanisms for improving national, regional and local productivity, innovation capacity and new business formation.[2]

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Previous research on Ireland by O'Connell, Van Egeraat, and Enright (1997), Clancy and Twomey (1997), and O'Gorman, O'Malley, and Mooney (1997) investigated the quality of the Irish business environment, finding little evidence of Porterian-type clustering[3] amongst a set of indigenous Irish activities: Irish dairy processing, Irish popular music and Irish indigenous software activities. However, cluster-based studies in Ireland have not been limited to the Porterian framework with other research (Van Egeraat & Curran, 2013) drawing on early location theory (Weber, 1929) and on New Economic Geography (Krugman, 1991a, 1991b) to consider the spatial concentration of industrial activities in Ireland. Despite the growing importance of service-based economic activities, they have received relatively little attention in general or in specific discussions of clusters of economic activity.

Developments in research on clusters increasingly focus on cluster performance and outcomes over cluster 'life cycles', i.e., the evolution of clusters over time (e.g., Boschma & Fornahl, 2011; Fornahl & Hassink, 2017). Such approaches emphasize dynamic features that influence cluster development and transformation – building on foundations mainly from product life-cycle and, more recently, ecology research (Martin & Sunley, 2011; Vernon, 1966). The role of actor-centric approaches has also recently been identified as contributing to understanding cluster performance over time (Giuliani, 2007). Implications for policy are surprisingly absent from research (with the exception of Brenner & Schlump, 2011), given the wide acceptance and implementation of cluster-related policy.

With advances in cluster research evident internationally, both empirical and conceptual, to date cluster studies for Ireland have been limited. Doyle and Fanning (2007) note that clusters are not confined explicitly to high-level industrial classifications (e.g., the two-digit Statistical Classification of Economic Activities in the European Community – NACE) but rather take the form of different groupings of businesses capabilities. Thus, focusing on highly aggregated industrial classifications may not facilitate cluster analysis since they are product or output focused. The selection of *non*-internationally competitive activities and sectors in previous Irish empirical studies meant cluster identification was impeded: Porter's (1990) cluster approach emphasizes success in international competition as a fundamental determining feature of clusters.

This paper organizes Irish data through a cluster lens across various levels of geographical scope, acknowledging data constraints. Newly defined classifications of clusters highlight economic activities which are internationally competitive, including both manufacturing *and* services elements of those successful activities, and regions in which there is a specific geographical concentration. Therefore, this paper's main contribution is in providing a top-down quantitative organization and analysis of Ireland's economic activity and it is a complement and aid to bottom-up qualitative research in identifying and understanding the nature of clustering in Ireland. While the time-frame of the analysis (2008–12) limits comprehensive dynamic or life-cycle considerations, implications are drawn for incorporation into further cluster research for Ireland, specifically those features of relevance for complex adaptive systems (Cumming & Collier, 2005).

The paper is structured as follows. The next section details the approach and methods in the context of the current understanding of cluster dynamics and their performance over time, including the data employed and their limitations. The third section presents comparisons between economic features of *traded* and *local* clusters at different spatial scales across Ireland. The fourth section presents a further disaggregation of traded clusters focusing on Ireland's most prominent clusters as measured by export performance, noting the duality between indigenous and foreign-owned plants. Export patterns across clusters are identified in terms of their associations with the cluster life cycle and systemic features influencing dynamics. The fifth section identifies, at the NUTS-3 (Nomenclature of Territorial Units for Statistics) level, the geographical concentrations of these export-intensive clusters in employment terms and identifies implications for regional wages. The sixth section summarizes and draws conclusions.

FUNDAMENTAL ECONOMIC FEATURES: CLUSTERING

The analysis of an economy can include many facets depending on the characteristics of interest, e.g., scale, ownership, location or technological orientation. Whereas O'Leary (1999, 2001) and Morgenroth (2007) examined Irish regional economic performance, this study focuses on applying the cluster definitions and structure set out in Ketels and Protsiv (2014).

The appropriate categorizations for economic activity have long exercised researchers (Studenski, 1958; Coyle, 2015). Insofar as clusters are concerned, one standard definition employed is 'geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions … in particular fields that compete but also cooperate' (Porter, 1998, p. 197). The range of historical intellectual antecedents to the cluster are outlined by Brosnan et al. (2016) with a key addition of the cluster identified as its linking of locational features – across different spatial scales – to drivers of business competitive advantage that generate international market positions. The systemic nature of such features bridge locational and relational elements.

Recent extensions and development of the cluster concept have progressed to consider its evolution, or life cycle, through periods of emergence, growth, decline and perhaps renewal (Fornahl & Hassink, 2017). While an appropriate framework or approach to analysing clusters over time has not been agreed, several authors borrow from the product life-cycle approach to use a cluster life-cycle strategy (e.g., Bergman, 2007; Ter Wal & Boschma, 2011). But while a cyclical approach might have relevance for products, its suitability for a concept as broad and encompassing as the cluster has been questioned. Martin and Sunley (2011) propose an alternative phylogenetic evolutionary conception as potentially more appropriate and examine the implications of applying a complex adaptive systems approach to the cluster. This matches the reported capacity of clusters to take account of novel, new or extended linkages, absent from standard industry product-based classifications: linkages that would otherwise have gone unnoticed were identified through the use of cluster categorizations (Neffke & Henning, 2013).

Cumming and Collier (2005) identify meta-models of complex systems identifying three features that distinguish the models. The breadth of these models suits the nature of the cluster concept and its applicability to different geographical scales, geographies, and interfirm and inter-institutional linkages. The features relate to the maintenance of a continuous identity of the system over time, whether an alternative stable state of the system could exist, and the strength or weakness of exogenous forces on the system. Adding both evolutionary and life-cycle models to Cumming and Collier's (2005) analysis, Martin and Sunley (2011) assess implications for the cluster. The adaptive cycle model displays many general features with broad applicability to clustering phenomena, i.e., features which explain stability, decline, mutation or re-orientation of clusters in different locations and incorporating contingent agency. A number of development trajectories emerge dependent on strategic decision-making of cluster-firms. These trajectories relate also to the role of increasing returns (both local and distant) that impact potential benefits exploitable through agglomeration and co-location via clustering (see the discussion based on Young, 1928, in Brosnan et al., 2016).[4]

Although outside the focus of the conceptual research above (Cumming & Collier, 2005; Martin & Sunley, 2011), the issue of data arises for those interested in operationalizing the meta-models. Concepts of accumulated specialized capital, specialized knowledge, the nature and range of specialized supporting institutions, and resilience, i.e., system adaptability, all feature as important for understanding system outcomes. Challenges exist in generating reasonable and robust measures of these features and require substantial research with some measures appropriate for primary data collection and qualitative research.

In the context of the current study, and as a first approach, employment, wages and productivity data offer high-level measures of the relative importance of a cluster in its regional and

national context. Employment trends across clusters offer insight, albeit within limits, on the relative positioning of clusters. Employment is of particular interest for employment related key performance indicators (KPIs) of relevance for economic development policy-makers and practitioners. Regional skill-mix data, and their changes over time, would offer further granular information on labour market dimensions of relevance – but with the disadvantage of not being as widely available, and not on a cluster basis in the Irish case. Production-related measures could include stock-keeping units (SKUs) as a measure of the diversity of consumption, or complexity of production offers an additional product-based perspective as provided through complexity analysis in, e.g., Hausmann et al. (2014). Similarly, export data offer an insight into the trading performance of clusters. To date, such data vary in terms of availability on a cluster basis as well as concordance across classifications used for compilation and reporting.

Cluster-based data

Using benchmark cluster definitions (BCDs), we group Irish economic activities from NACE Rev. 2 into distinct, disaggregated (four-digit) and analytically separate classifications which Porter (2003) denoted as traded and local clusters.[5] Both contribute in different ways to the local, regional and national economy. Local economic activities provide goods and services primarily targeting local markets (Porter, 2003) and compete in a limited way with activities in other regions. Examples include retailing, private healthcare services or local amenities. In contrast, traded activities provide goods and services that may cross not only regions but also countries. Porter (1990, 2003) notes that traded activities tend to locate based not on resource supply or availability but on broader competitive considerations. Examples include the biopharmaceutical, automotive or insurance sectors. It is these traded activities where internationally competitive clusters of firms can develop in particular locations.

Recent cluster definitions were identified by Delgado, Porter, and Stern (2016), who grouped 1088 narrowly defined US sectors (six-digit North American Industry Classification System – NAICS) in manufacturing and services into a set of BCDs. Data for 2009 were sourced across county business patterns, national input–output tables and occupational employment statistics. (The earliest classification of traded and local activities was based on 1996 US data and four-digit standard industrial classification (SIC) codes for economic activity and state regions; Porter, 2003.)

The basis for defining and measuring clusters from these data relate to the various and complex linkages across firms and activities, which involve knowledge, skills, technology, inputs and demand, which generate benefits from co-location of certain types of activities in some locations rather than others. Co-location patterns are the outcome of that complexity without providing insight into its specific nature for any location or economic activity.[6] The cluster definitions and measures that emerge are regionally comparable. An algorithm is used to define clusters of economic activities including criteria for scoring alternative cluster configurations. Once the most promising configurations are identified, the algorithm addresses outlier activities to define mutually exclusive cluster definitions. The approach allows the measurement of relatedness between any pair (mutually exclusive) of clusters and the creation of overlapping clusters (with some individual activities shared by multiple clusters). A set of 51 distinct clusters was identified.[7]

Cluster definitions in Ketels and Protsiv (2014) incorporate the above BCDs into previously developed cluster categories prepared in a first phase of the European Cluster Observatory Project (ECOP),[8]) which had included 38 cluster categories across 302 four-digit NACE activities.[9] Applying these categories to Irish data, although developed from the structure of the US economy and its underlying interlinkages, is appropriate for a number of reasons. To date, the available data across European economies are not available at sufficiently granular levels – by plant – or at geographically appropriate levels to permit the assembly of more meaningful cluster-based data. In addition, the United States has been a more fully integrated economy then

the European Union and for a longer period. To the extent that productivity improvements are supported by such integration, the types of benefits of linkages that are encompassed in clusters would be more likely where market frictions are absent due to integration. In relative terms, the 'productivity effect of local externalities' may be expected to be larger for the United States than for the European Union, whereas the extent of the market and market access is a 'more powerful driver' of productivity for Europe (Ketels & Protsiv, 2014, p. 5). Applying BCDs based on US data to other economies assumes stronger productivity-enhancing linkages than may actually be the case for European economies and regions. Ketels and Protsiv (2014) make adjustments too for European data for activities that are prominent in a European context, e.g., shipbuilding, and pulp and paper.

Data set for cluster analysis

Core data are taken from the Census of Industrial Production (CIP), Annual Services Inquiry (ASI) and Business Demography (BD) from the Irish Central Statistics Office (CSO), and the International Cluster Competitiveness Project (ICCP) of the Institute for Strategy and Competitiveness.[10] ICCP data are sourced from the United Nations Commodity Trade Statistics and International Monetary Fund Balance of Payments Statistics. Given the availability of data according to NACE Rev. 2, our analysis is conducted for the period 2008–12. Data from the CIP are regionally representative for Ireland. However, the ASI is survey based for all enterprises with 20 persons or more and is considered not regionally representative below the NUTS-2 level. For services enterprises with fewer than 20 persons engaged, a stratified random sample is selected, with decreasing sampling proportions taken in the lower ranges. Therefore, data from the ASI are considered representative at a regional (NUTS-2) level, of which there are two in Ireland.

The CIP data can be organized into 34 separate regions (CSO, 2012, 2014). Business demography data, while having broad industrial and services coverage at an identical geographical scope to the CIP[11], are available only for employment data – whereas ASI and CIP provide data on exports, wages and performance variables including turnover at plant level. Following Ketels and Protsiv (2014), cluster classifications allow for grouping 406 distinct four-digit NACE Rev. 2 categories into 51 separate clusters. Of these, economic activity in 36 clusters can be identified for Ireland, with some qualifications.

Data for BCDs of Financial Services, Forestry, Insurance Services and Performing Arts are not collected through either the CIP or ASI. As neither the CIP nor ASI include certain NACE activities, e.g., NACE A – Agriculture, Forestry and Fishing, some BCD contain fewer four-digit activities than the corresponding general cluster definition. For instance, Agricultural Inputs and Services in benchmark categories consist of five four-digit NACE codes. Only one of these is available from the ASI or CIP (specifically 20.15 Manufacture of Fertilisers and Nitrogen Compounds), meaning that employment data from the CIP in this cluster are understated relative to employment data available from the BD source. This is similar for the Education and Knowledge Creation cluster as neither CIP nor ASI provide information on certain activities. However, in using CIP and ASI data sources, rather than BD, average wages data are available by cluster.

Some Irish clusters cannot be reported due to confidentiality issues, i.e., when three or fewer firms dominate the cluster, nationally or regionally. These include Aerospace Vehicles and Defence, Appliances, Coal Mining, Electric Power, Jewellery and Precious Metals, Leather and Related Products, Marketing, Design and Publishing, Music and Sound Recording, Oil and Gas Production and Transportation, and Tobacco.

The ASI utilizes a grossing factor to obtain national and NUTS-2 regional-level figures, with certain challenges. As some clusters, e.g., Hospitality and Tourism, consist of NACE data from across very different four-digit activities, as well as some clusters requiring a combination of both ASI and CIP data (e.g., Information Technology and Analytical Instruments), care must be taken

when interpreting figures, as the grossing factors (calculated by the Irish CSO) have not been constructed with the purpose of amalgamating data into the BCD.

IRELAND'S TRADED AND LOCAL CLUSTERS

Table 1 provides a breakdown of local and traded economic activity over the period 2008–12 based on data for employment growth, output share (gross value added – GVA), exports (i.e., turnover attributable to exports), average wages and wage growth.[12]

We note local activities account for the largest share of Irish employment, at 66%.[13] We identify a small proportion of Irish local activity is engaged in international trade, contributing a little over 2% to exports – revealing slight variation relative to the US-based definitions.

Although traded economic activities account for one-third of national employment, they are central to prosperity, generating 85% of output and 98% of exports. Average wages were 162% for traded relative to local activities. While local activities experienced an average 6.1% annual decline in wages and a 4.9% decline in employment over the period, wages in traded activities grew by over 1% annually, despite economic crisis. The annual decline in employment featured for traded activities at a rate of 3.7%, was approximately 75% of the decline exhibited in local activity. Employment growth rates over the period highlight how local activities responded more adversely to the economic downturn.

Drilling into the regional picture, Irish employment data were taken from BD, with wages and output (GVA) drawn from the CIP and ASI. With limitations of ASI data, output and wages analysis of local and traded economic activities is limited to two NUTS-2 regions in Table 2.

Again, shares of employment are most concentrated in local activities in both regions. The South and East region exhibited higher employment concentration in traded activities. In both regions, over 75% of the GVA is contributed by traded activities and the share, at 87%, is highest in the Border, Midlands and West (BMW) regions. Export shares in both regions are over 97% for traded activities.

National and NUTS-2 data point to additional considerations to those identified in either the life-cycle context or the adaptive cycle preferred by Martin and Sunley (2011). The role of the local environment in determining the employment and output performances of clusters, 'local' referring to NUTS-2 geography, is quite different. In terms of prosperity indicators for the two regions, average wages are higher for both traded and local activities in the South and East region: the average traded wage was 28% higher and local wage was 12% higher. Within the South and East region, workers in traded activities earned 62% more than workers in local activities: the comparable figure for the BMW region was 43%. Annual wage growth in traded activities of 1.8% was faster in the BMW region than the 1.1% observed for the South and East

Table 1. Traded versus local activities in Ireland, 2008–12.

Variable	Traded	Local
Share of employment (%), 2012	35.1	65.9
Employment growth (CAGR) (%), 2008–12	–3.7	–4.9
Share of output GVA (%), 2012	85.4	14.6
Share of exports (%), 2012	97.6	2.4
Average wage (2014€)	41,411	25,497
Wage growth (CAGR) (%), 2008–12	1.1	–6.1

Note: CAGR, compound annual growth rate; GVA, gross value added.

Sources: Employment data are taken from Central Statistics Office (2008b, 2012b). Output and wage data are taken from Central Statistics Office (2008a, 2008c, 2012c).

Table 2. NUTS-2 traded and local economic activities, 2008–12.

	Traded activities		Local activities	
Variable	South and East	Border, Midland, West	South and East	Border, Midland, West
Share of employment (%), 2012	37.2	28.0	62.8	72.0
Employment growth (CAGR) (%), 2008–12	–3.3	–5.1	–4.8	–5.2
Share of output GVA (%), 2012	76.6	87.1	23.4	12.9
Share of exports (%), 2012	97.4	97.7	2.6	2.3
Average wage (2014€)	42,878	33,620	26,379	23,568
Wage growth (CAGR) (%), 2008–12	1.1	1.8	–6.4	–3.4

Note: CAGR, compound annual growth rate; GVA, gross value added.

Sources: Employment data are taken from Central Statistics Office (2008b, 2012b). Output and wage data are taken from Central Statistics Office (2008a, 2008c, 2012c).

region. In both regions, local average annual wages declined with decline faster in the South and East (–6.4%) than in the BMW region (–3.4%).

The complex adaptive system represented by each cluster (definition) confronts different feedback mechanisms, depending on regional context and its self-reinforcing interactions. Cluster-wide features are identified as macro-scale characteristics (Sawyer, 2005) that can exert downward causation effects on micro-scale components of the cluster, e.g., individual firms. Unobserved differences in localization economies, agglomeration effects and knowledge development and spillovers could thus play roles in the variability of regional cluster performance. This is considered further in the fifth section for different regions (NUTS-3) and clusters.

As data on services are not considered representative at more granular geographical levels, the consideration of local and traded clusters is limited to employment data only. Considering a breakdown of traded and local employment shares across Ireland's eight NUTS-3 regions, similar trends are evident (not detailed here). An average 60%/30% split between traded and local employment is evident. While traded activities pay higher average wages and generate higher levels of GVA and exports, local activities were more susceptible to the contractionary employment effect of the economic downturn (echoing Tables 1 and 2).

EXPLORING TRADED CLUSTERS

We exploit the CIP and ASI data to construct cluster-based wages data. Table 3 presents data for each of Ireland's 36 clusters on employment, wages and their respective growth rates from 2008 to 2012 (rankings for the top 10 performing clusters by employment share, wage level and wage growth are shown in bold). The largest cluster is identified as Business Services, in which 119,004 people were employed in 2012 (similar to the United States in Porter, 2003). Average cluster wages in 2012 ranged from €60,915 and €60,422 in Upstream Chemical Products and Biopharmaceuticals respectively to a low of €19,510 for Hospitality and Tourism (ranked second for employment share).

To the extent that employment share and its trajectory is indicative of cluster stage, Table 3 provides information on these aspects of performance. Brenner and Schlump (2011, p. 1365) relate employment shares to a 'critical mass' that is reached after the initial phase of a cluster life cycle and is the outcome of '[l]ocal conditions as well as the kind and number of firms in

the region'. Elsewhere, the authors note the similar dynamics of regional employment and firm growth (Schlump & Brenner, 2010).

Additionally, we can identify those clusters for which average wages exceeded the average for the economy (averaged across 36 traded clusters) which was just over €41,400 in 2012 (Table 3, column 6: figures shown in bold are higher than the national average). Central to the arguments of Porter (1990, 1998) was that evidence of clustering is found in productivity and reflected in wages, i.e., assuming pass-through from productivity to prosperity. Wages' trajectory over time, and across clusters, should reveal those economic activities where productivity is highest and thus also link to stages of life-cycle characteristics.

Focusing on growth rates of average wages, Video Production and Distribution saw the fastest increase, while Non Metal Mining witnessed the largest decrease. Of the 36 clusters, only seven recorded employment growth. Of these, two clusters, Medical Devices and Livestock Processing, rank in the top 10 for employment shares (2012).

Textile Manufacturing ranked 22 out of 36 for wage level and exhibited the fastest wage growth (6.2% per annum (p.a.)) over the period, followed by Information Technology and Analytical Instruments (5.2%). Video Production and Distribution exhibited fastest employment growth, but the greatest wage decline, at 4.1%.

International performance of clusters

Given Ireland's reliance on exports as a route to industrialization and to fuel economic growth (Brady, Doyle, & Noonan, 2013), Table 4 presents the top 10 best-performing clusters by export value. In terms of the cluster life cycle, export trends offer additional perspective on relative performance, particularly in the light of the product-cycle origins of the concept and the changing geographical sources of competitive advantage explicit therein (Vernon, 1966).

Although data on GVA, wages and exports are not available from the CSO for Insurance Service or Financial Service, export data are available from the Institute for Strategy and Competitiveness for Ireland (Porter & Bryden, 2015) through its International Cluster Comparison Project (ICCP). In this context, and as a small, open economy, it is appropriate to acknowledge the role of structural and trading relationships for clusters in Ireland for properly delineating the cluster boundaries, and the sources of 'downward causation' via international channels. The strong foreign direct investment (FDI) component within Irish clusters is likely to lead to stability in the identity of the clusters over time, but also plays an important role in the ability to move into new product lines and reoriented clusters. The role of exogenous forces (Cumming & Collier, 2005) would appear strong in such a context notwithstanding the inherent susceptibility to changes in exogenous forces that could be generated by changes in trading conditions or the attractiveness of Ireland as a location for multi-national corporation (MNC) activity.

The combined value of exports from the top 10 clusters accounted for 65% of all Irish exports for services and goods. Nine of these top 10 clusters rank highly by employment (Table 3) with only the final cluster, Downstream Chemical Production, ranked outside the top 10 (ranked 17th).

Biopharmaceuticals, Information Technology, and Analytical Instruments, along with Business Services and Food Processing, are some of the Irish traded clusters that generated the highest export values. Information Technology and Analytical Instruments, Transportation and Logistics, Production Technology and Heavy Machinery and Downstream Chemical Production all witnessed declines in export values over the period.

The Business Services cluster witnessed a notable substantial increase in exports between 2008 and 2012 of over 55%. By 2012, exports of Irish services had almost caught up with merchandise exports – by 2014, services exports edged ahead of merchandise exports for the first time. Between 2000 and 2014, the share of Irish services exports increased from 22% to over 50%, relative to international shares of 20.7% and 21.2% respectively (Byrne & O'Brien, 2015). The main sectors

Table 3. Traded clusters in the Irish economy, 2008–12.

Cluster		Employment, 2012	CAGR employment, 2008–12	Employment growth rank (1 = highest growth)	Average wage, 2012 (2014€)	Wage rank (1 = highest growth)	CAGR average wage, 2008–12	Wage growth rank (1 = highest growth)
1	Business Services	119,004	–3.6	19	**42,681**	13	3.5	**6**
2	Hospitality and Tourism	85,413	–2.8	14	19,510	36	–1.7	31
3	Distribution and Electronic Commerce	80,642	–3.4	16	**43,419**	11	4.7	**5**
4	Transportation and Logistics	39,159	–3.2	15	**48,432**	**8**	1.4	18
5	Information Technology and Analytical Instruments	26,265	–8.5	24	**59,180**	**3**	5.2	**2**
6	Medical Devices	24,109	4.9	**3**	**41,537**	14	3.0	**9**
7	Food Processing and Manufacturing	21,501	–2.2	11	**45,554**	**9**	1.0	21
8	Biopharmaceuticals	14,621	–0.5	**8**	**60,422**	**2**	3.0	**8**
9	Livestock Processing	13,406	1.7	**5**	28,243	32	–1.2	29
10	Production Technology and Heavy Machinery	7872	–14.0	31	36,970	19	1.7	14
11	Plastics	6591	–6.3	22	33,398	27	1.0	20
12	Footwear	6208	–18.8	35	28,447	33	–1.1	28
13	Construction Products and Services	6049	–10.2	27	**41,403**	15	1.0	19
14	Communications Equipment and Services	5659	–3.5	17	**57,559**	**4**	5.2	**3**
15	Metalworking Technology	5588	–12.8	30	36,276	21	1.5	17
16	Automotive	4901	–5.4	21	37,596	18	2.7	11
17	Downstream Chemical Products	4351	–9.9	26	**50,942**	**7**	1.9	13
18	Education and Knowledge Creation	4277	1.0	**6**	**51,830**	**6**	–0.6	25
19	Printing Services	3445	–10.6	28	34,364	23	–0.4	24

(*Continued*)

Table 3. (*Continued*)

Cluster		Employment, 2012	CAGR employment, 2008–12	Employment growth rank (1 = highest growth)	Average wage, 2012 (2014€)	Wage rank (1 = highest growth)	CAGR average wage, 2008–12	Wage growth rank (1 = highest growth)
20	Upstream Chemical Products	3239	–1.8	**9**	**60,915**	**1**	0.8	22
21	Video Production and Distribution	3111	8.7	**1**	39,433	16	–4.1	36
22	Downstream Metal Products	3048	–4.1	20	33,232	28	–1.8	32
23	Paper and Packaging	3011	–2.7	13	36,841	20	–0.8	26
24	Lighting and Electrical Equipment	2954	–8.3	23	33,845	26	–1.0	27
25	Wood Products	2753	–18.8	34	33,953	25	2.9	**10**
26	Recreational and Small Electric Goods	2336	6.9	**2**	33,955	24	1.6	16
27	Non Metal Mining	2210	–19.4	36	38,625	17	–2.8	35
28	Water Transport	2043	–3.6	18	**55,349**	**5**	3.4	**7**
29	Textile Manufacturing	1862	–11.7	29	36,225	22	6.2	**1**
30	Upstream Metal Manufacturing	1848	–9.8	25	**43,399**	12	2.0	12
31	Fishing and Fishing Products	1830	0.12	**7**	25,378	34	0.5	23
32	Environmental Services	1788	3.12	**4**	32,762	29	–2.4	34
33	Vulcanized and Fired Materials	1482	–15.9	32	31,669	30	–1.5	30
34	Apparel	1209	–18.0	33	22,994	**10**	–2.2	33
35	Agricultural Inputs and Services	368	–2.0	**10**	**43,901**	35	1.6	15
36	Furniture	103	–2.5	12	27,674	31	4.7	**4**

Note: CAGR, compound annual growth rate.

Sources: Central Statistics Office (2008a, 2008c, 2012a, 2012c) – Annual Services inquiry and Census of Industrial Production.

Table 4. Top ranked traded clusters by exports for Ireland, 2012.

Rank	Cluster	Exports (€, thousands)	CAGR, 2008–12	Per Irish plant (€, thousands)	Per foreign plant (€, thousands)[a]
1	Biopharmaceuticals	31,818,151	4.1	5909	704,838
2	Information Technology and Analytical Instruments	23,354,219	–6.0	1987	176,820
3	Business Services	20,141,212	55.4	335	28,197
4	Distribution and Electronic Commerce	15,272,480	21.8	444	16,254
5	Food Processing	14,440,756	3.4	9334	464,229
6	Medical Devices	8,359,329	13.5		
7	Livestock Processing	2,573,482	4.5		
8	Transportation and Logistics	1,612,012	–10.6		
9	Production Technology and Heavy Machinery	1,333,948	–3.7		
10	Downstream Chemical Production	748,975	–2.7		
	Total	119,654,564			
Total merchandise exports		94,154,125	1.4		
Total service exports		90,920,187	7.5		

Notes: [a]Foreign is defined as non-Irish.

CAGR, compound annual growth rate.

Sources: Central Statistics Office (2008a, 2008c, 2012a, 2012c, 2016a, 2016b) – Annual Services Inquiry, Census of Industrial Production and Balance of Payments.

accounting for this shift were Business Services, which grew from 18% in 2000 to 29% by 2014 (aggregate Irish services exports) and Computer and Information Services, which grew from 35% in 2000 to 42% in 2014. A decline in merchandise exports of Office Machinery (declining from 35% in 2000 to 7% in 2014) reveals the extent of the structural shift in the economy and reorientation towards services.

The substantial difference in exports per plant between foreign and Irish plants in Table 4 while notable is not surprising given the prominence of foreign firms for Irish export performance, along with the impact 'contract manufacturing' can have on official statistics (O'Leary, 2015). The duality of the Irish economy in terms of Irish and foreign-owned economic activity has been widely studied (e.g., Barry & Bradley, 1997; Barry, Görg, & Strobl, 2005; Barry & Hannan, 1995; Breathnach, van Egeraat, & Curran, 2015; O'Leary, 2015). We disaggregate the five largest clusters by exports (2012 value) into Irish and foreign-owned plants in Table 5 to provide further indications of their relative employment, output and wages per worker trends.

Similar to Table 4, foreign plants display higher employment intensity, and also generate higher GVA per plant and wages. In the Food Processing cluster, comparing the relative productivity of Irish with foreign plants indicates that output per foreign plant is 50 times greater than for their Irish counterpart (the largest productivity differential across the five clusters), while wages per plant are 1.7 times greater. While these clusters play a key role in reported Irish economic activity, much of the productivity is generated from 'foreign' rather than 'Irish' plants. The average

Table 5. Traded clusters for Irish and foreign plants, 2012.

		Employment per plant		Output per plant (€, thousands)		Wages per worker per plant (€)	
Rank	Cluster	Irish	Foreign	Irish	Foreign	Irish	Foreign
1	Biopharmaceuticals	62	295	318,884	671,294	46,081	61,560
2	Information Technology and Analytical Instruments	14	113	1238	59,742	46,990	62,336
3	Business Services	8	57	354	6335	38,395	50,904
4	Distribution and Electronic Commerce	10	27	613	7036	33,717	65,827
5	Food Processing	51	260	4469	223,134	36,877	62,197

Sources: Central Statistics Office (2008a, 2008c, 2012a, 2012c) – Annual Services Inquiry and Census of Industrial Production.

employment differential across the selected clusters is over 5.5, i.e., foreign plants employ over five times as many employees; for output, the average differential is 26. In the case of wages, it is 1.5, indicating that labour market forces rather than relativities in output or productivity drive discrepancies in wage rates. While such indicators may not be of general interest when considering life-cycle features of clusters, for a small, open economy, not only the indicators but also their trends over time represent important considerations for understanding the linkages between local clusters and their international value chain positions that generate important feedback mechanisms driving local cluster outcomes.

As our data sources do not provide data on exports of the Financial Service or Insurance Service sectors, we employ ICCP data (Porter & Bryden, 2015) to consider global export performance. Figure 1 presents the top 10 Irish clusters in 2012 by export value, comparing performance relative to global peers. The size of the circles indicates the amount of Irish exports from each cluster. Ireland competes in Communication Services, Biopharmaceuticals and Insurance Services (each Irish cluster contributing about 10% to global cluster-specific exports in 2012).[14]. The dashed horizontal line indicates the average annual growth rate of global cluster exports (51 cluster categories, unweighted) over the period 2008–12, at 3.3%. The value of each cluster's Irish exports is graphed relative to its average growth rate for Ireland (on the horizontal axis) and relative to each cluster's average international growth rate (on the vertical axis).

Irish clusters with growth rates above the average international rate appear in the top-right quadrant including Communication Services, Agricultural Products and Inputs, and Transport and Logistics. While Biopharmaceuticals and Business Services are key export clusters for Ireland, both exhibited lower growth rates than for those clusters globally.

Clusters of Information Technology and Analytical Instruments, Food Processing and Manufacturing although exhibiting growing exports globally, experienced dramatic declines in Ireland. Relative to strong international growth Insurance Services, and Downstream Chemical Products, Irish exports from these clusters were substantially slower: similarly, although to a lesser extent for Financial Services.

For future data requirements and research on Irish economic and regional development, clusters for which local data sources do not provide comparable data, namely Insurance Services and Financial Services, contribute substantial shares of international trade.

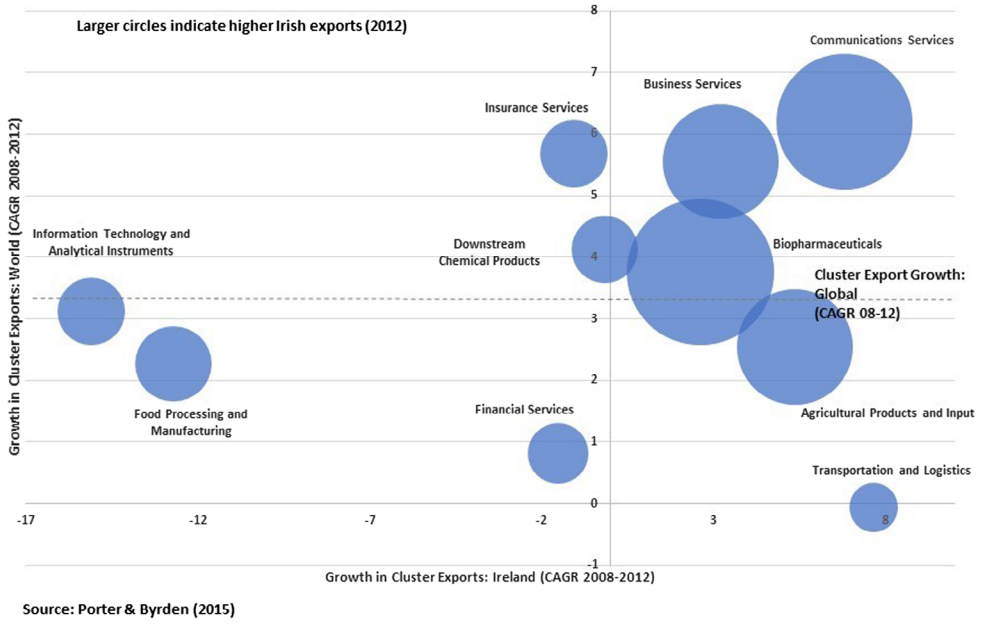


Figure 1. Top 10 globally competitive Irish traded clusters, 2008–12.

REGIONAL CONCENTRATION OF GLOBALLY COMPETITIVE CLUSTERS

Using Haig's (1926) location quotient (LQ), we can identify at the NUTS-3 level those regions where specific traded clusters have strong geographical employment concentrations. The LQ method has been utilized previously to determine the location of a cluster, although with a non-Porterian connotation (Brenner & Schlump, 2011; Kelton, Pasquale, & Rebelein, 2008; Miller, Botham, Martin, & Moore, 2001; Sforzi, 1990).[15] We combine the LQ spatial approach with the BCDs of NACE four-digit data. We utilize the LQ method to map 14 clusters, selected for export performance from 2008 to 2012: the 10 reported in Table 5 along with Agricultural Products and Inputs, Financial Services, Insurance Services and Transport and Logistics from Figure 1. Table 6 presents the LQ scores for 2012 for these internationally competitive clusters.

An LQ score greater than 1.0 (shown in bold) indicates employment in a specific cluster is more concentrated in the region relative to the national share. Underlined values indicate the highest regional LQ score for each cluster. The highest cluster concentration for each region is italicized. Taking a regional view (NUTS-3), the Border region exhibits concentrations in five clusters, Dublin six, Mid-east five, Midlands one, Mid-west five, South-east eight, South-west nine and West three.

For the Border region, concentration is evident in Agricultural Inputs and Services (at 2.5); however, this cluster is most highly concentrated in the Mid-west (3.0). The Border exhibits the highest regional LQ score for one cluster, i.e., Food Processing (2.2).

Of the six clusters in which Dublin exhibits concentrations, four of these are regional LQ highest scores, i.e., Financial Services (2.0), Insurance Services (1.9), Communications Equipment and Services (1.8) and Business Services (1.4). The Mid-east exhibits regional high concentrations in Livestock Processing (3.6) and Information Technology and Analytical Instruments (2.8) clusters. The Midlands' only concentration in Livestock Processing (1.6) puts it in the top four locations for that cluster, across eight regions.

Table 6. Location quotients: 14 prominent Irish traded clusters for NUTS-3 regions, 2012.

Cluster	Border[a]	Dublin	Mid-east	Midlands[a]	Mid-west	South-east	South-west	West[a]
Agricultural Inputs and Services	***2.5***	0.2	**1.5**	0.5	***3.0***	**2.7**	**1.3**	0.5
Biopharmaceuticals[cd]	0.5	0.8	**1.2**	0.0	0.0	**2.2**	**2.0**	**1.4**
Business Services[bd]	0.5	**1.4**	0.8	0.2	0.9	0.6	**1.1**	0.5
Communications Equipment and Services[c]	0.1	**1.8**	0.3	0.1	0.4	0.4	0.7	0.2
Distribution and Electronic Commerce[bd]	1.0	**1.1**	0.9	0.4	**1.2**	0.8	**1.1**	0.7
Downstream Chemical Products	0.8	0.6	**2.4**	0.2	***3.0***	**1.3**	**1.5**	0.2
Financial Services	0.2	***2.0***	0.3	0.0	0.1	0.1	0.4	0.2
Food Processing[d]	**2.2**	0.6	1.3	0.4	0.9	**2.1**	**1.8**	0.3
Information Technology and Analytical Instruments[bd]	0.3	0.7	**2.8**	0.1	**2.0**	0.5	**1.7**	0.9
Insurance Services	0.7	**1.9**	0.2	0.1	0.2	0.7	0.2	0.2
Livestock Processing	**1.6**	0.1	***3.6***	***1.6***	1.0	***3.5***	0.6	0.9
Medical Devices[b]	**2.1**	0.1	0.3	0.9	**2.0**	**1.7**	**1.1**	***4.0***
Production Technology and Heavy Machinery	**1.5**	0.2	0.9	1.0	**1.2**	**1.9**	***2.3***	***1.7***
Transportation and Logistics[bd]	0.9	**1.3**	0.8	0.3	**1.2**	**1.1**	0.6	0.5

Notes:LQ scores in bold indicate regional concentration (> 1.0) relative to the national employment share; underlined LQ scores indicate the highest cluster concentration relative to national employment shares; and LQ scores in italics indicate the most concentrated cluster in that region.

[a]These NUTS-3 regions make up the NUTS-2 region BMW. The reminder constitute the South-east region.

[b]Clusters in the top five by employment share (see Table 3).

[c]Clusters in the top 5 by wage level (see Table 3).

[d]Clusters in the top 5 by export share (see Table 4).

Sources: Central Statistics Office (2012b) – Business Demography.

For the Mid-west, two clusters occupy the highest regional cluster measures in both Agricultural Inputs and Services, and Downstream Chemical Products (both at 3.0). In the South-east, the most clustered activity is measured in Livestock Processing (3.5) and Agricultural Inputs and Services (2.7), but the cluster with the leading regional value is Biopharmaceuticals (2.2). In the South-west, the highest concentration is evident in Production Technology and Heavy Machinery (2.3), for which the region also has the highest regional LQ score. For the West region, of its three observed clusters, one has the highest regional LQ score, i.e., Medical Devices (4.0). The Transportation and Logistics cluster, unsurprisingly, has the least dispersion across the regions in its employment concentration with the highest LQ scores in Dublin, Mid-west and South-east respectively.

The capital city of Dublin's high concentrations in Financial Services and Insurance Services activities are notable in the absence of concentrations in any other regions and given the strong performance in GVA per person. Everett, McNeill, and Phelan (2013), while noting the difficulties in measuring financial services output, indicated that the Irish National Accounts report the sectors' contribution of 10% of Irish gross domestic product (GDP) in 2011. As Table 6 indicates, the majority of employment shares in these clusters lies in the Dublin region, and given the contribution it makes to national accounts, it sheds a light on Dublin's performance relative to other regions in Ireland. A regional wage comparison is only possible at a NUTS-2 level. A marked difference is evident in wages between specific clusters in the South and East region relative to the BMW region. Specifically, a differential of €20,000 is evident for wages in Biopharmaceutical and Information Technology and Analytical Instruments between the two regions.

Adaptive cycles – regional considerations

The final element in our analysis relates traded clusters and regional economic outcomes. In the context of Table 6, we reviewed wage and wage-growth trends by cluster, as outlined in Table 3. Concentration displayed in specific regions in specific clusters and the relative wage rates of different clusters determine regional average wages. This means that for each cluster with plants across regions, regional conditions vary and different adaptive cycles prevail. For example, regions with employment concentration in Livestock Processing experienced declining wages, and because wage levels in that sector are the fifth lowest of all clusters, the impact of such clustering is compounded and revealed in relatively weak regional performance.

Across our NUTS-3 regions we assessed the change in regional average wages (2008–12) apportioning the change into two effects: a wage level effect and a cluster mix effect (following Porter, 2003).[16] The non-availability of services data at a NUTS-3 level necessarily limited this analysis to CIP data only. We observed a duality in the results with Dublin, Mid-east, Mid-west and South-west regions displaying both positive mix and level effects. These regions compete disproportionately positively in employment terms in clusters with relatively high wages. They also outperform in average wage terms, i.e., relative to the national average wages in those clusters in which they compete. The four other regions exhibited both negative mix and level effects. The level effect represented 39% on average of the variation in average wages across regions and 61% for the cluster mix effect.[17]

The stark pattern evident in the two sets of regions points to quite different features at work within similar clusters and of relevance for regional outcomes. Features of 'maladaptive collapse' that Martin and Sunley (2011, p. 1315) associate with 'poverty traps' and the cluster life cycle appear here to be associated with different regions rather than clusters. A substantial portion of Irish regional wage variation relates to the cluster mix within regions. Initiatives focusing on regional economic development require complex programmes that address the more significant issue of how to target transformation from less to more desirable clusters to generate higher wages, and regional prosperity. Such programmes also, although less significantly, require targets to upgrade activities (to increase wages) in those clusters where the regions hold concentrated positions.

DISCUSSION AND CONCLUSIONS

This paper presents Irish economic activity according to benchmark cluster definitions (BCDs). As a small, open economy, and within data limitations, Ireland exhibits economic activity across a limited breadth of 36 of a possible 51 benchmark clusters. Across selected clusters, a number of globally significant competitive positions are evident. While our limited data set (2008–12) necessarily inhibits the comprehensive analysis of cluster development dynamics, a number of initial implications can be identified for further cluster-based analysis.

The attractiveness of the life-cycle approach lies largely in its potential for linking development policies and business supports with requirements that change over the cluster life-course. Both modelling approaches and case studies are evident in related research (Brenner & Schlump, 2011; Isaksen & Karlsen, 2012). For Ireland, a number of successful clusters can be identified that have established substantial international positions and are thus well beyond the emergent phase. Cluster emergence in Ireland is linked unequivocally to multinational subsidiary activities. One substantial transformation revealed, despite the short time frame of available data, is the growth of services exports driven largely by the doubling of the share of business services exports. This points to the strength of cluster benchmark definitions for analysing economic trends nationally and regionally as increasing importance of services demands greater attention and analysis in terms of both its export contribution and linkages across other activities.

Understanding the dynamics of these Irish clusters may be based on features of the adaptive cycle model from complex adaptive systems and its incorporation of a variety of scales of relevance including the supra-regional and global levels (Gunderson and Pritchard, 2002). System resilience emphasized in the model rests on the balance between the internal connectedness of components of the system and its tendency to increased order over time, relative to the negative impact of such increasing order on adaptability potential to external forces. For small, open economies such as Ireland, the success of a system of clusters relies on the ability to adapt to external environmental conditions (including at individual cluster level), despite the growth of internal (Irish) cluster network relations. The necessity to connect internationally in supply terms to MNC partners and headquarters, and in demand terms with market networks, counteracts the potential for local absorptive capacity to deteriorate when faced with cluster participants when these are envisaged as operating only in the direct cluster locality (e.g., Menzel & Fornahl, 2010). An emphasis in the adaptive cycle model on key resources of specialized capital, specialized knowledge and supporting institutions points to necessary elements for the ongoing fit of the clusters to local conditions; for Irish-based cluster firms, their geographical focus associated with key resources must necessarily be substantially wider than the local territory. Hence, the relevant scale of analysis for such cluster life cycles and adaptive cycles must be found beyond the small, open economy and include the small open economy (SOE) itself (Moon, Rugman, & Verbeke, 1998). Analysing broadly defined clusters – in geographical terms – not only is made easier by the benchmark definitions but also acts to avoid the type of negative lock-in effects, knowledge homogeneity and cognitive isomorphism that cluster life-cycle literatures have identified as being important to guard against (Pouder & St John, 1996; Menzel & Fornahl, 2010; Fornahl & Hassink, 2017).

We identify where the most internationally competitive clusters are concentrated regionally in Ireland (NUTS-3), noting some of the most productive as located in the capital city of Dublin and in which other regions exhibit no clustering tendencies, i.e., Financial Services, Insurance Services, Business Services and Communications Equipment and Services. The relative concentration of these sectors within Dublin, and the relatively high wage rates in Business Services and Communications Equipment and Services, add to understanding Dublin's contribution to national performance, relative to other regions. The argument that cluster policies could more effectively target clusters given the cluster development stage through identifying targeted instruments could be applied to the Dublin region with the view to supporting network measures, e.g.,

to ensure linking regional to international sources. Governmental focus on implementing and research and innovation strategies for smart specialization (known as RIS3), as outlined in Irish Action Plans for Jobs[18] published at national and regional levels are the mechanisms through which such instruments would be delivered.

For those clusters in which a number of regions display relative strengths, different challenges are relevant. In examining regional cluster performance, the important role played by internationally competitive clusters (and their relative wage rates) for regional (and national) prosperity creates additional insight and questions, in terms of cluster cycles. We find that half the NUTS-3 regions do not enjoy the local business conditions appropriate to supporting higher wage rates achievable in the same clusters in other regions. In addition, these same regions exhibit lower average wages due to the range of clusters in which the regions concentrate – and this effect is the larger factor in explaining differences between average regional wages and the national average. Cognisant of the data limitations that underlie these assessments, they point to a need for further research to examine whether cluster stages offer an explanation for differences in relative performance across the regions. This is important in identifying the most appropriate instruments to support economic development. The application of cluster benchmarks assumes homogeneity across the cluster firms, which needs to be tested. The 'critical mass' identified through LQs might well mask differences in the cluster cycle of firms in different regions, or the fit of local conditions to the region's cluster firms. A consideration of these factors, in addition to labour market factors, e.g., the urban wage premium experienced in Dublin, need to be better understood to develop and implement targeted business supports across regions and clusters.

Limitations in services data in the above analysis point to a wider issue regarding data quality and the improvement necessary in services data given their increasingly important role in economic activity generally and, particularly for Ireland, in exports. This would also permit improved understandings of the relationships across services and other economic activities. To generate the type of evidence base to support better regional development programmes, such data are increasingly required at both disaggregated cluster and regional levels.

This study, therefore, offers a starting point for Irish cluster-based research and points to substantial scope for further research to add to the understanding of regional, cluster and cluster-cycle determinants of economic performance and development.

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NOTES

1. A set of activities and clusters were selected for analysis across 10 economies: Denmark, Germany, Italy, Japan, Korea, Singapore, Sweden, Switzerland, the UK and the United States.
2. A substantial literature has developed on the clarity of the cluster concept. Elsewhere (Brosnan, Doyle, & O'Connor, 2016), we contribute to that debate but focus here on issues related to the measurement of clusters.

3. As viewed in Goetz and Jankowska (2017) and Brosnan et al. (2016), clustering as a process is emphasized as opposed to an organizational form.
4. For example, Martin and Sunley (2011) note that clusters may atrophy when increasing returns effects are exhausted.
5. Traded and local clusters, and traded and local economic activities are used interchangeably.
6. In a related but separate line of analysis, Neffke and Henning (2013) apply the concepts of skill-relatedness and industry space to identify significant skill linkages across activities that remain unnoticed when traditional activity classification codes are used. Such research eschews the geographical considerations included in cluster studies.
7. These definitions drive the analyses on the US Cluster Mapping Website (http://www.clustermapping.us).
8. Cluster data for Ireland, as well as other European countries, can be accessed at http://ec.europa.eu/growth/smes/cluster/observatory/cluster-mapping-services/cluster-mapping/mapping-tool/index_en.htm.
9. Earlier ECOP work involved translation from the US SIC of economic activities to the NACE classification. Development of the more recent (late 1990s) NAICS provides common industry definitions for Canada, Mexico and the United States to support comparable economic analyses. According to the NAICS, data have the benefit that they may be aggregated into the two-digit divisions of NACE Rev. 2: the new definitions can easily be incorporated into European data.
10. Data are compiled by the Harvard Business School, and can be accessed upon free registration at https://secure.hbs.edu/login/isc-iccp/index.html?oamreferred=true.
11. Business demography data provide information on all active firms in Ireland, but do not accurately geocode every firm. Therefore, the data relate to approximately 75% of all enterprises that are geocoded.
12. All data are in real (€2014) terms using a national Consumer Price Index (CPI).
13. A similar figure is found for the US economy in 2000 (Porter, 2003).
14. The impact of Irish global export shares can be considered in terms of the global output share of the Irish economy, which was 0.23% in 2015.
15. The LQ is not without its drawbacks (Woodward & Guimarães, 2009) as, for example, it does not take into account the number of plants within a region and may be hampered by the predetermined definition of appropriate spatial units. Research on Germany (Scholl & Brenner, 2016) and Ireland (Van Egeraat, Morgenroth, Kroes, Curran, & Gleeson, 2015) address these issues using geocoded plant data for two- and three-digit industrial classifications.
16. This approach is similar to shift–share measures using counterfactual wage levels and cluster mixes. The level effect is found by the sum of differences between a region's wage in each cluster and the national average for that cluster multiplied by the region's employment share in that cluster. The mix effect is found by the sum of differences in each cluster's employment share compared with the national proportion multiplied by the cluster's national average wage.
17. These are in contrast to the shares found for the United States (including services data) of 76% and 24% (Porter, 2003).
18. For details on these plans since 2012, see the Department of Jobs, Employment and Innovation (https://www.djei.ie/en/What-We-Do/Business-Sectoral-Initiatives/Action-Plan-for-Jobs/).

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