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A Tale of Two Clusters: The Evolution of Ireland's Economic Complexity since 1995

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Abstract This paper characterizes the evolution of the manufacturing and industrial export structure of Ireland since 1995 within the framework of Economic Complexity and the Product Space. We observe a high level of specialisation in Ireland's export structure, coupled with high income per capita as compared to the complexity level of its industrial activities (as captured by its Economic Complexity Index). We identify a dual structure within the economy, with domestic and foreign-owned exporters exhibiting distinct characteristics. In the latter case, we observe a recent consolidation and reduction in complexity level by the foreign-owned high tech pharmaceuticals and electronics sectors, with limited evidence of spill-overs leading to growth of domestic firms in these sectors. This contrasts with a dynamic and growing domestic food and agriculture sector, which is well positioned for continued expansion of Ireland's indigenous activities into more complex goods. Finally, we illustrate this framework as a tool for policy-makers by identifying some potential new sectors that share many inputs with Ireland's current domestic capability base, and could increase Ireland's complexity level for future growth.

Keywords: manufacturing, exports, Ireland
JELs: L16, L60, O14

1. WHY DO COUNTRIES GROW?

Building on classical theories which focus on the relative contributions of capital, labour and technology to economic growth[1] [2] [3] recent work has proposed that countries grow by expanding their knowledge and capability base, enabling them to diversify into new industries and economic activities.[4] [5] [6] [7] The specific capabilities and inputs available to a country determine the set of 'nearby' or likely new industries, and govern its diversification. While classical trade theory suggests that current industrial make-up has little to no effect on future structure, new research provides strong signals that the capabilities or skills a country has today affect its industrial path in the future.[8]

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[1] Flam H & Flanders MJ (1991*) Heckscher-Ohlin Trade Theory.* Cambridge, Mass.: MIT Press
[2] Romer PM (1990) 'Endogenous Technological Change'. *Journal of Political Economy* 98 (5, II): 71–102.
[3] Aghion P & Howitt P (1992) 'A Model of Growth Through Creative Destruction'. *Econometrica* 60 (2): 323–351.
[4] Hausmann R & Klinger B (2006) *Structural transformation and patterns of comparative advantage in the product space*. Inter-American Development Bank.
[5] Hidalgo CA, Klinger B, Barabasi AL & Hausmann R (2007) 'The product space conditions the development of nations'. *Science*, 317:482-487.
[6] Hidalgo CA & Hausmann R (2009) 'The Building Blocks of Economic Complexity'. *PNAS* 106 (106(26)): 10570–10575.
[7] Hausmann R & Hidalgo CA (2011) 'The network structure of economic output'. *Journal of Economic Growth*, 16(4):309--342.
[8] Hausmann R, Hidalgo CA, Stock D & Yildirim M (2014) *Implied comparative advantage*. Center for International Development, Harvard University.

In order to describe this process, the Economic Complexity framework employs the Product Space,[4 5 6 7] a network that models the process of industrial diversification of an economy. The Product Space is based on the intuitive idea that a country that exports fabrics is more likely to next export garments than it is to export jet engines. Metrics derived from the structure of the network, such as the Economic Complexity Index (ECI), which ranks countries by the knowledge accumulated via production in their economies, have been shown to rival alternative predictors for industrial growth such as education and quality of institutions.[7]

This paper characterizes the evolution of the manufacturing and industrial export structure of Ireland since 1995 within the framework of Economic Complexity and the Product Space. We observe a high level of specialisation in Ireland's export structure, coupled with high income per capita as compared to the complexity level of its industrial activities (as captured by its Economic Complexity Index). We identify a dual structure within the economy, with domestic and foreign-owned exporters exhibiting distinct characteristics. In the latter case, we observe a recent consolidation and reduction in complexity level by the foreign-owned high tech pharmaceuticals and electronics sectors, with limited evidence of spill-overs leading to growth of domestic firms in these sectors. This contrasts with a dynamic and growing domestic food and agriculture sector, which is well positioned for continued expansion of Ireland's indigenous activities into more complex goods. Finally, we illustrate this framework as a tool for policy-makers by identifying some potential new sectors that share many inputs with Ireland's current domestic capability base, and could increase Ireland's complexity level for future growth.

2. CONTEXT: AN ECONOMIC RECOVERY DEPENDANT ON EXPORTS

Ireland is a country in recovery. A domestic housing and construction bubble, fuelled by cheap credit and lax banking oversight, led Ireland to the edge of the abyss in 2008. As the world suffered a global financial crisis, Ireland's banks buckled under massive exposure to real-estate related debt. However, strong fundamentals in terms of quality and competitiveness, coupled with public support for reforms, have enabled Ireland to embark on a successful program of economic recovery. Yet, with domestic demand lagging due to low (but improving) employment figures, Ireland's recovery in the short term is heavily dependent on the success of its export activities.[9]

Ireland's domestic economy is driven mainly by services (constituting over 60% of GDP), with manufacturing a growing component of an overall declining industrial sector. Figure 1 shows that exports of goods and services are high (and growing) as compared to other countries with a similar GDP. Goods exports have traditionally been the dominant factor, but recently services exports – dominated by financial services and IT - have caught up with (and very recently overtaken) goods exports.

A key component of its growth and industrial strategy, Ireland is a major recipient of net inflows of foreign direct investment (FDI) compared to other countries at a similar GDP per capita as seen in Figure 1 of the Supplementary Information (SI), driven by a competitive tax regime and a young, highly educated and skilled labour force. In fact, in 2011, a small number of sectors dominated by foreign-owned multinational enterprises accounted for one quarter of total economy-wide gross value added,[10] and today Ireland is home to a plethora of international brand names in high tech, electronics and pharmaceuticals. In contrast, Irelands' national producers typically focus on high quality foodstuffs and agricultural products with recent growth in medical devices.

Attracting firms to Ireland, and driving domestic growth, Ireland exhibits extraordinarily high levels of tertiary education, and high ranking in both overall competitiveness (ranked 25th in the world in 2015) and ease of doing business (ranked 15th in the world in 2014) as seen in Figure 2 of the SI. In particular, it excels in competitiveness in areas such as health, education, goods and labour market efficiency and technological readiness/innovation. This is coupled with excellent performances in financial and administrative areas related to starting and maintaining a business, including providing access to credit, setting attractive tax rates and protecting investors. Some challenges remain in practical areas such as electricity and construction permits.

Here we focus on the evolution of Ireland's exports, both as a important component of Ireland's growth, and as a signal of international competitiveness in particular products and industries. The composition of Ireland's exports has evolved towards an increasing reliance on pharmaceuticals and chemicals in terms of export share since 1995, as seen in Figure 2. While we observe a decline in the share of exports from the food and agriculture sector, their total value has been increasing (see Figure 3 of the SI). Similarly, while maintaining their export value, the share of electronics and machinery exported has declined in recent years, dominated by the growing pharmaceuticals sector.

[9] Byrne S & O'Brien M (2015) 'The Changing Nature of Irish Exports: Context, Causes and Consequences'. *Irish Central Bank April Quarterly Bulletin*

[10] Irish Department of Finance (2014) *Economic Impact of the Foreign-owned Sector in Ireland*.

Ireland's main export partners include the US, the UK and various large European economies. Figure 4 of the SI shows that export to the North America and Western Europe has been increasing since 1995, driven by the USA and Belgium, who mainly buy pharmaceutical inputs (much of Ireland's imports and exports are subsidiary goods that serve as inputs for other products, forming part of a global supply chain). Closer to home, the UK and Germany also import a large range of products including food and agricultural products.

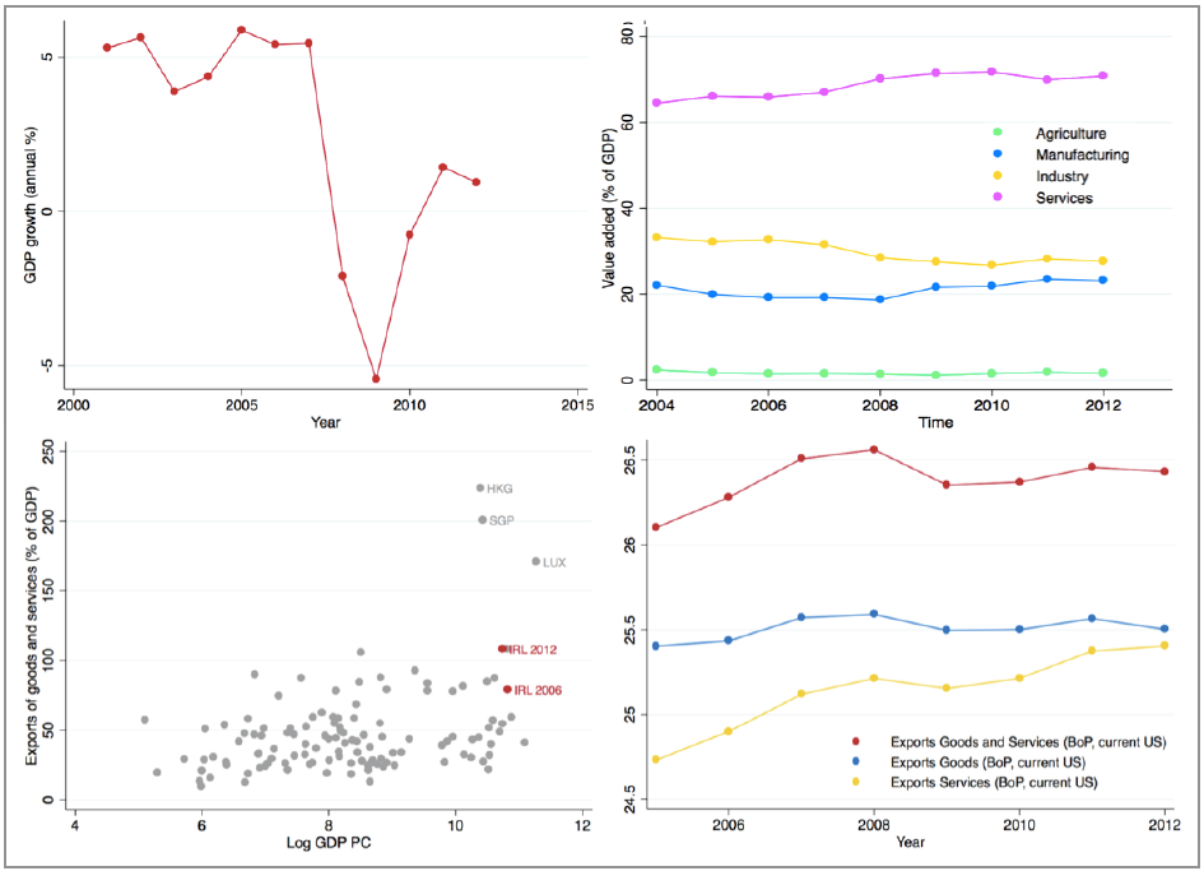


Figure 1: Ireland has experienced erratic GDP growth since a major fall in 2008/9. Driving the Irish economy, the proportion of services as a share of GDP has been increasing since 2000, with a corresponding decrease in size of the industrial sector. Manufacturing (a component of industry), however, has shown a recent increase, with a decline in agriculture. With domestic demand lagging, Ireland relies on exports as the underlying factor behind recent growth, including an increasing share of services exports. [Source: The World Bank's World Development Indicators (WDI) 2012]

We note that the total value of some foreign-owned or operated industries in Ireland may be over-stated. To avail of Ireland's low corporation tax, foreign businesses often engage in transfer pricing in order to divert their profits to Ireland,[11] and may include the returns from R&D, marketing and management practices undertaken by multinationals in other countries. While it is difficult to estimate the extent of transfer pricing in Ireland due to a lack of data, productivity levels in sectors such as chemicals, electronics and printing/publishing in Irish plants are nearly 100% greater than the US, UK and EU average.[12] Since the majority of the metrics introduced below are derived from international export data – transfer pricing in Ireland won't significantly affect their computation. We acknowledge, however, that there may be an effect when we look at the relative size and distribution of industries in Ireland. We ameliorate this issue by frequently considering domestic and foreign-dominated sectors separately in the analysis that follows.

[11] O'Leary E (2015) *Irish Economic Development: Serial Under-Achievement or High-Performing EU State*. London Routledge Studies in Modern World Economy

[12] National Competitiveness Council (2012) *Ireland's Productivity Performance, 1980–2011*. Dublin: Forfas.

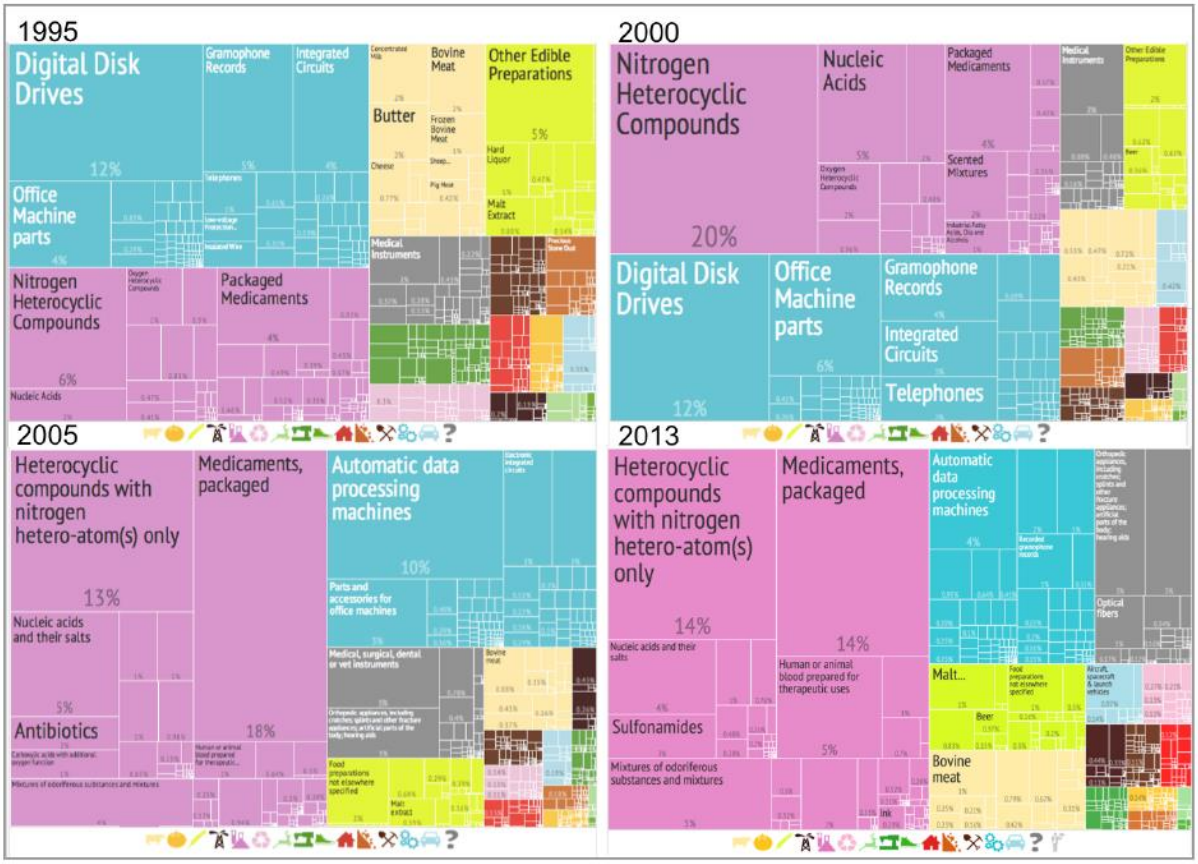


Figure 2: While Ireland's export basket has consistently relied on electronics, pharmaceuticals, food and agricultural produce since 1995, we observe a shift in composition derived from a huge growth in the share pharmaceuticals (and to a lesser extent medical devices), and a decline in electronics (and to a lesser extent food). [Source: The Atlas of Economic Complexity]

It must also be emphasised that much of the analysis to follow does not include traditional services industries such as personal services (e.g. hairdressing) and accounting, or newer services industries that are important for Ireland such as computer software. While the omission of service exports might have limited implication for the analysis of under-developed countries (given their industrial structure), it has significant implications for high-tech economies heavily reliant on services such as Ireland. Nevertheless, since exports are a primary driver of growth for Ireland, important insights may still be derived from examining the nature and dynamics of goods exports within the Economic Complexity framework.

3. THE PRODUCT SPACE & ECONOMIC COMPLEXITY: DOES WHAT A COUNTRY PRODUCES MATTER FOR ITS FUTURE ECONOMIC GROWTH?

Many early texts of development economics argued that externalities or spill-overs created during the process of industrialisation, as new products were introduced, lead to increased economic growth.[13] [14] [15] However, more recent theories focus instead on the relative contributions of core productive factors such as capital, labour, human capital and institutions[1] and technological differences of Romer[2], Aghion and Howitt.[3]

In the first case, poor countries tend to specialize in goods that rely mainly on labour and land, while richer countries focus on producing goods that use more human and physical capital and demand better institutions. Under the second technological differences theory, countries continually move into slightly more advanced products. In both cases particular products are ignored, or abstracted. But is there truly no product-specific pattern or path dependence inherent in the process of industrial diversification and growth?

[13] Rosenstein-Rodan P (1943) 'Problems of Industrialization of Eastern and South Eastern Europe'. *Economic Journal* 53: 202–211.
[14] Hirschman A (1958) *The Strategy of Economic Development*. New Haven, Conn.: Yale University Press
[15] Matsuyama K (1992) 'Agricultural Productivity, Comparative Advantage, and Economic Growth'. *Journal of Economic Theory* 58 (December): 317–334

An alternative perspective[4,5,6,7] focuses on the mechanisms by which the diffusion of capabilities spurs diversification and generates growth. Under this framework, 'capabilities' are typically thought of as skills,[16] know-how or tacit knowledge, but can also include physical inputs, and other localised attributes such as institutions, culture and natural amenities. It is hypothesised that countries grow as they acquire new capabilities, and learn to combine these capabilities to make increasingly sophisticated products requiring many complementary skills and inputs

Employing a simple analogy, we consider skills as letters in a game of scrabble. The more letters - or capabilities - a country has, the greater the number of words, or industries, that the country can build, and the longer and more sophisticated the words become. Critically, these new industries will be very similar to the old ones in their production needs as economies exploit existing capabilities to move into new economic activities requiring similar inputs. Hence, this perspective sees industrialisation as a path dependent process, whereby the appearance of new industries is conditional on the presence of relevant capabilities, often in the form of similar industries.

The Product Space[4,5,6,7,] as seen in Figure 3, is a network that models this process of industrial diversification, where nodes represent products (or industries) that are connected based on how similar their the capability requirements are. In practice, the similarity or edge weight between two nodes is estimated using a measure of co-export – i.e., a pair of products is connected by an edge if they are exported by a similar set of countries. The logic behind this approximation is that if a pair of products is co-exported by a large subset of countries, then these products must require a similar capability base.[17] This approach is related to the classical theories of Marshall[18], Porter[19] and more recent work of Glaeser et al.[20] who study the drivers of co-location of industries.

The Product Space network is highly heterogeneous. Some regions in the network are tightly connected, implying that neighbouring products use a similar set of capabilities. Countries exporting or producing products in these regions will find it relatively easy to diversify their export basket since they already have most of the capabilities required by many nearby products. On the other hand, countries that have products which are located in sparsely connected regions of the Product Space will find it more difficult to diversify since many new capabilities will be needed to 'jump' longer distances. The Product Space structure has been shown to be a successful predictor of the appearances of new industries, and the growth of existing industries, in terms of global export patterns8.

This view of growth through industrial diversification remains the focal point of much debate. Traditional economic theory held that specialization is needed for efficiency reasons. For example, the Ricardian trade model suggests that countries should focus on their strengths, and engage in international trade to acquire goods for which they do not exhibit comparative advantage.[21] In contrast, more recently others have argued that diversification is a much more importance source of productivity growth, protecting against shocks and terms of trade erosion due to declining commodity prices.[22] There remains much debate surrounding the nature of observed diversification (or specialisation), the theoretical foundations of such dynamics, and the optimal path for developing countries.

[16] Hanushek EA & Woessmann L (2008) 'The Role of Cognitive Skills in Economic Development'. *Journal of Economic Literature*, 46(3): 607-68

[17] We estimate this co-location measure using international trade data (UN Comtrade data provided by CEPII) from the Harmonized Commodity Description and Coding System for 129 countries and 1240 product classes – technical details are to be found in the Appendix.

[18] Marshall A (1890) *Principles of Economics*. London: Macmillan.

[19] Porter ME (1998) 'Clusters and the New Economics of Competition.' *Harvard Business Review*, November–December: 77–90.

[20] Ellison G, Glaeser E & Kerr W (2010) 'What Causes Industry Agglomeration? Evidence from Coagglomeration Patterns'. *American Economic Review*, 100(3): 1195-1213.

[21] Ricardo D (1971) *On the Principles of Political Economy, and Taxation*. Harmondsworth: Penguin Books

[22] Kaulich F (2012) 'Diversification vs. specialization as alternative strategies for economic development: Can we settle a debate by looking at the empirical evidence?' United Nations Industrial Development Organization, Development Policy, Statistics and Research Branch Working Paper 3/2012.

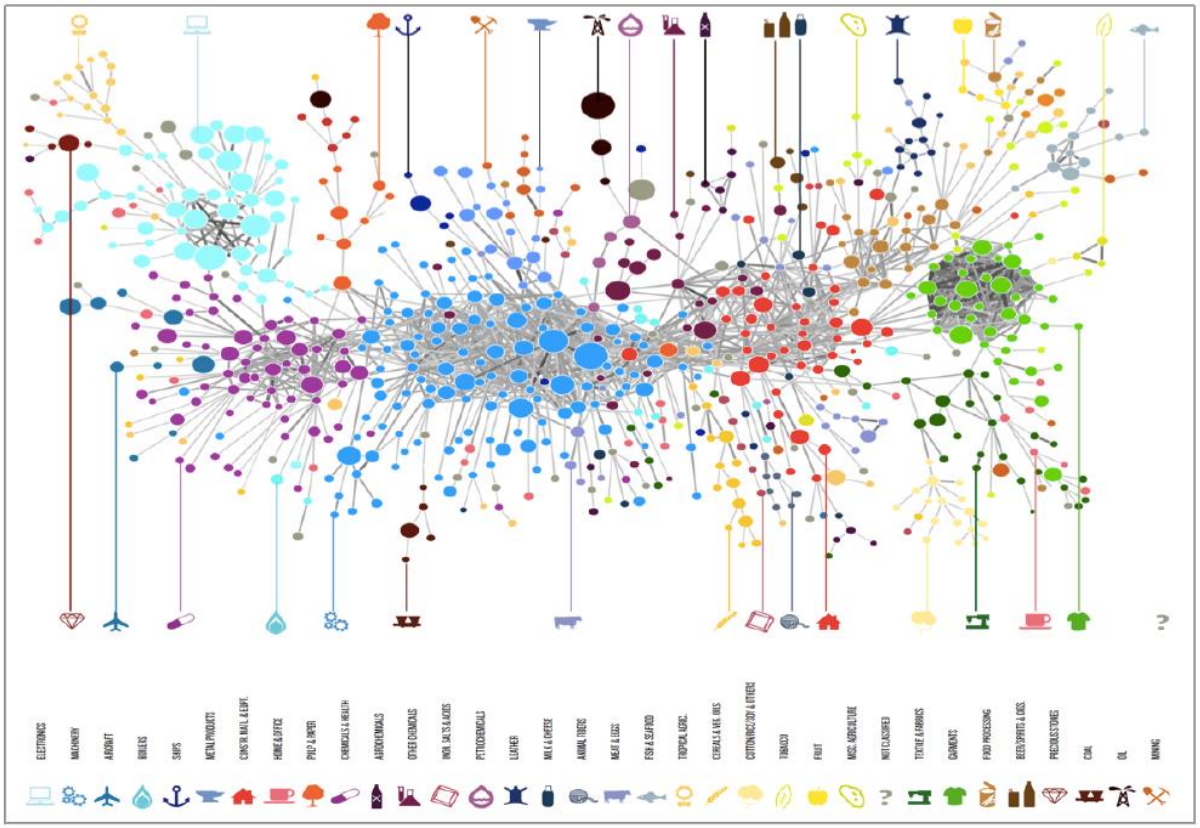


Figure 3: The Product Space is a network that describes the process of industrial diversification via the acquisition of capabilities. Nodes, or industries, are connected via edges representing the similarity between the capabilities needed to develop each industry. Research has shown that countries grow by diversifying into nearby industries requiring similar inputs in a path dependant manner. Hence, countries with existing industries in the interior of the network, represented by densely connected nodes, have increased opportunity for diversification – they have more possibilities to jump into nearby industries requiring similar capabilities. We observe that industries with similar inputs cluster together, such as the green textiles cluster seen on the far right hand size. [Source: The Atlas of Economic Complexity]

For example, Imbs and Wacziarg[23] employed empirical analysis to show that countries tend to diversify, followed by a period of specialisation after a sufficient level of wealth is reached (around 9,000 1985 US dollars per capita). Others disagree, arguing that re-specialisation is difficult to conclusively identify in the data – largely due to measurement difficulty.[24] The debate is more intense, however, surrounding the question of whether diversification, and subsequent re-specialisation, has a positive impact on economic growth. In the former case, there is some consensus: diversification is correlated with economic growth for developing countries[22]. However, on the question of specialisation economists are more divided[22,23,4,5,6].

From these questions, a more nuanced theory has emerged[4,5,6,7], holding that it is not the number of products which a country exports that is the key: it is the type or sophistication of those products. Highly developed countries export more complex products: those requiring rare capabilities and inputs possessed by only a handful of technologically advanced economies. The Product Complexity Index (PCI), a quantitative measure of product sophistication, is a metric derived from the structure of the Product Space. It is calculated by computing the average diversity of countries that make a specific product, and the average ubiquity of the other products that these countries make – see Supplementary Information for a technical definition.

[23] Imbs J & Wacziarg R (2003) 'Stages of Diversification'. *American Economic Review*, vol. 93, no. 1, pp. 63-86.
[24] De Benedictis L, Gallegati M & Tamberi M (2007) 'Overall Specialization and Income: Countries Diversify'. Working paper 73, University of Rome La Sapienza, CIDEI.

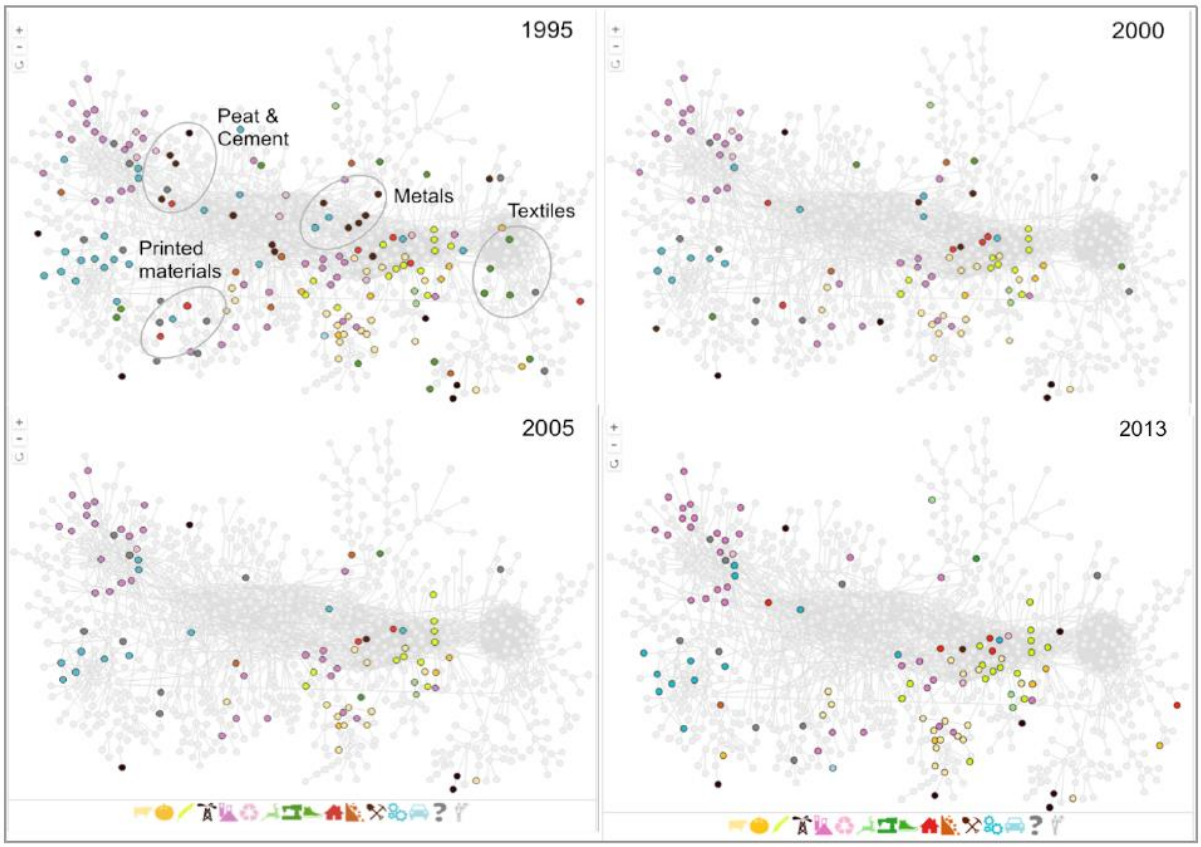


Figure 4: Ireland's export basket has been shrinking since 1995, when it exported a wide range of products including some textiles, metals, printed materials and peat and cement. Today Ireland resides in two distinct clusters of the product space, with electronics and pharmaceuticals clustering together on the left periphery – and food and agricultural products residing in a cluster on the centre right. Note: nodes or products are coloured if Ireland exports the product with Revealed Comparative Advantage. [Source: The Atlas of Economic Complexity, with artistic and text overlays by Author]

Figure 3, and Figure 5 of the SI, shows that the least complex products (such as primary agriculture and commodities) typically inhabit the right hand side – especially the right-hand periphery - of the Product Space, while more complex products (such as chemicals and electronics) typically inhabit densely connected central regions of the left hand side of the Product Space. Less developed countries typically diversify and grow by expanding their export base from the centre/right region towards the more complex left hand side[5].

We can also derive a metric for the composite sophistication or complexity level of a country's export basket. A country is considered complex if it produces a wide range of products, including many complex products that require rare inputs that only few countries possess. The Economic Complexity Index (ECI)[6] of a country is a measure of the complexity of its industrial structure, and is driven by aggregate PCI of the products it exports – see Supplementary Information for a mathematical definition.

It has been shown that the residual derived from the relationship between GDP per capita and ECI is highly predictive of economic growth[6]. In other words, countries with low levels of GDP relative to others at a similar complexity level are in some sense under-utilising their capability base and tend to grow faster in the future. Conversely, countries that exhibit high levels of GDP compared to other countries at a similar complexity level (perhaps, for example, due to natural resource wealth) do not have a broad capability base, and tend to exhibit lower levels of future growth. The fact that this residual is highly predictive of economic growth – even more so than traditional indicators measuring school and institutional quality – has led to arguments that ECI is an important measure of economic well-being or potential.[6]

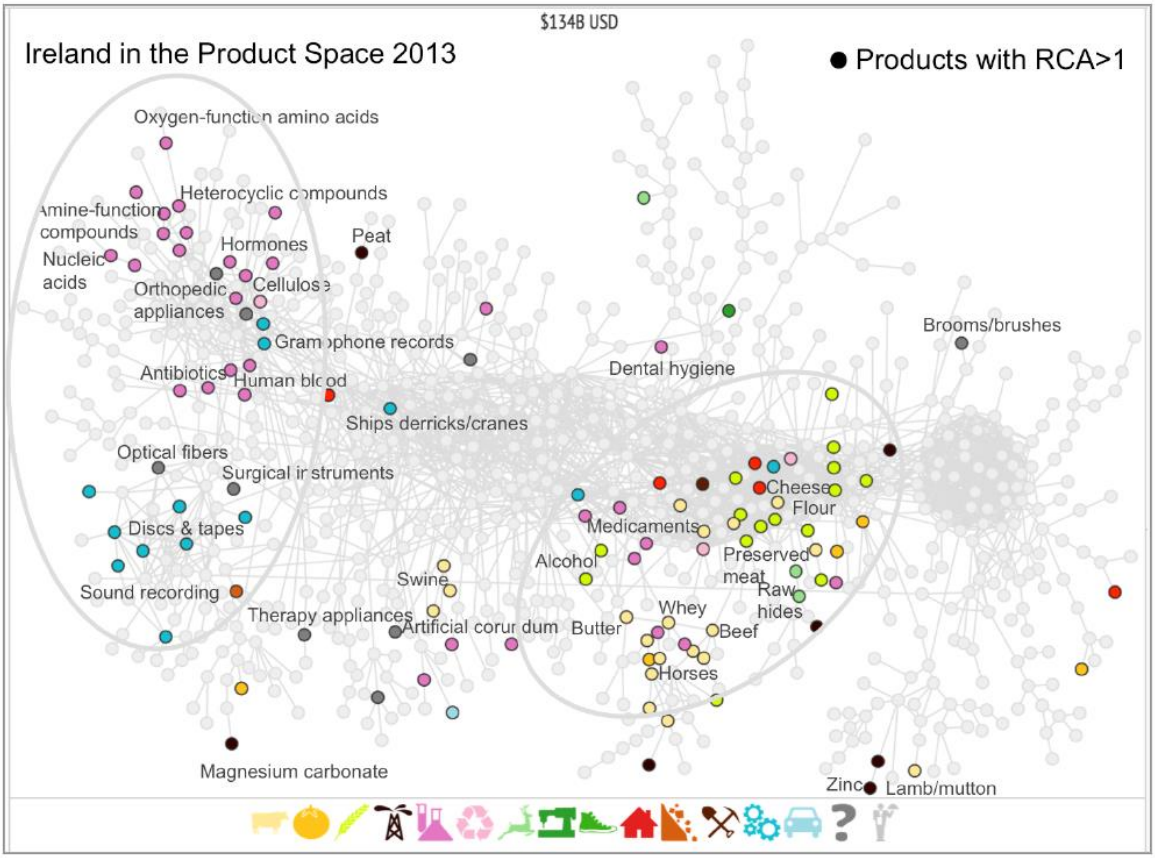


Figure 5: We have seen that, over the last decade, Ireland has specialised. In 2012 Ireland occupied two distinct regions of the Product Space – including a cluster of high complexity mainly foreign-owned chemical, pharmaceutical (pink) and electrical products (blue) on the left-hand periphery and a separate cluster of mainly domestic food and agricultural (yellow/orange/red nodes) industries on the centre-right. The presence of domestic industries in highly connected central regions of the Product Spaces implies that Irish firms have many options for diversification in terms of the capabilities they already possess. In contrast, the peripheral nature of some of the foreign-owned industries implies that spill-overs may be limited due to their highly specialised nature - coupled with very high entry costs. [Source: The Atlas of Economic Complexity, with artistic and text overlays by Author]

4. EXPORT DIVERSITY AND COMPLEXITY IN IRELAND

Under the assumption that industrial diversification occurs via the acquisition of new capabilities, by locating the products which Ireland is able to make in the Product Space, we can examine how the productive structure of the Irish economy evolved over time. Later, we can also employ the Product Space to identify potential new industries by locating complex industries (nodes) at short distance from the Ireland's current export basket.

We measure the 'presence' of products in the Product Space by determining if they are exported with Revealed Comparative Advantage (RCA). A product is exported with RCA when the relative share of a country's exports in the product exceeds the global share of exports in that product. For example, if apples compose 10% of Irelands export basket, but just 2% of global exports, then Ireland would have an RCA factor of 5. If Ireland exports any product with RCA factor>1, we say that Ireland exports that product with RCA.

Over the past decade Ireland's coverage of the Product Space, in terms of the number of products exported with RCA, has been shrinking. Figure 4 shows that in 1995 Ireland exported a wide range of products including some textiles, metals, printed materials and peat and cement. However, since then Ireland has specialised, exporting fewer and fewer products with RCA (a list of products exported in 2012 with RCA is provided in Tables 1-3 of the Supplementary Information). This behaviour contrasts to that typically observed for less developed countries that diversify in the Product Space as they grow, and more developed countries which tend to be highly diversified[25] . The observed consolidation and specialisation for Ireland is supported by analysis by other authors[9], and in contrast to a global trend.

[25] Bahar D, Hausmann R & Hidalgo CA (2012) 'International Knowledge Diffusion and the Comparative Advantage of Nations' Center for International Development, Harvard University.

Figure 5 shows that today Ireland occupies two distinct clusters in the Product Space – one including mainly complex but peripheral industries such as high tech/electronics and chemicals/pharmaceuticals, and a second cluster in the densely connected, but slightly less complex, central region of the Product Space including foodstuffs, animals and agriculture. We note that the former cluster includes mainly high-tech industries that are the product of a very successful campaign to attract foreign investment (FDI) to Ireland, whereas the latter is composed of mainly domestically-owned and operated industries (noting that certain sectors of the food industry such as baby food and concentrates are foreign-owned, see Figure 15).

We will come back to this point later, but for now we note that Ireland's position in highly connected central regions of the Product Space – with particular reference to the domestic cluster - implies it has many options for future diversification in terms of the capabilities it already possesses. Specifically, if Ireland wants to capture more of the value-added in sophisticated sectors, domestic producers will have to expand into more complex products typically located in the left-hand side of the Product Space.

We can quantitatively estimate Ireland's relative level of specialisation via its diversity – in this context measured via the number of products it exports with RCA. Figure 6 illustrates that Ireland's diversity has been decreasing – its level of specialisation increasing - and today is very high within the context of similar nations, approaching that of oil-rich Norway.

We can also compare Ireland's export basket in 1995 to that in 2012 (via correlation of the industry-specific RCA values in those years – shown in Figure 6 of the Supplementary Information). We observe a low correlation value within the context of other Northern European countries suggesting that Ireland has not only specialised, but also radically changed its export mix relative to its neighbours during this period.

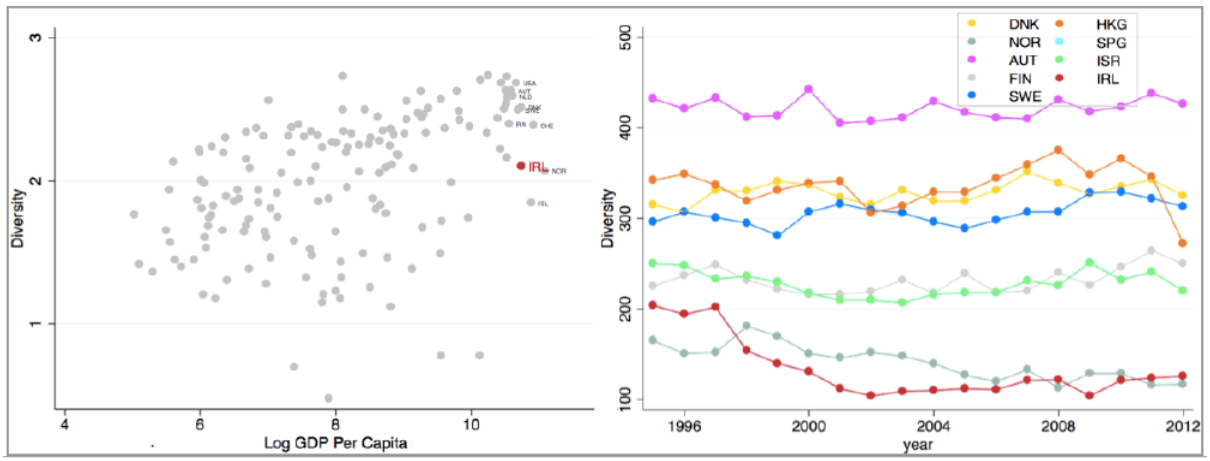


Figure 6: We can measure Ireland's level of specialisation via its diversity - the number of products it exports with RCA. For its level of GDP, Ireland has low diversity – or high specialisation, close to that of oil-rich Norway and only exceeding that of high-tech Israel. Ireland's diversity has been decreasing – its specialisation increasing – since 1995, and today is very low within the context of similar comparator nations. [Source: Author's calculations using CEPII COMTRADE dataset, and UN World Development Indicators]

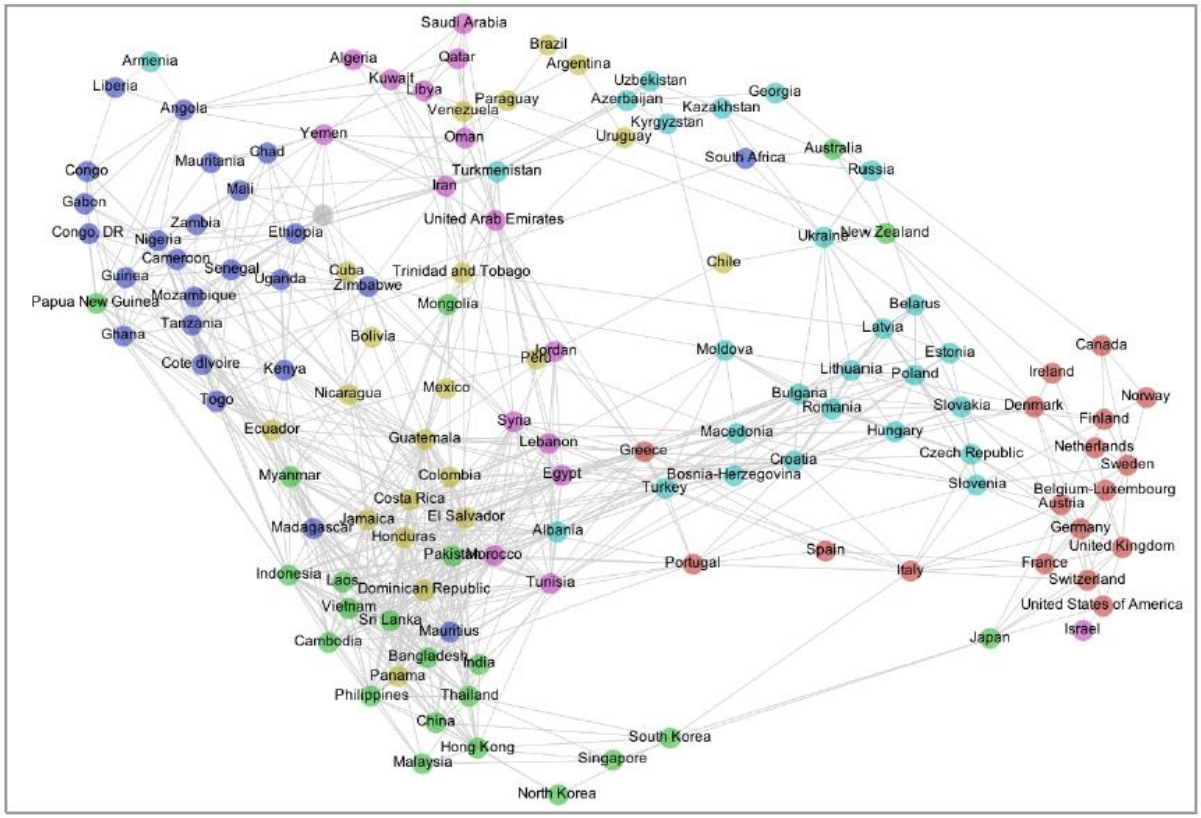
We can visually compare Ireland's export structure, as represented by the Product Space, to other countries. The distribution of products with RCA is shown in Figure 7 of the Supplementary Information for Sweden, Denmark, Hong Kong and Singapore. We find, somewhat surprisingly, that the current Product Space of Ireland appears to be most similar to those of highly specialised high-tech Asian economies such as Singapore and Hong Kong. Indeed, previous analysis has compared Ireland to other small open economies such as Taiwan[26].

In order to systematically study the similarity of Ireland's export structure to other countries, we consider Ireland's position in the Country Space – an analogue of the Product Space where edges represent similarity in product exports. In a similar manner to the Product Space, high levels of co-exported products between pairs of countries capture an underlying similarity in capability base.

As expected, the Country Space for 2012, shown in Figure 7, exhibits significant geographical clustering. For example, Northern European countries are tightly clustered on the periphery of the network with the exception of a small number of countries heavily affected by the 2008 financial crisis such as Greece, Spain, Portugal and Italy. We also observe distinct clusters of oil-producing states, and continental blocs such as African and South American states.

[26] Lin G, Shen Y & Chou J (2010) 'National innovation policy and performance: Comparing the small island countries of Taiwan and Ireland'. *Technology in Society* Volume 32, Issue 2, May 2010, Pages 161–172

Ireland is nestled between other Northern European and similar wealthy nations on the periphery of the network. When we compare Ireland's position in 1995 and 2012, we observe that Ireland has migrated from its position between the Scandinavian nations and Canada, and the Eastern European bloc, to be close to countries reliant on high tech exports such as Japan, Singapore and South Korea – mirroring Ireland's transformation in the Product Space during this period. We note that Ireland is simultaneously be similar to both Northern European countries and high-tech Asian economics based on overlapping export baskets for different product groups.



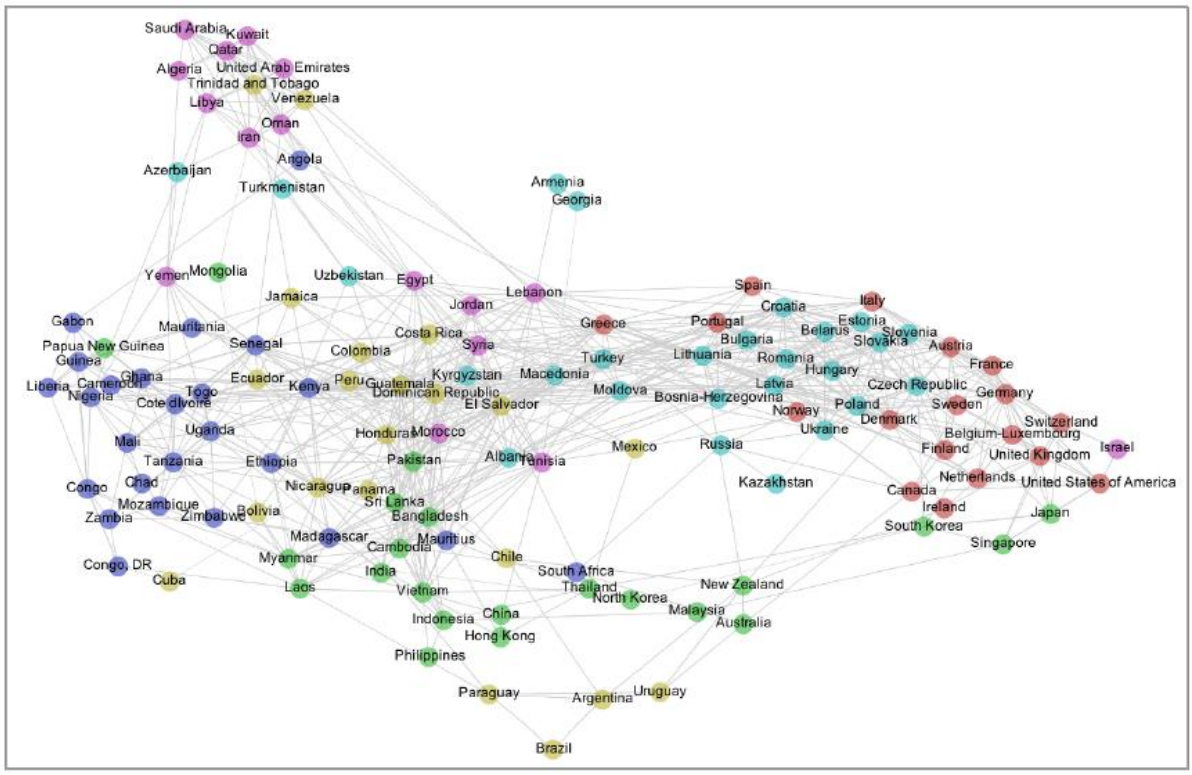


Figure 7: Analogous to the Product Space, we can derive a Country Space for which nodes, or countries, are connected via edges that represent the similarity in underlying capability structure. As with the Product Space, we estimate this similarity by measuring the extent to which pairs co-export the same products. Here we show the Country Space in 1995 (top) and 2012 (bottom) with nodes sized by GDP per capita, and coloured by geographical region. We observe heavy geographical clustering – for example, Northern European countries are tightly clustered on the periphery of the network with the exception of a small number of countries heavily affected by the 2008 financial crisis such as Greece, Spain, Portugal and Italy which are disconnected from the main Northern European bloc. In 1995, Ireland was positioned between the Scandinavian nations and Canada, and the Eastern European bloc. However, in 2012 Ireland had migrated to be more similar to countries reliant on high tech exports such as Japan, Singapore and South Korea. [Source: Author's calculations using CEPII 2012 COMTRADE data, and WDI 2012]

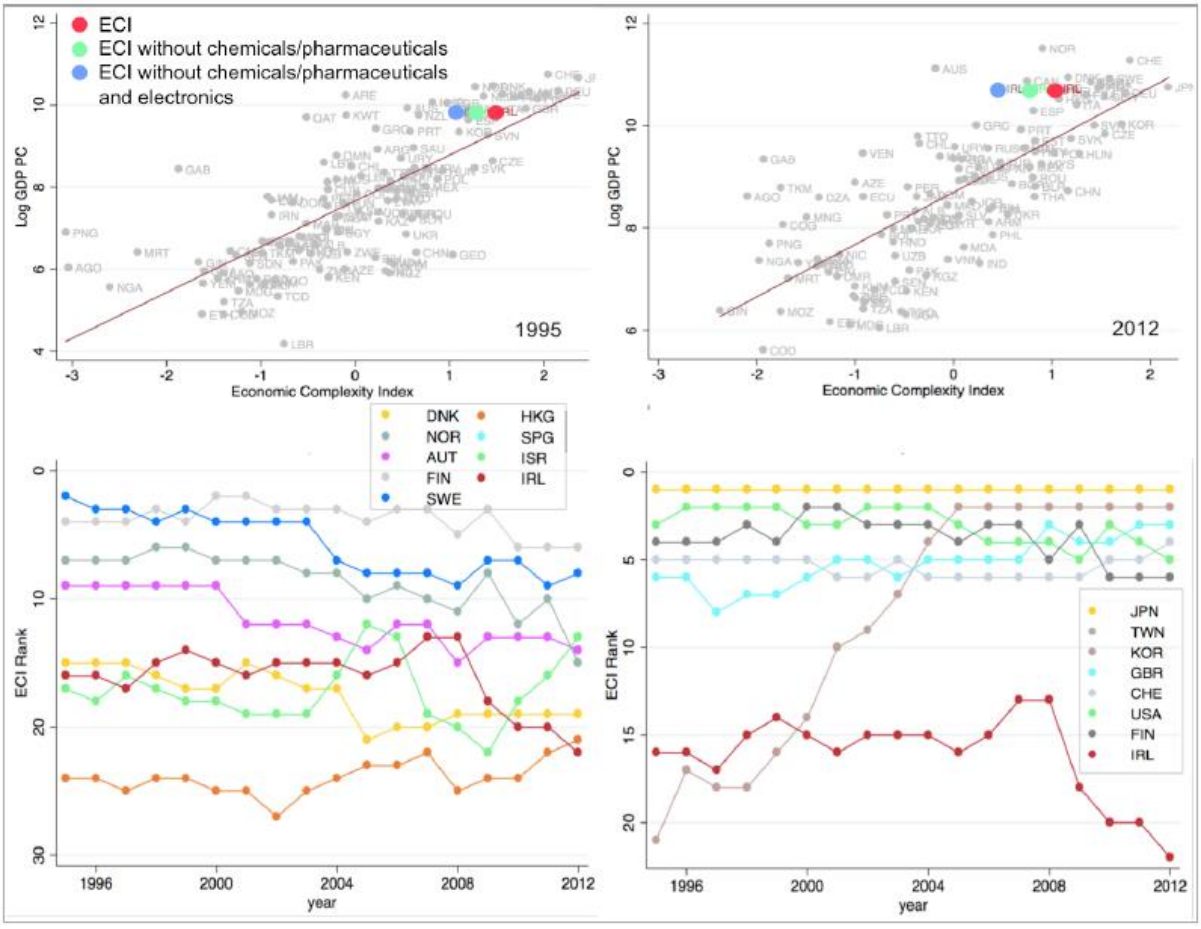


Figure 8: Ireland's ECI is high relative to other countries with comparable per capita GDP (red), and even more so excluding chemical industries (green), or excluding both chemical and electrical industries (dark grey). Over time, we also see an increasing negative residual, implying that Ireland's GDP per capita is increasingly very high as compared to its underlying capability base. Furthermore, relative to similar countries (bottom left) and the most complex countries (bottom right), Ireland exhibits a declining complexity rank. [Source: Author's calculations using CEPII COMTRADE dataset, and UN World Development Indicators]

Finally, we consider Ireland's overall complexity level within the context of its wealth, and dual Product Space structure observed above. Figure 8 shows that Ireland's GDP per capita relative to other countries with comparable ECI is high in both 1995 and 2012, suggesting limited growth potential at the current complexity level - or possibly even predicts a contraction[5].

Given that a cluster of industries, namely chemicals, pharmaceuticals and electronics are mainly foreign-owned, and hence are not fully integrated into Ireland's capability base (this point is discussed and explored extensively below), we also show the ECI excluding these products from the complexity calculation. In this case, we observe an increasing negative residual, further confirming that Ireland exhibits high wealth compared to its observable capability base, and diversity, as captured by exports. We also note that this result is robust when using GNP rather than GDP (see Figure 8 of the Supplementary Information). As GDP is heavily influenced by foreign earnings from Irish output, GNP is often cited as a more reliable measure of the income of residents.

However, it is prudent to note again that services – particularly tradable services which tend to perform better in terms of growth potential[27] - are not included in this analysis, and which may be a source of increased complexity unseen here.

Relative to similar countries (bottom left of Figure 8) and the most complex countries (bottom right of Figure 8), Ireland exhibits declining complexity rank (we consider ranks rather than levels when comparing complexity across time). This indicates that Ireland either is losing high complexity products, or it is gaining low complexity products - or a combination of these factors.

We have seen that Ireland has exhibited intense export specialisation, and a decline in aggregate complexity level, over the past two decades, cumulating in a dual structure in the Product Space most similar to a handful of high tech Asian economies in terms of export basket. We will explore these dynamics further when we look at the evolution of product exports and complexity over time below.

5. INDUSTRY APPEARANCES AND DISAPPEARANCES: WHAT HAS BEEN DRIVING THE OBSERVED RECENT DECREASE IN COMPLEXITY FOR IRELAND?

We have previously observed that Ireland has experienced a period of intense specialisation over the past two decades. Globally, however, we observe that most highly complex countries are highly diversified. In fact, while complex countries tend to make a range of products including rare products, less complex countries tend to make ubiquitous products, i.e., those made by a wide range of countries. Has Ireland, in some sense, over-specialised leading to an increased exposure to external risks, and limitations in future growth due to a contracting capability base? By considering the past evolution and future potential of Ireland, in terms of both complexity level and position in the Product Space, we can begin to address this question.

We have seen that Ireland has been experiencing a decline in the number of industries it participates in with a Revealed Comparative Advantage, and overall or aggregate complexity level. We first group products into sectors at Harmonized System (HS) 2-digit sector level, and analyse product presences, appearances and disappearances since 1995.

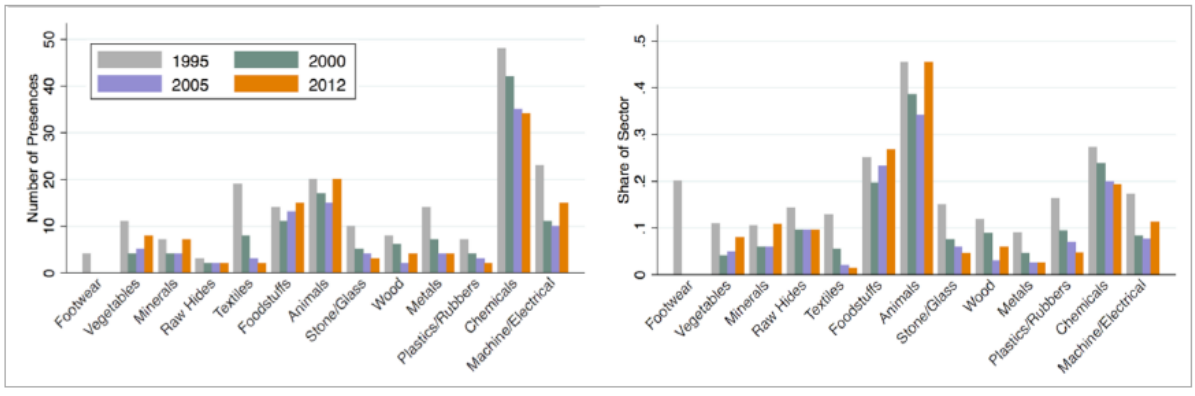


Figure 9: Here we consider the evolution of sectors (ordered in terms of mean product complexity) in terms of the number of products exported with RCA. We observe that the most complex sectors, such as chemicals and electrical products, have been declining since 1995 in both the number of products exported with RCA, and the share of products in the sector exported with RCA. On the other hand, lower complexity sectors such as foodstuffs, animals and agriculture have shown an increase in the number of products exported with RCA since 2005. [Source: Author's calculations using CEPII COMTRADE dataset]

[27] Aghion P, Boulanger J & Cohen E (2011) *Rethinking Industrial Policy*. Bruegel Policy Brief

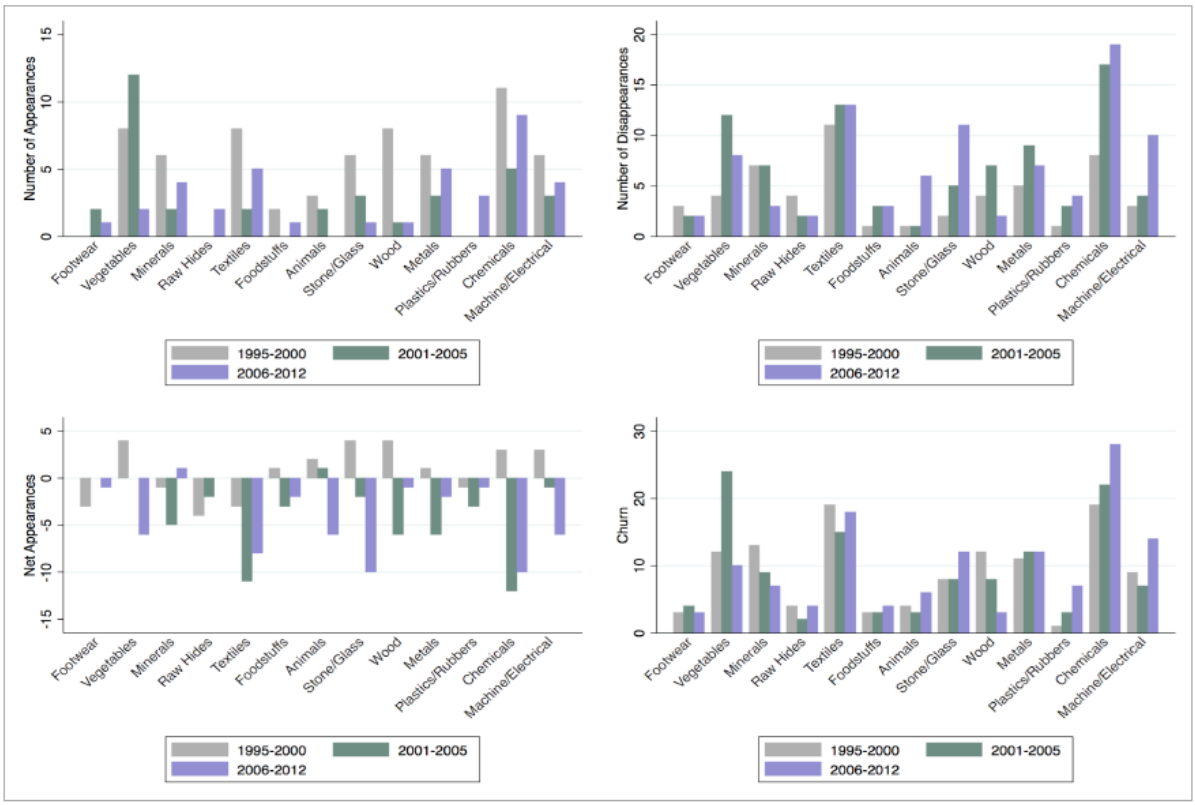


Figure 10: Most sectors have seen a declining number of appearances over time, with vegetables showing a significant increase during the period 2001-2005. Conversely, most sectors have seen an increase in disappearances over time, particularly in the chemical and electrical industries, with the exception of some lower complexity sectors such as vegetables and minerals. In many cases the net appearances of new industries was positive during the period 1995-2000, yet turned negative in later years. There was high entry and exit of many sectors, with increasing churn in high complexity sectors such as stone/glass, plastics, chemicals and machinery/electrical. [Source: Author's calculations using CEPII COMTRADE 2012 data]

Figure 9 shows that most complex sectors, such as chemicals and electrical products, have been declining since 1995 in both the number of products exported with RCA, and the share of products in the sector exported with RCA. On the other hand, lower complexity sectors such as foodstuffs, animals and agriculture have shown an increase in the number of products exported with RCA since 2005. Hence, it is clear that a combination of a decrease in high complexity products, and an increase in low complexity products, has driven the decrease in overall complexity (the ECI) as previously observed.

Considering appearances and disappearances in more detail, as seen in Figure 10, we observe that:

- While most sectors have seen a declining number of appearances since 1995, vegetables, metals and minerals have seen a modest increase in recent years.
- Almost all sectors have seen an increase in the number of disappearances in recent years, in particular chemicals and electronics. Similarly, in contrast, vegetables and minerals have seen a decline in disappearances.
- We see a negative net number of appearances (i.e., net disappearances) for all sectors for the most recent time-period, with greatest net negative appearances in chemicals, stone/glass and textiles.
- The churn (number of appearances and disappearances) has been high for chemicals/pharmaceuticals, textiles and machinery (driven by disappearances). However, churn is lower for animals and food, and declining for vegetables, minerals and wood.

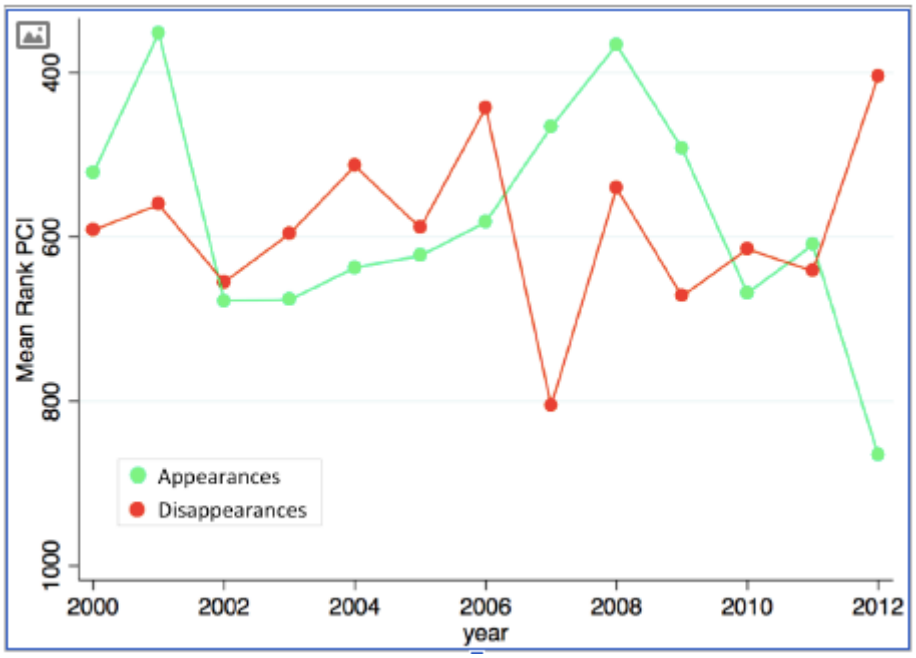


Figure 11: We observe here that, after a sustained rise in the mean complexity of product appearances between 2002 and 2008, since 2008 the complexity of new products exported with RCA has been falling. Hence, overall we observe a worrying trend: declining complexity of appearances coupled with increasing complexity of disappearances. [Source: Author's calculations using CEPII COMTRADE 2012 data]

Hence, overall we see high churn and a recent acceleration in disappearances for chemicals/pharmaceuticals and electrical/machinery. In contrast the domestic food and animal sectors are largely stable with some increase in presences.

We can also consider more closely the mean sophistication of both appearances and disappearances, as measured by complexity index (PCI). Figure 11 shows that, after a sustained rise in the mean complexity of product appearances between 2002 and 2008, after 2008 the complexity of new products exported with RCA has been falling. Figure 9 of the Supplementary Information shows a breakdown for product groups: after an increase in complexity of both presences and appearances in high tech sectors including machinery/electrical and pharmaceuticals/chemical before 2008, we observe a dramatic decrease in complexity level. When we aggregate food and vegetable sectors, representative of Ireland's domestic cluster, we observe a recent tentative but erratic increase in complexity of both presences and appearances, which bodes well for increasing the overall domestic complexity level in the long run.

6. AGGLOMERATION ECONOMIES

Underlying the capabilities model introduced above, the creation and growth of industries relies on the transfer of knowledge, and sharing of inputs, between firms. This perspective is closely related to models of regional and urban growth, which typically focus on effects of co-location or agglomeration for both similar and complementary industrial activities. Such models emphasise the localised nature of the drivers of growth, as firms locate in close proximity in order to reduce costs.

Marshall (1920)[18] argued that firms benefitted from a reduction in transport costs, namely the cost of moving goods, people, and ideas. For example, firms may locate near suppliers or customers to save shipping costs, or near specific workers to take advantage of labour market pooling or intellectual spill-overs. He suggested that, in agglomerations, "the mysteries of the trade become no mystery, but are, as it were, in the air." Porter[19] proposed a similar mechanism in which clusters of similar industries use related technologies and foster innovation and competition, which in turn promotes productivity.

The role of foreign-owned and operated firms is important within the context of the Product Space framework as the dynamics of industrial diversification, under the assumption that it is based on the percolation of capabilities within an economy which may be significantly altered by FDI as new knowledge, skills and inputs are 'parachuted in' leading to varied – potentially positive or negative - effects. Aside from the well-publicised risks of heavy reliance on FDI including issues such as plant relocation, patent expiry etc.[28], the key implication here is that a variety of mechanisms could result in limited benefit or knowledge spillover to the local economy in terms of the appearance of similar or related domestic industry.

For example, large number of inputs and capabilities critical to foreign-owned operations – and in particular large multi-nationals operating a highly complex global supply chain – are sourced internationally (through a variety of channels). Hence, while local workforces benefit from such experience, the fact that just a subset of the highly technical inputs needed are sourced locally may mean that these newly acquired capabilities have a more limited impact in terms of the growth of similar industries. Conversely, external inputs such as FDI could have the opposite effect when injected into industries close to the current capability structure – complementing and amplifying existing strengths thus promoting and accelerating growth into nearby products.

Here we consider the evidence for such spill-overs within the Irish economy within the Economic Complexity framework, and ask if its diversification over time is well-described by the Product Space model. But first, we look for further evidence of a dual economy – composed of domestic and foreign producers exhibiting distinct characteristics as seen previously via our Product Space clusters – in firm-level data.

If we consider the set of all manufacturing firms (not restricted to exporters) captured by Ireland's Central Statistics Office Census of Industrial Production, we observe almost complete dominance of foreign firms across the board – in terms of the number of firms, employees and annual turnover - with the exception of the food and agriculture sector. Specifically, Figure 12 shows that:

1. Chemicals/pharmaceuticals: Foreign firms are dominant in terms of number of enterprises, number of employees (by a factor of 5) and annual turnover (by a factor of 20) for the chemical and pharmaceutical sectors.

2. Electronics/computers: While Ireland has approximately twice as many domestic firms as compared to foreign-owned firms in electronics/computers, foreign firms dominate in terms of employees (by a factor of 4) and turnover (by a factor of 21).

3. Manufacturing: Similarly for 'other manufacturing', foreign firms dominate in terms of employees (by a factor of 15) and turnover (by a factor of 38).

4. Food: Somewhat surprisingly, while Ireland has a greater number of firms (570 Irish firms compared to 37 foreign firms) and employees, foreign firms have larger turnover than domestically-owned firms ($US 14m compared to $US 12 for Irish firms) in the food sector.

[28] McKinsey & Co. (2014) *Capturing the value of Ireland's global connections*

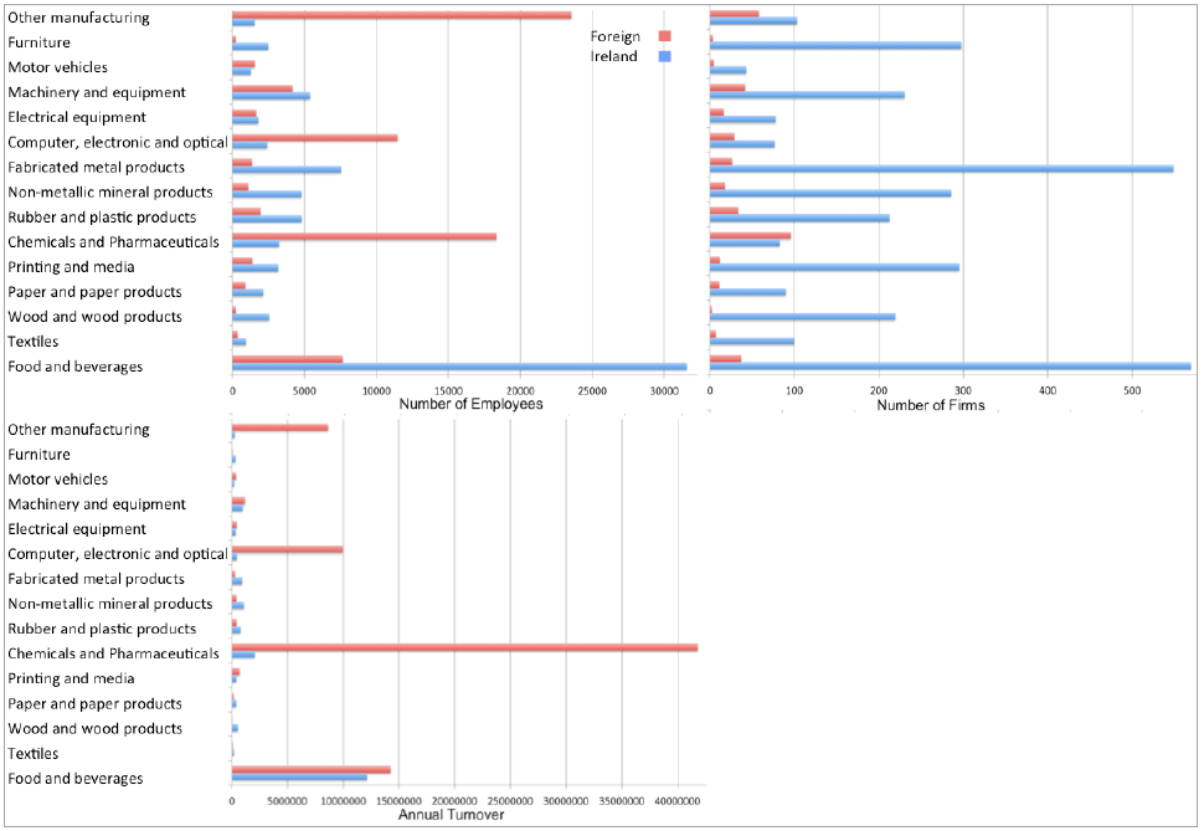


Figure 12: We observe broad-based dominance of foreign-owned manufacturing firms over Irish manufacturing firms for various key sectors (NACE 2-digit sectors) in 2012. In particular, we can see that foreign firms are dominant in terms of number of enterprises, number of employees and annual turnover for the chemical and pharmaceutical sectors. While Ireland has a significant number of firms in electronics/computers and other manufacturing, foreign firms dominate in terms of employees and turnover. Somewhat surprisingly, while Ireland has a greater number of firms and employees, foreign firms have larger turnover than domestically-owned firms in the food sector. [Source: 2012 Census Industrial Production from CSO Ireland]

Hence, foreign firms appear to dominate domestic firms in almost all key sectors, while Irish firms have only a significant foothold in the food sector.

Ireland has traditionally followed what has been termed an 'industrialisation by invitation' approach whereby policy-makers believed that attracting FDI in a range of high-tech clusters would both lead to economic growth and foster indigenous industrial activity[11]. Yet, despite concerted efforts to foster spill-overs[11], evidence of the occurrence of positive externalities are mixed[11] [29] and this seemingly singular approach has come under criticism[30].

A 2014 report by the Irish Department of Finance[10] highlights the current dis-connect between domestic and foreign dominated sectors:

- Due to the high value-added nature of foreign-dominated sectors, productivity levels are higher than in Irish-owned firms. This differential holds across all sectors but is particularly pronounced in manufacturing.
- Higher productivity levels are reflected in wage levels which are nearly twice as high in foreign-owned firms as compared with indigenous ones.

[29] The Lucerna Project (2010) *Capabilities & Competitiveness: A Methodological Approach for Understanding Irish Economic Transformation*

[30] Bailey D & Lenihan H (2015) 'A Critical Reflection on Irish Industrial Policy: A Strategic Choice Approach'. *International Journal of the Economics of Business* Volume 22, Issue 1, 2015.

- While the presence of foreign-owned companies in the economy can benefit domestic firms, the industry output and employment multipliers in terms of indirect effects on the economy are much higher for domestic sectors than for FDI.

For example, high-tech foreign-owned businesses are typically integrated into vertical supply chains often reliant on suppliers in the owners country and distributors on mainland Europe, and often lead to little demand for Irish suppliers[31] [32]. There is also limited evidence of labour market pooling. For example, evidence suggests that skills needed by Irish pharmaceutical industry have been acquired in third level institutions and not 'on-the-job'[33]. Finally, limited evidence also exists for knowledge spill-overs with the exception of the Dublin software industry[34].

Indeed, analogous to the Product Space distribution of industries observed above, a dichotomous innovation system has also been observed regarding the ways in which indigenous and foreign-owned businesses conduct innovation in Ireland[11]. For example, indigenous firms are more likely to interact with customers and suppliers, which both spurs innovation and leads to a higher return on that innovation[35]. On the other hand, foreign-owned businesses based in Ireland tend not to develop in-house R&D capacity, but rather engage with higher education institutes doing research in their respective field[36]. This latter approach, driven by tax incentives, has again failed to compelling spur on domestic innovation and generate high-tech start-up activity[11].

Hence, both a range of data sources and previous research support our earlier observation that Ireland inhabits two distinct clusters in the Product Space. Here we complement this work by developing a data-driven approach to investigate of the pattern of Ireland's industry appearances in the Product Space, as documented in Tables 4-7 of the SI. We would expect that over time, as clusters of products form in the Product Space and the likelihood of new neighbouring products increases due to concentration of industries, we could better predict new appearances. However, external processes such as injections of FDI may disrupt this path-dependent process and render the Product Space model less predictive of industry growth.

In order to estimate the likelihood of product appearances, and compare this estimate to actual industry appearances, we use a measure of 'distance' in the Product Space from a particular product to the export basket of a specific country (i.e., the industries it inhabits) – where a closer industry is more likely to appear[8], see SI for a detailed derivation. Conversely, we can identify which appearances were in some sense unexpected due to their increased distance. For example, if Ireland already exports apples and pears – neighbours of plums in the Product Space – it is more likely to export plums in the future. Conversely, Ireland might be less likely to export rubber as it does not already export any of the products neighbouring rubber in the Product Space, and hence an appearance of rubber would be unexpected.

Figure 13 shows that, splitting the data into domestic and foreign-owned sectors, we observe that appearances in domestic sectors became more predictable over time suggesting that an expansion of the underlying capability base (which could be augmented by FDI into these sectors) has given rise to new products as modelled by the Product Space.

However, in the latter case we observe a decrease in the prediction power of the Product Space structure, suggesting a lack of spill-over from the high-tech foreign sector possibly due to a lack of transfer of sufficient capabilities to the indigenous workforce due to their relative distance[37] (in the Product Space) from existing local capabilities, specialised input needs, very high start-up and R&D costs, and other barriers to entry such as patent protection in pharmaceuticals and electronics.

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[31] Gallagher L, Doyle E & O'Leary 'E (2002) 'Creating the Celtic Tiger and Sustaining Economic Growth: A Business Perspective'. *Quarterly Economic Commentary*, Economic and Social Research Institute, Dublin, Spring, 63-81.

[32] Barry F, Gorg H & Strobl E (2003), Foreign Direct Investment, Agglomerations and Demonstration Effects: An Empirical Investigation'. *Review of World Economics/Weltwirtschaftliches*, 139, 4, 583-600.

[33] Van Egeraat C (2006) 'The Pharmaceutical Industry in Ireland: Agglomeration, Localisation or Simply Spatial Concentration?' NIRSA Working Paper Series, 28, February, National Institute for Regional and Spatial Analysis, Maynooth.

[34] Crone M (2004) 'Celtic Tiger Cubs: Ireland's VC-Funded Software Start-ups'. The Institute for Small Business Affairs, National Entrepreneurship and SME Development Conference, Newcastle-Gateshead.

[35] Doran J & O'Leary E (2011) 'External Interaction, Innovation and Productivity: An Application of the Innovation Value Chain'. *Spatial Economic Analysis*, 6(2): 199–222

[36] Jordan D & O'Leary E (2008) 'Is Irish Innovation Policy Working? Evidence from Irish High-Technology Businesses'. *Journal of the Statistical and Social Inquiry Society of Ireland*, XXXVII: 1–45.

[37] Our distance metric is based on the RCA level of neighbouring nodes – i.e., industries surrounded by high RCA existing industries are more likely to appear. See Appendix for a technical definition.

7. OPPORTUNITIES FOR GROWTH

We have seen that the structure of the Product Space enables us to estimate if past appearances and disappearances were 'expected' based on their 'distance' to Ireland's export structure at that time. This logic can be extended to predicting or designing – via, for example, policy actions such as grants or subsidies - future industry appearances under the same logic that nearby industries require similar inputs to current capabilities, and are thus more likely to be good candidates for strategic investment.

On an international level, industrial policy has had a chequered history. Accused of promoting graft, and reducing competition via 'picking winners' without clear theoretical foundation, there has been much scepticism regarding a state's ability to conduct this role fairly and effectively. However, industrial policy has recently enjoyed somewhat of a resurgence as data-driven tools such as the Product Space have become available, and governments in both the developing and developed world attempt to actively promote the growth of specific sectors in the face of emerging threats from a diverse range of sources including climate change, the proliferation of low-growth non-tradable services industries, and the success of China which has long conducted wide-ranging industrial policy[38].

We have seen in the previous section that Ireland has traditionally engaged in industrial policy, attracting FDI in a range of high-tech clusters in the hope that this would generate spill-overs and foster indigenous economic activity[11]. Today, it is widely acknowledged that better linkages between industries, and increased opportunity for bottom-up growth, is needed for diversification and expansion of domestic sectors.[11, 39]

Before proceeding any further, it is important to note that we seek here to simply illustrate the potential of the Economic Complexity framework and the Product Space as a tool for industrial policy. Further in-depth analysis of market dynamics and a range of internal and external factors, which is beyond the scope of this paper, would be necessary to robustly identify in detail promising sectors for investment.

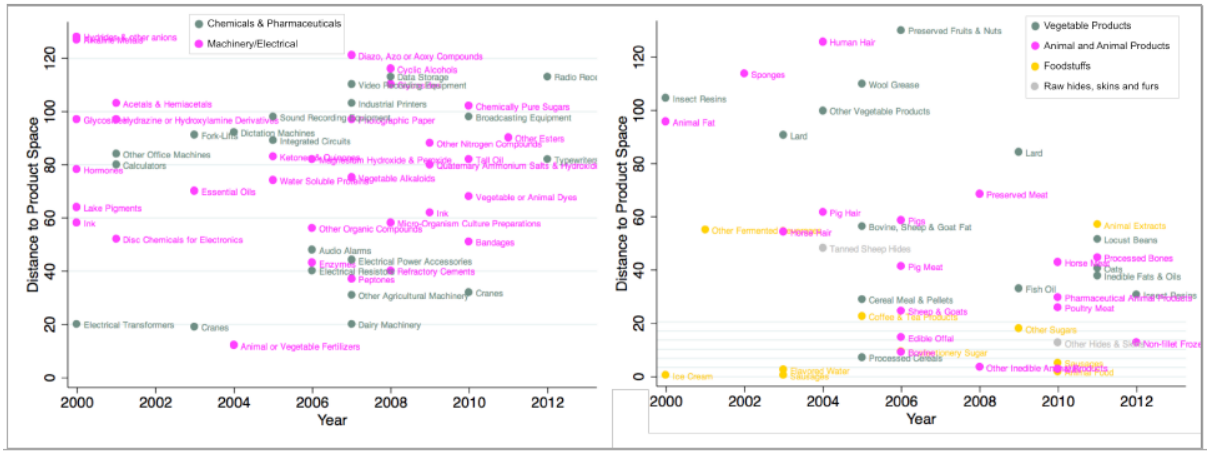

Figure 13: We observe that appearances of chemicals/pharmaceuticals and machinery/electrical have occurred at both close and further distances from the current Product Space over time, yet vegetable products and animal products have been appearing in a more predictable fashion (we find that the relationship between distance and year is statistically significant with t=-2.43 and r2=0.12) – i.e., increasingly in close proximity to the Ireland's position in the Product Space. [Source: Author's calculations using CEPII COMTRADE 2012 data]

[38] Aghion P, Boulanger J & Cohen E (2011) *Rethinking Industrial Policy*. Bruegel Policy Brief

[39] Irish Department of Jobs Enterprise and Innovation (2014) *Ireland's Smart Specialisation Strategy for Research and Innovation, Summary*

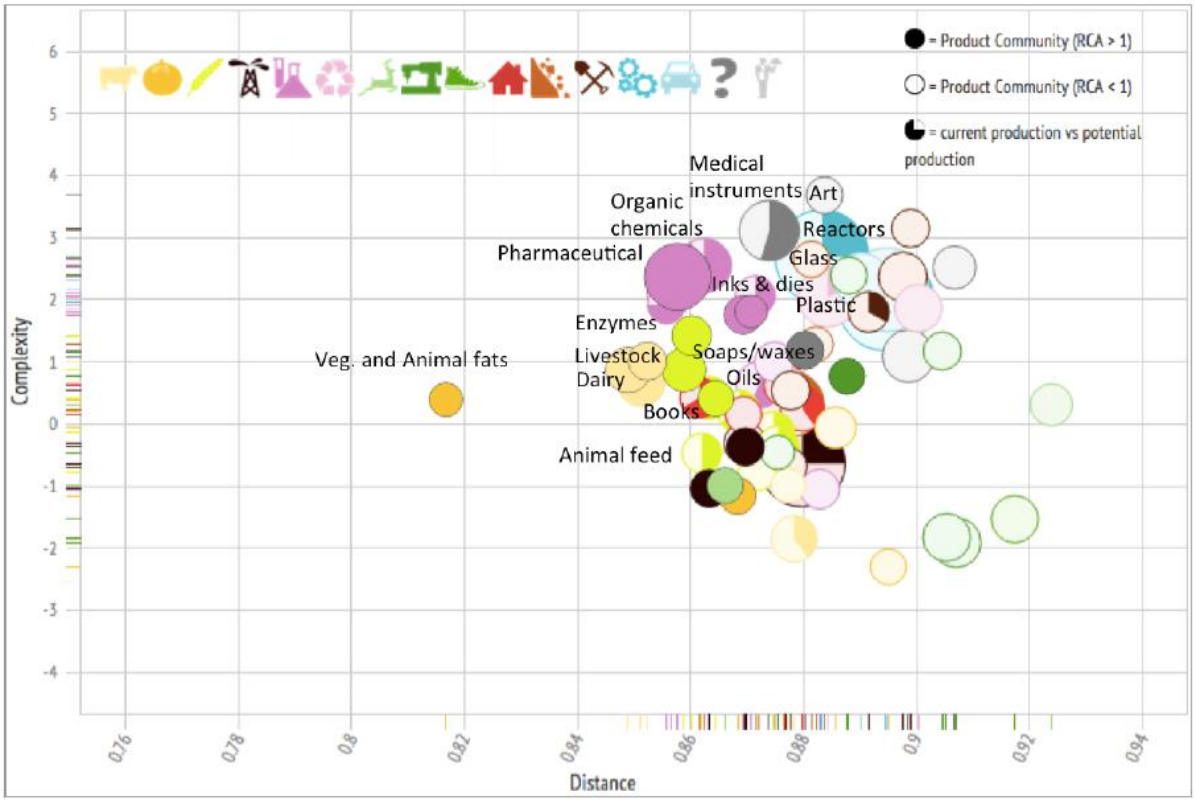

Figure 14: For developing countries, we often have the situation where complex industries are further away (i.e., the distance is greater). However, in Ireland's case, many complex industries are close to current products. Here the sectors (HS 3-digit aggregation) are sized by world trade, and filled according to the number of sub-sectors Ireland exports with RCA. Hence, the non-filled space corresponds to the 'opportunity' for growth of new products within these sectors. [Source: The Atlas of Economic Complexity 2012, with artistic and text overlays by Author]

We have seen that under the Economic Complexity model, countries grow as they diversify into more complex industries in a step-wise fashion (typically moving from right to left) in the Product Space. For many developing countries, complex industries are far away in the Product Space and strategic diversification is difficult. However, in Ireland's case, a large range of complex industries are close to current products and hence Ireland is well-positioned in the Product Space to increase its aggregate complexity level, as seen in Figure 14.

Quantitatively, the metric Opportunity Value measures how well a country is positioned in the Product Space by calculating the distance of the country to the products it is currently not exporting with RCA, weighted by the complexity value of each product (see SI for a detailed definition). Figure 15 shows that Ireland's Opportunity Value is more or less as expected for its level of wealth, confirming that it is in a reasonably good position to move into nearby more complex industries.

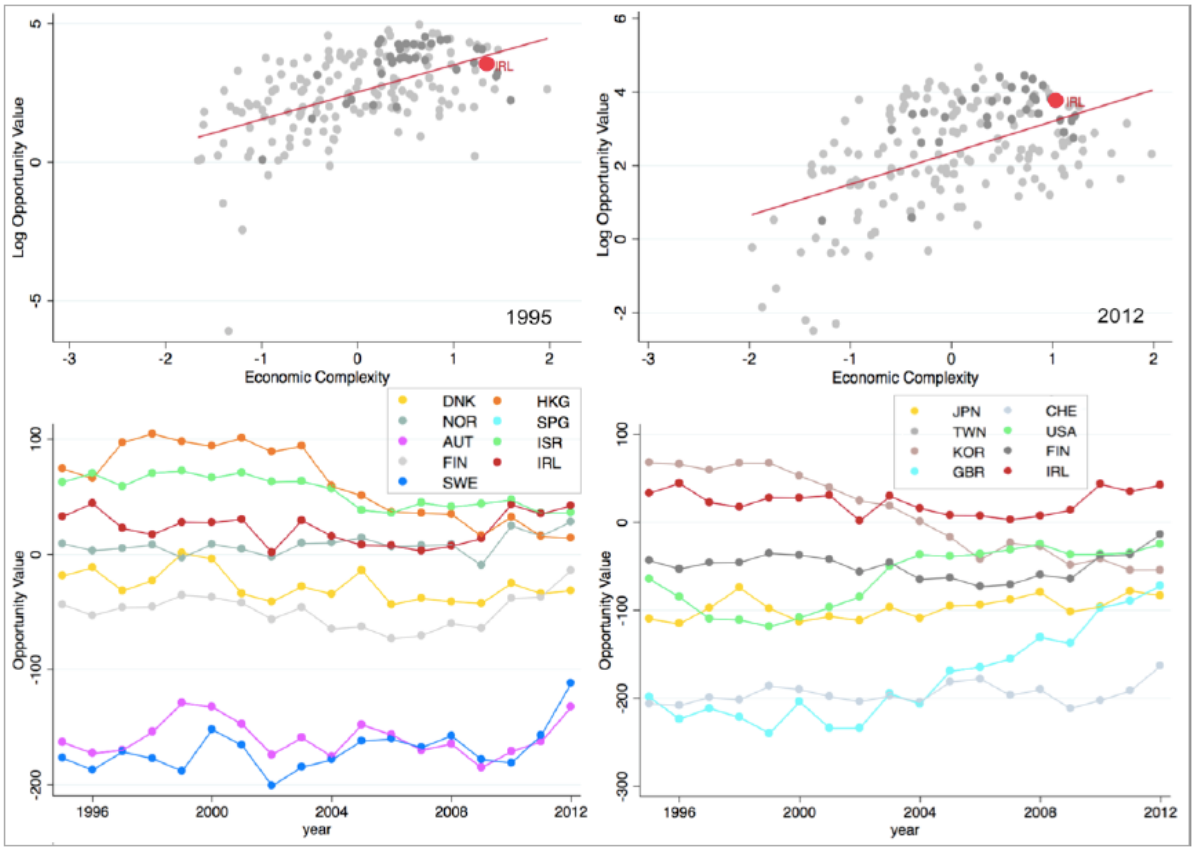

Figure 15: Ireland occupies a densely connected central cluster, and a high complexity peripheral cluster, in the Product Space leading to many nearby potential new industries and a consistently high opportunity value (see Appendix for definition). Compared to similar countries (bottom left) and the most complex countries (bottom right), Ireland exhibits a relatively high and stable opportunity value. [Source: Author's calculations using CEPII COMTRADE 2012 data]

Individual products are chosen because they exhibit close distance to Ireland's current export basket, have complexity greater than the current mean complexity value, and high Opportunity Gain (a metric that combines both distance and complexity analogous to the country-level aggregate measure Opportunity Value).

We wish to identify promising products that are both close the Ireland's current export or capability structure, and have will increase overall complexity level). Potential products fulfil several criteria:

- Currently not exported with RCA>1
- Small 'distance' to Ireland's current Product Space;
- PCI greater than current mean PCI
- RCA in previous years such that 0.05<RCA<1 in order to eliminate products such as kiwis, for example, which may not be suited to Irelands climate (and have hence never been exported in any quantity), and industries in which Ireland previously had a comparative advantage and exited the market.

Figure 16, and Figures 10 and 11 of the SI, highlights a range of products which balance distance and complexity. In particular, we note that diversification into varied machinery sectors which are at close proximity to the current domestic cluster could be a stepping stone to higher complexity measurement instruments towards the left-hand side of the Product Space. These strategic industries include various measurement instruments, pumps (liquid and fire extinguishers) and a range of machinery including lifting, harvesting, excavation, and agricultural and stone-

working machinery. Consistent with developments on the ground, the former set of products fit well within existing growth of the medical devices sector. Agricultural machinery has also been recently independently identified as having significant export potential[40].

An extensive list of potential industries and their corresponding distance and complexity is included in the Supplementary Information, see Tables 8-13.

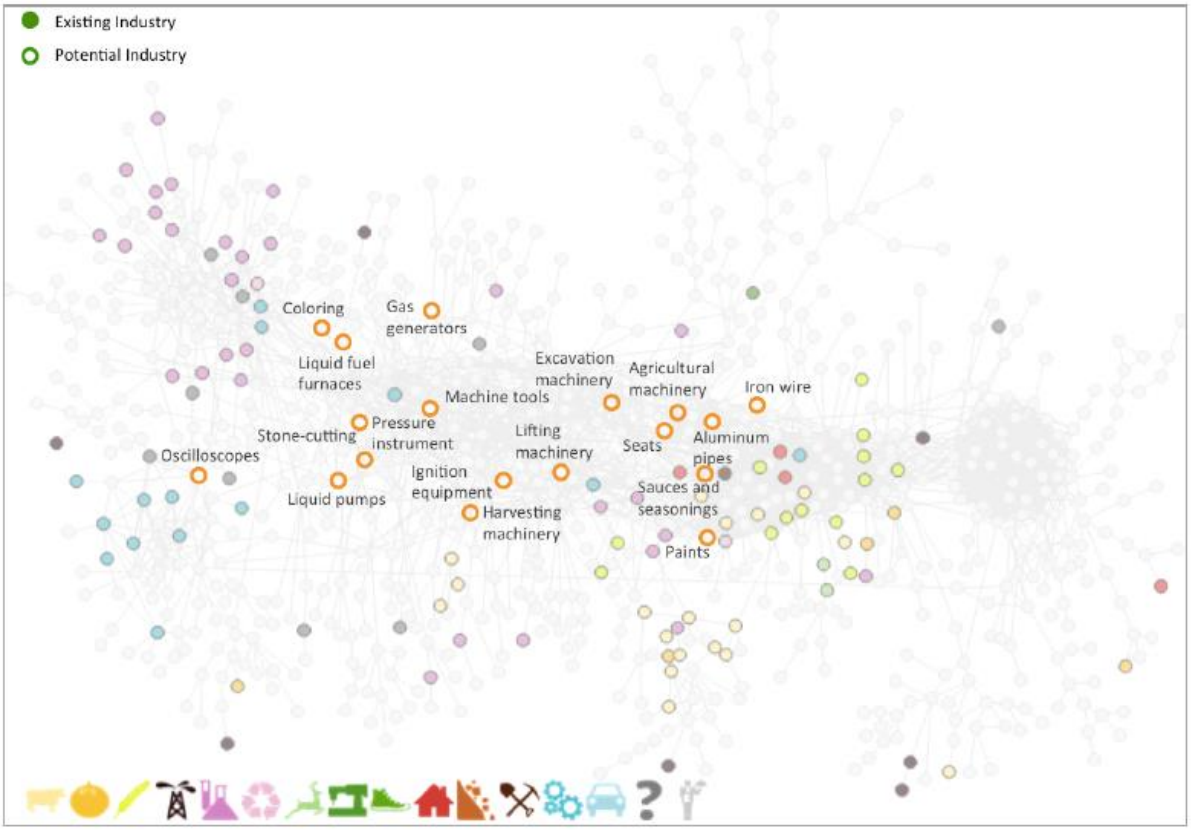

Figure 16: Finally, we illustrate the position of several potential industries in the Product Space. We observe that diversification into varied machinery sectors could be a stepping stone to higher complexity measurement instruments. [Source: The Atlas of Economic Complexity 2012, with artistic and text overlays by Author]

8. DISCUSSION AND CONCLUSIONS

In this paper we have explored the evolution of Ireland's export structure and complexity in the Product Space over the past two decades within the context of an economy heavily dependent on exports, and a long-standing focus on attracting FDI as a means to foster domestic activity.

This analysis has identified several risks to Ireland. In particular, Ireland exports fewer and fewer products with RCA over time, with an acceleration in the number of high complexity products observed exiting the market since 2008. This shrinking Product Space indicates that it is specialising – yet we observe an intense level of specialisation as compared to similar countries. Furthermore, the evidence that specialisation leads to economic growth for developed countries is mixed.

Ireland's position in the Product Space exhibits a dual structure with two disconnected clusters representing domestic and foreign-owned industries respectively. Due to this distinctive feature, Ireland is today most similar in terms of productive structure to high-tech Asian economies such as Japan, Singapore and Hong Kong.

During this period of consolidation, Ireland has experienced a decline in its Economic Complexity Index driven by industry exits in high-tech sectors such as electronics, and increasing domestic exports of low complexity

[40] Irish Times Article (2015) http://www.irishtimes.com/business/agribusiness-and-food/farm-machinery-manufacturers-have-eyes-on-export-market-1.2093199

agricultural and food goods. As a result, Ireland has a very high level of GDP per capita as compared to other countries at a similar complexity or capability level.

Most of Ireland's high-value foreign-owned exporters, brought to Ireland by a very successful campaign to attract FDI, are located in peripheral regions of the Product Space far away from the domestic cluster. This suggests that knowledge and skills are not easily transferable to the indigenous workforce, and we observe that evidence of spill-overs in terms of the creation of new closely-related domestic-owned industries is limited. We note that, however, spill-overs in terms of the creation of new related services industries (not present in our data sets) – such as computer software and maintenance – have been observed.

The peripheral nature of the foreign-owned cluster does indicate Ireland might enjoy some protection in terms of competition as it is 'distant' in terms of the capabilities needed move into this region in the Product Space for many countries. However, the trend towards high levels of diversification for developed countries will likely negate any such protection in the longer run. Specialisation could also leave Ireland open to industry shocks such as patent expiry, changing tax rules, competition from emerging manufacturing bases and changes in the organisation of international supply chains.

However, on the domestic front things are more positive in terms of future trajectory. Ireland's domestic exporters are located in central highly connected regions of the Product Space leading to high opportunity value and plenty of potential nearby industries (requiring similar capabilities) for expansion. Furthermore, lower complexity but domestically-owned sectors such as foodstuffs, animals and agriculture have shown a recent increase in products exported with RCA – suggesting that the domestic capability base is expanding. FDI into these sectors is also significant which, in this case due to its proximity to Ireland's current domestic productive capabilities, is likely to bring new complementary expertise and accelerate the observed expansion of the cluster. Ireland has also seen recent growth in domestic industries in medical and optical devices straddling the divide between foreign and nationally-owned firms in the Product Space (yet has not yet increased the number of products with RCA in this sector).

Hence, overall the Economic Complexity framework suggests that Ireland's complexity level is below that which would be expected for a country of comparable wealth. However, while this low and declining complexity level has been driven by high specialisation and recent consolidation in some highly sophisticated FDI-driven sectors, the evidence is more promising that an increase in 'domestic' complexity can be driven by expansion into products and industries nearby to the existing food and agriculture cluster.

APPENDIX: SUPPLEMENTARY INFORMATION

1. GLOSSARY

- Revealed Comparative Advantage (RCA): A product is exported with RCA when the share of that product in a country's export basket exceeds the global share of exports in that product.
- Product Space: The Product Space is a network that models the process of industrial diversification of an economy. Constructed from international export data, nodes (products) are connected based on the similarity between the sets of countries that export each product pair. This metric is intended to capture shared inputs or required knowledge or skills.
- Country Space: Analogous to the Product Space, nodes of the Country Space are countries which are connected based on their shared capability base. Again, the edge weights are derived from the similarity between the sets of products that each country pair exports.
- Ubiquity: Product ubiquity is the number of countries that export the product with RCA.
- Diversity: Country diversity is the number of products that a country exports with RCA.
- Product Complexity Index (PCI): The PCI measures the number and type of capabilities needed to manufacture a product. It is determined by calculating the average diversity of countries that make a specific product, and the average ubiquity of the other products that these countries make.
- Economic Complexity Index (ECI): The ECI of a country ranks how diversified and complex the country's export basket is. Analogous to PCI, it is computed iteratively via a country's diversity refined by the ubiquity of it's products.
- Distance: Distance in the Product Space is measured from a single (non-exported) product to the current set of products exported by a country. Mathematically, it is the sum of the RCAs of exported products weighted by the edge weights connecting these products to the non-exported product.
- Opportunity Gain: The Opportunity Gain measures the potential complexity gain for a country with respect to an individual product. It is computed by calculating the distance of the country to the product (in the Product Space) weighted by the complexity value of the product.
- Opportunity Value: The Opportunity Value measures how well a country is positioned in the Product Space. It is computed by calculating the distance of the country to the products it is currently not exporting with comparative advantage, weighted by the complexity value of each product.

2. ECONOMIC COMPLEXITY VARIABLES

The Product Space and accompanying complexity metrics are derived from CEPII international trade data between 1995 and 2013, including 129 countries and 1240 product classes[4] which can be aggregated at various levels. Typically we consider product classes at the Harmonised System (HS) 4-digit level, and sectors at the HS 2-digit and HS 3-digit levels.

We measure the intensity with which a country exports a product by computing its Revealed Comparative Advantage (RCA). The RCA (corresponding to a product in a country) is defined as the ratio between the share of total exports that the product represents in the country's export basket, and the global share of exports of that product. A product is over-represented in a country's export basket if its RCA is above 1.

Formally, if $X_{c,i}$ is equal to the export value of country c in industry i, then the RCA of country c in industry i is defined as:

$$M_{c,i} = \frac{X_{c,i} / \sum_i X_{c,i}}{\sum_i X_{c,i} / \sum_c \sum_i X_{c,i}}.$$

We say that

- A product is **present** if RCA≥1
- A product is **absent** if RCA≤1
- A product **appears** in t_1 if RCA≤1 in t_0 and RCA≥1 in t_1
- A product **disappears** in t_1 if RCA≥1 in t_0 and RCA≤1 in t_1

for some combination of times t_0 and t_1. Tables 1-7 show industry presences, appearances and disappearances for Ireland during the period 1995-2012.

The Product Space

The Product Space, introduced by Hausmann and Hidalgo [1, 5], is a network where nodes represent industries that are connected - via weighted edges - based on how similar their knowledge or input requirements are. In practice, the similarity or edge weight between two nodes is computed using a measure of co-export between two products. The logic behind this approximation is that if two products are co-exported by a subset of countries, then these countries must have a similar capability base.

The structure of a network such as the Product Space may be represented by an adjacency matrix Φ, with entries ϕ_{ij} corresponding to the weight of an edge from node *i* to node *j*. If we denote the indicator matrix for RCA>1 via $M_{c,i} = M_{c,i} > 1$, the edge weight between node *i* and *j* is the minimum of the conditional probability of exporting a product *i* given the export of another good *j*, and is computed as

$$\phi_{i,j} = \frac{\sum_c \hat{M}_{c,i}\hat{M}_{c,j}}{\max(U_i, U_j)}$$

where the diversity of country c and the ubiquity of industry *i* are defined as

$$D_c = k_c^0 = \sum_i \hat{M}_{c,i} \text{ and } U_i = k_i^0 = \sum_c \hat{M}_{c,i}$$

respectively.

In practice, since this is a dense (full) matrix, we cannot represent the whole matrix when illustrating the Product Space visually. Hence various techniques, including the Minimum Spanning Tree [8], are applied to reduce the number of edges to illustrate the underlying structure of the network [6].

The Country Space

The Country Space may be defined analogously to the Product Space, where the network structure enables us to compare the relative productive structure of country pairs in terms of shared skills and capabilities. In a similar fashion to the construction of the Product Space, these similarities are estimated by measuring co-export of traded products [3]. In this case, we log transform the RCAs (adding a small constant due to zero values) such that $L_{c,i} = log_{10}(M_{c,i} + 0.1)$, and define edge weights that are the entries in adjacency matrix Ψ

$$\psi_{i,j} = \frac{1}{2}(\text{corr}(L_{i,.}, L_{j,.}) + 1).$$

where L_j denotes the vector of the log transformed RCA's (for all industries) corresponding to country *j*.

Similarly to the Product Space above, since this is a dense (full) matrix, we cannot represent the whole matrix when illustrating the network visually. The Country Space, shown in Figure 7 of the main paper, was laid out by the author using the two highest edges connected to each node/industry plus high edge weights over a threshold equal to 0.6. This layout currently features on the Atlas of Economic Complexity website http://atlas.cid.harvard.edu/.

Complexity Indices and Opportunity Value

As proposed by Hausmann and Hidalgo [2], the complexity of an economy is related to the range of useful knowledge embedded in it, which can then be combined to make products. These products cannot be made by countries that are missing parts of the required capability set. The complexity metric attempts to estimate this capability set for a given product or country.

Hence, beyond country diversity and product ubiquity, in order to generate a more accurate measure of the number of capabilities available in a country, or required by a product, we need to incorporate more information about the nature of the products. For example, for countries, this requires us to calculate the average ubiquity of the products that it exports and the average diversity of the countries that make those products and so forth. For products, this requires us to calculate the average diversity of the countries that make them and the average ubiquity of the other products that these countries make.

These relationships can be expressed in a recursive format, known as the 'Method of Reflections'. The average diversity of country *c* and analogously the average ubiquity of industry *i* may be expressed as:

$$k_c^1 = \frac{1}{D_c}\sum_i \hat{M}_{c,i}k_i^0 \text{ and } k_i^1 = \frac{1}{U_i}\sum_c \hat{M}_{c,i}k_c^0.$$

Continuing the iteration, we reach a pair of expressions:

$$k_c^n = \frac{1}{D_c}\sum_i \hat{M}_{c,i}k_i^{n-1} \text{ and } k_i^n = \frac{1}{U_i}\sum_c \hat{M}_{c,i}k_c^{n-1}$$

which, via substitution, can be expressed in closed form in terms of either *c* or *i*:

$$k_c^n = \sum_{c'} \tilde{M}_{cc'}k_{c'}^{n-2} \text{ and } k_i^n = \sum_{i'} \tilde{M}_{ii'}k_{i'}^{n-2}$$

with

$$\tilde{M}_{cc'} = (1/D_c)\sum_i \hat{M}_{c,i}\hat{M}_{c',i}/U_i \text{ and } \tilde{M}_{ii'} = (1/U_i)\sum_c \hat{M}_{c,i}\hat{M}_{c,i'}/D_c.$$

The application of eigenvalue methods enables us to obtain the long-run solution of the iterative systems above. In particular, the Economic Complexity Index (ECI) is the second largest eigenvector of $\tilde{M}_{cc'}$, and the Product Complexity Index (PCI) is the second largest eigenvector of the analogous matrix $\tilde{M}_{ii'}$.

Density, Distance and Opportunity Value

In order to estimate which products are 'close' to the current productive structure of an economy, we need to derive a metric of distance in the product space. We can define a density predictor variable, the reciprocal of distance, which essentially measures the likelihood of a product presence or appearance based on the RCA of its neighbours in the Product Space [7].

Specifically, the density of industry in country *c* is computed via the weighted average the edge weights for industries with RCA connected to product *i*:

$$d_{c,i} = \frac{\sum_{j\in N_i}\phi_{i,j}\hat{M}_{c,j}}{\sum_{j\in N_i}\phi_{i,j}}$$

where N_i is the neighbourhood of the k nearest neighbours of node i (defined via k largest out-edges from node i). The logic here is that if a node or product is surrounded by high RCA industries in the Product Space, then it is more likely that either this product is already present, or it will appear in the future. It has been shown that density, which captures path dependance in the Product Space, is highly predictive of export/employment/wage growth on an industry-country level [7].

The distance of industry i from country c can be seen as the inverse of density (i.e., less 'likely' products are 'further' away):

$$\delta_{c,i} = 1 - d_{c,i}.$$

Under this model, a country is well positioned to diversify if it has existing industries in dense well-connected regions of the Product Space, and close neighbours with high product complexity.

We define the opportunity value of country c, which can be seen as the level of complexity of the products that it does not currently export with RCA weighted by how close these products, as

$$O_c = \sum_i d_{c,i}(1 - \hat{M}_{c,i})PCI_i$$

and the opportunity gain, which measures the change in opportunity value for country c that would come as a consequence of developing industry i, as

$$O_{c,i} = \sum_{i'} \delta_{c,i'} PCI_{i'} - d_{c,i} PCI_i.$$

3. FIGURES AND TABLES

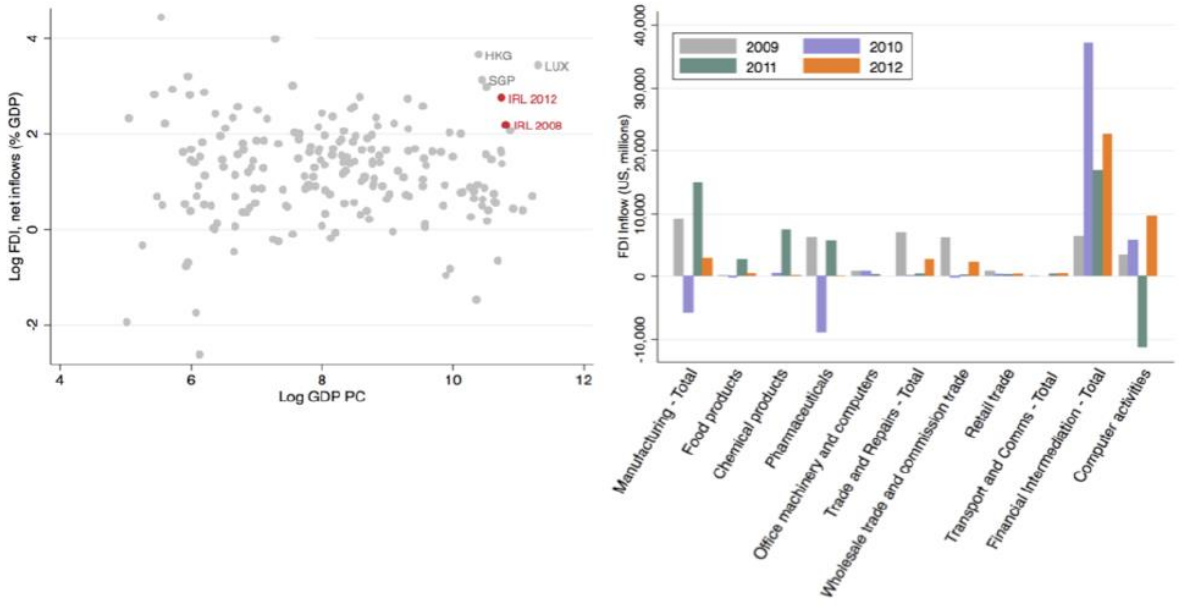

Figure 1: Ireland is a major recipient of net inflows of FDI, driven by favourable tax conditions and a highly educated and competitive workforce. Only Hong Kong, Singapore and Luxemburg exhibit similar levels of FDI for a comparable GDP level. Recent inflows were dominated by the services sectors including financial intermediation and computer activities, with manufacturing sectors experiencing a decline including chemicals and pharmaceuticals. [Source: WDI 2012 (left figure) and OECD (right figure)]

		Ireland	OECD
Protecting Investors *Rank 6*	Disclosure (0-10)	10	7
	Director Liability (0-10)	10	5
	Shareholder suits(0-10)	9	7
	Investor protection (0-10)	8.3	6.2
Paying Taxes *Rank 6*	Number of payments	9	12
	Time	80	175
	Profit Tax (%)	12.1	23.1
	Total Tax (% of profits)	25.7	41.3
Resolving Insolvency *Rank 8*	Time	0.4	1.7
	Cost	9	9
	Recovery	87.6	70.6
Starting a Business *Rank 12*	Number of Procedures	4	5
	Number of Days	10	11.1
	Paid-in min. capital (% income pc)	0	10.4
Credit *Rank 13*	Legal rights(1-10)	9	7
	Credit Info (0-6)	5	5
	Private bureau registration	100	66.7

		Ireland	OECD
Construction Permits *Rank 115*	Number of Procedures	12	13
	Number of Days	157	147
	Cost (% income/person)	446	84
Electricity *Rank 100*	Number of Procedures	5	5
	Number of Days for Connection	205	89
	Cost (% income pc)	89	79
Enforcing Contracts *Rank 62*	Number of Procedures	21	31
	Number of Days	650	529
	Cost (% claim)	26	21
Registering Property *Rank 57*	Number of Procedures	5	5
	Number of Days	37	24
	Cost (% claim)	26	21
Trade *Rank 20*	Days to export ($/container)	2	4
	Documents to export	8	11
	Cost to export	1160	1070
	Days to import	2	4
	Documents to import	10	10
	Cost to import ($/container)	1121	1090

Figure 2: We can also consider other aspects concerning the ease of doing business in Ireland via The World Bank's Doing Business Indicators. While Ireland has an impressive record in financial and administrative areas such as starting a business, providing access to credit, setting attractive tax rates and protecting investors, Ireland lags the OECD average in certain practical areas such as electricity and construction permits. [Source: The World Bank's Doing Business Indicators 2014]

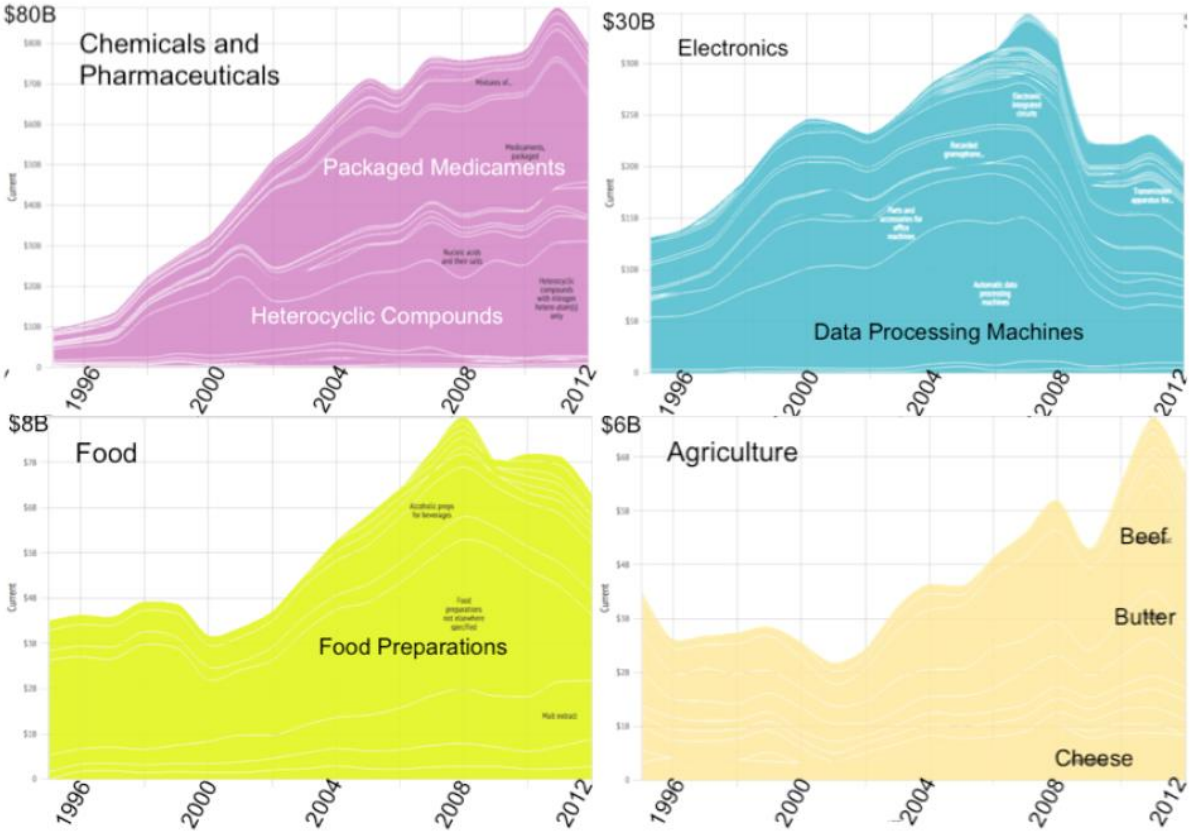

Figure 3: While we observe a decline in the share of exports from the food and agriculture sector, their total value has been increasing. Similarly, while maintaining their export value, the share of electronics and machinery exported have declined in recent years, dominated by the growing pharmaceuticals sector. [Source: The Atlas of Economic Complexity 2012]

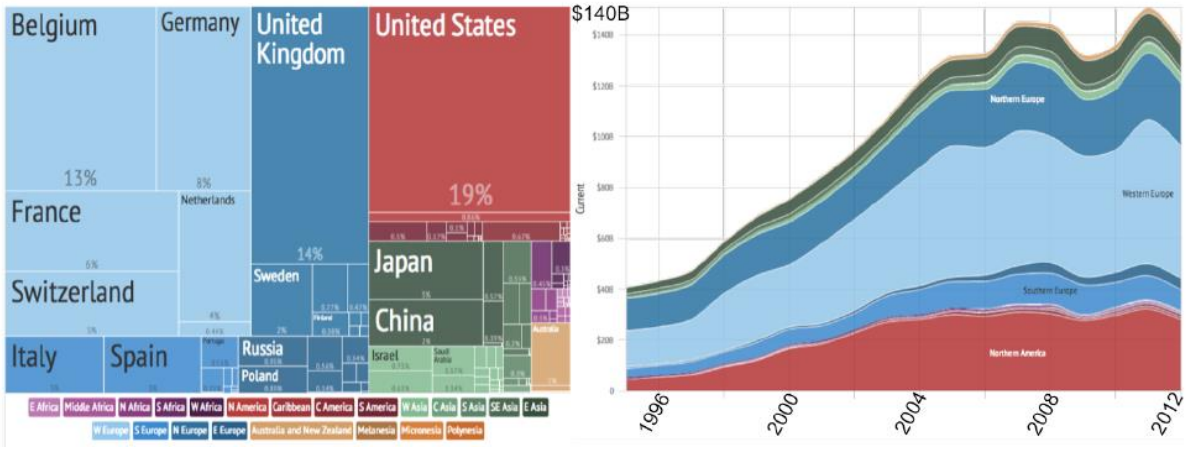

Figure 4: Ireland's main export partners include the US, the UK and various large European countries. Export to the US and Western Europe has been increasing since 1995, driven by the USA and Belgium, who mainly buy pharmaceutical inputs, and the UK and Germany who import a range of products including food and agricultural products. [Source: The Atlas of Economic Complexity 2012]

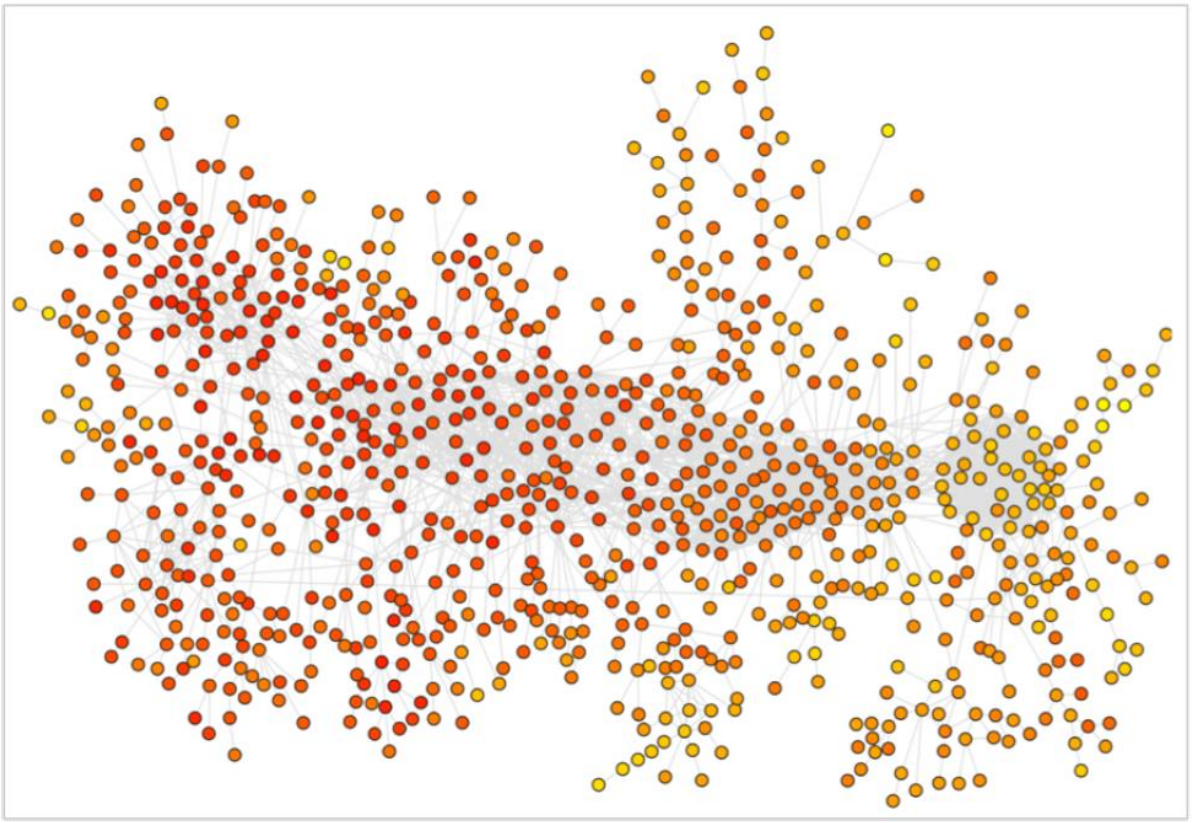

Figure 5: Here we see the Product Space with nodes coloured by Product Complexity Index (a measure of product sophistication in terms of the rarity of capabilities needed to manufacture the product). Darker nodes (more complex products) are mainly located in left-hand densely connected central regions of the network. [Source: The Atlas of Economic Complexity with custom node colouring by Author].

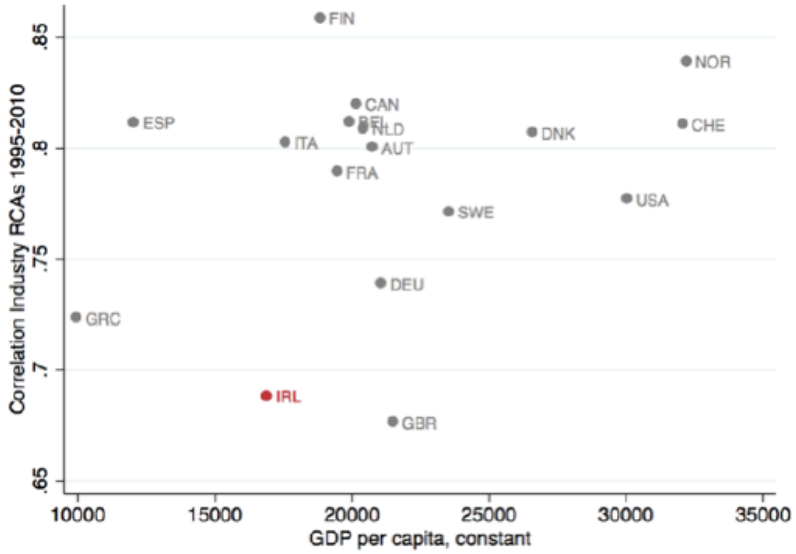

Figure 6: We compare the export basket for Northern European countries in 1995 to that in 2010 (via correlation of the industry-specific RCA values in those years). We observe a low correlation value for Ireland suggesting that Ireland has not only specialised, but also radically changed its export mix relative to its neighbours during this period. [Source: Author's calculations using CEPII 2012 COMTRADE data, and UN World Development Indicators 2012.]

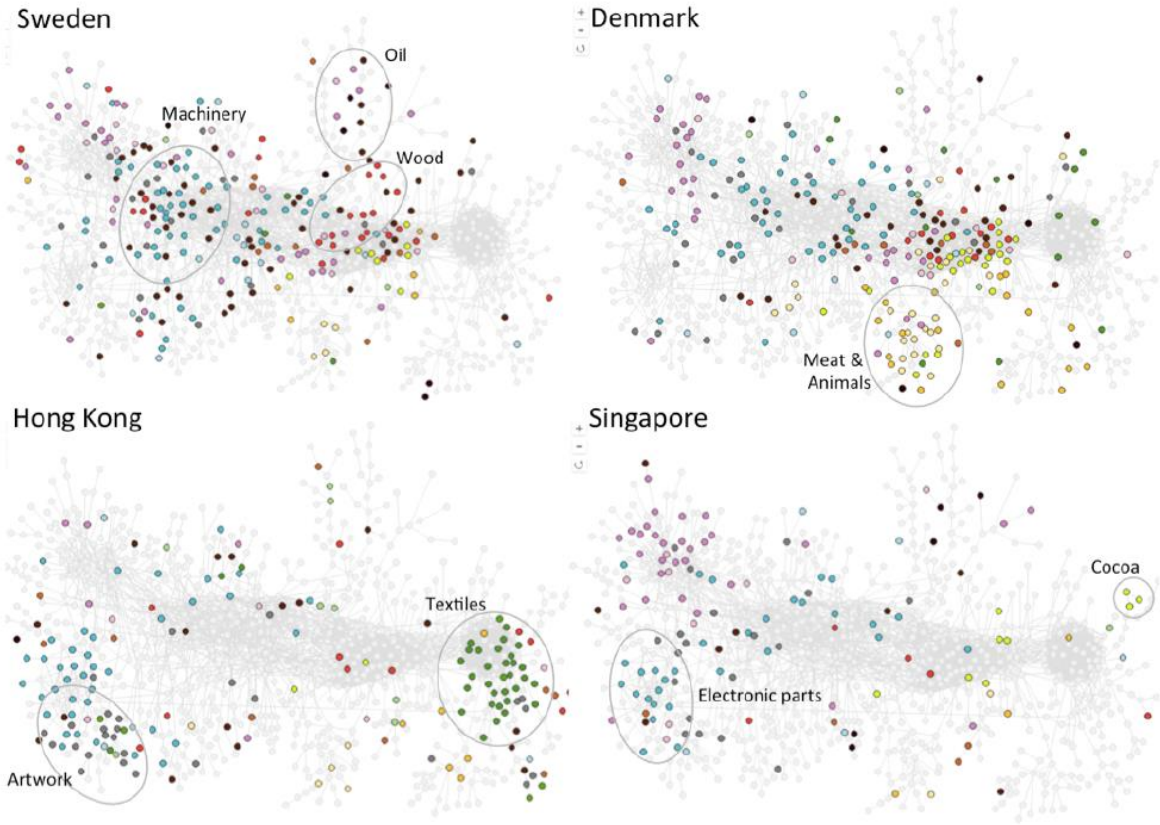

Figure 7: We observe that comparable Northern European countries export products located in diverse areas of the Product Space (data for 2012). In contrast, Hong Kong and Singapore are most similar to Ireland in the sense that they occupy distinct clusters and are mainly absent from the central interior. Singapore is particularly similar to Ireland in that it competitively exports pharmaceuticals, electronics and a small number of agricultural and food products. [Source: The Atlas of Economic Complexity, with artistic and text overlays by Author.]

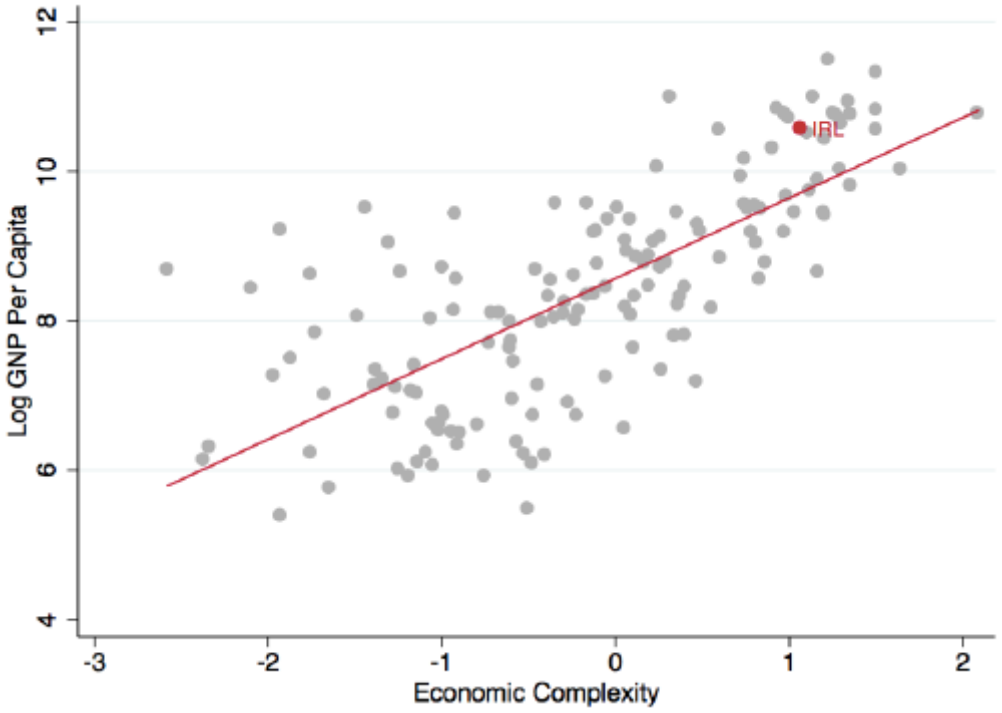

Figure 8: We show in the main text that Ireland exhibits high levels of GDP per capita as compared to its complexity level. As GDP is heavily influenced by foreign earnings in Ireland, GNP is often cited as a more reliable measure. Here we show that, irrespective of whether we use GDP or GDP, Ireland is wealthy as compared to other countries of a comparable complexity level. [Source: The Atlas of Economic Complexity, and UN World Development Indicators.]

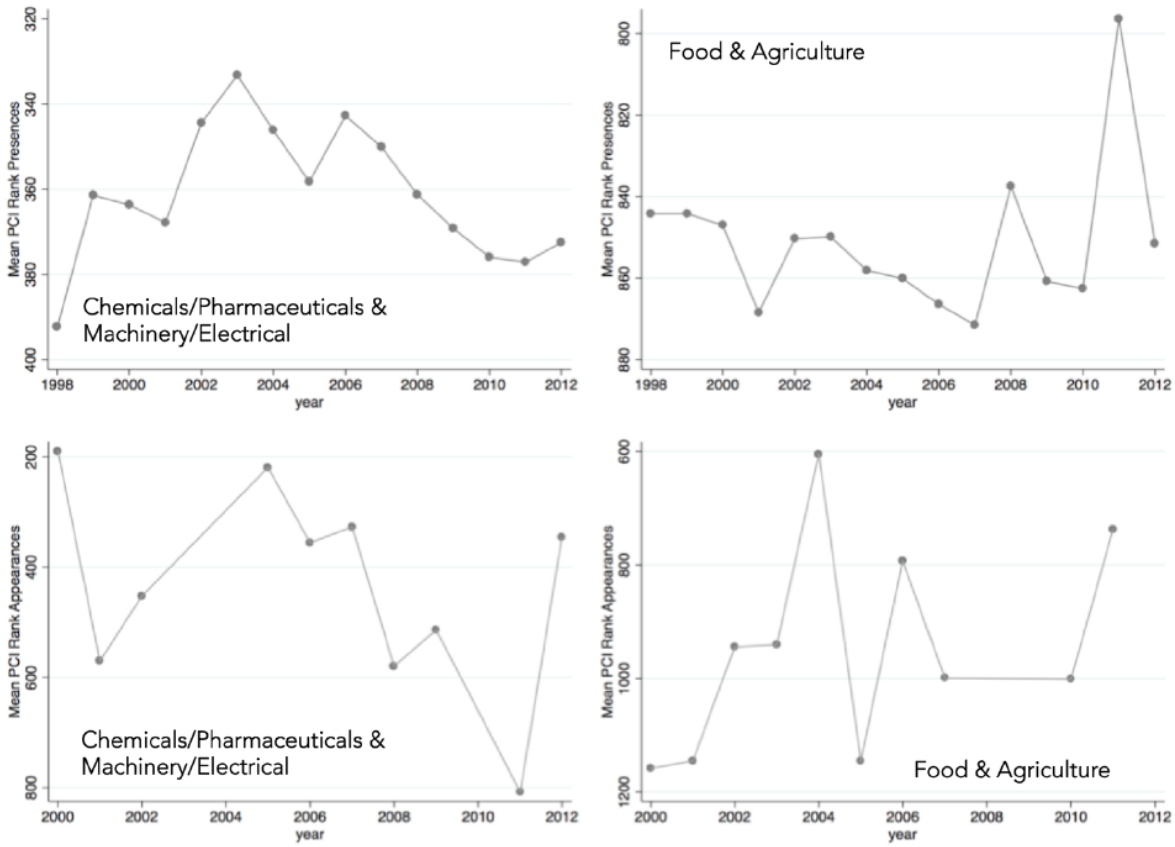

Figure 9: Since 2008 we observe a decrease in mean complexity for products from machinery/electrical, pharmaceuticals/chemicals or plastics (left column), while we observe an erratic recent increase in complexity in food/vegetable sectors (right column). Similarly, product appearances in the former case are also declining in complexity, while appearances in the latter case exhibit an erratic increase. [Source: Author's calculations using CEPII COMTRADE 2012 data.]

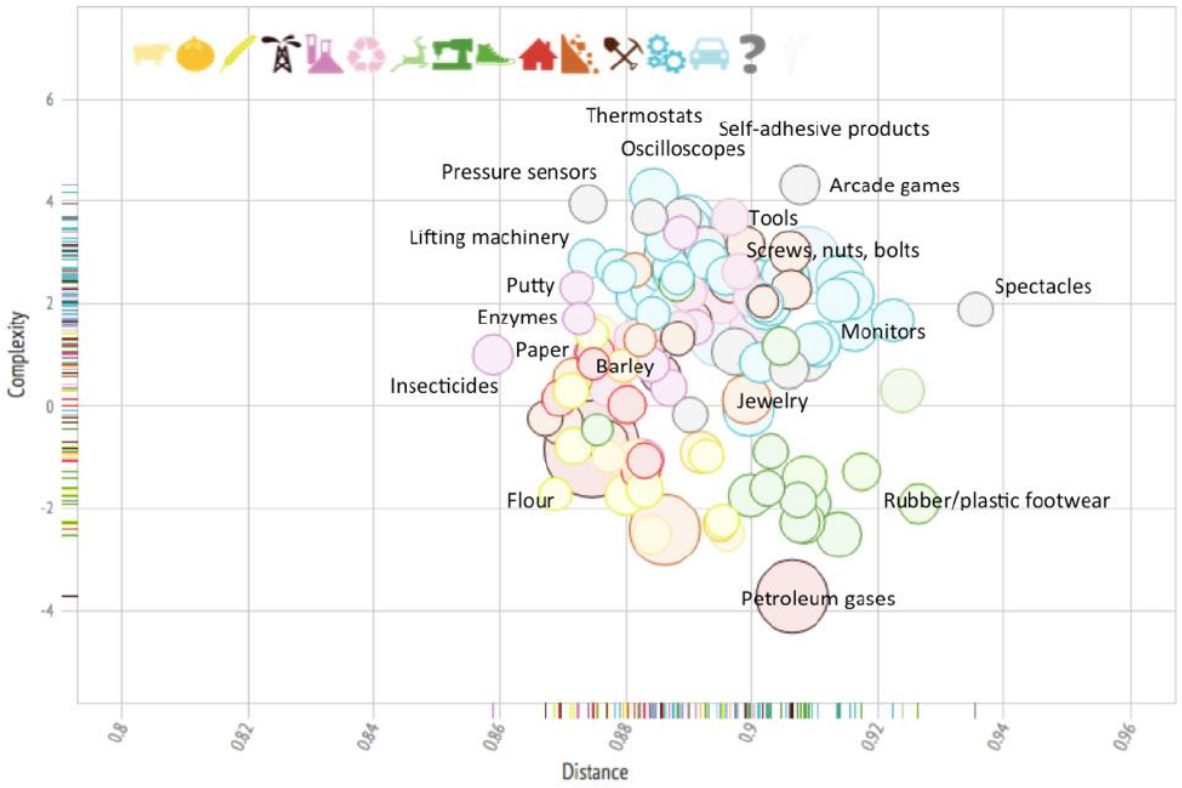

Figure 10: Considering the complexity-distance relationship for individual products not currently exported with RCA in Ireland, we see a wide range of industries represented (HS 4-digit aggregation). These include close but lower complexity products represented in yellow, and higher complexity chemicals/pharmaceuticals in pink and electronics/machinery in blue/grey (and textiles in green). [Note: markers are sized by global market size]. [Source: The Atlas of Economic Complexity 2012, with artistic and text overlays by Author.]

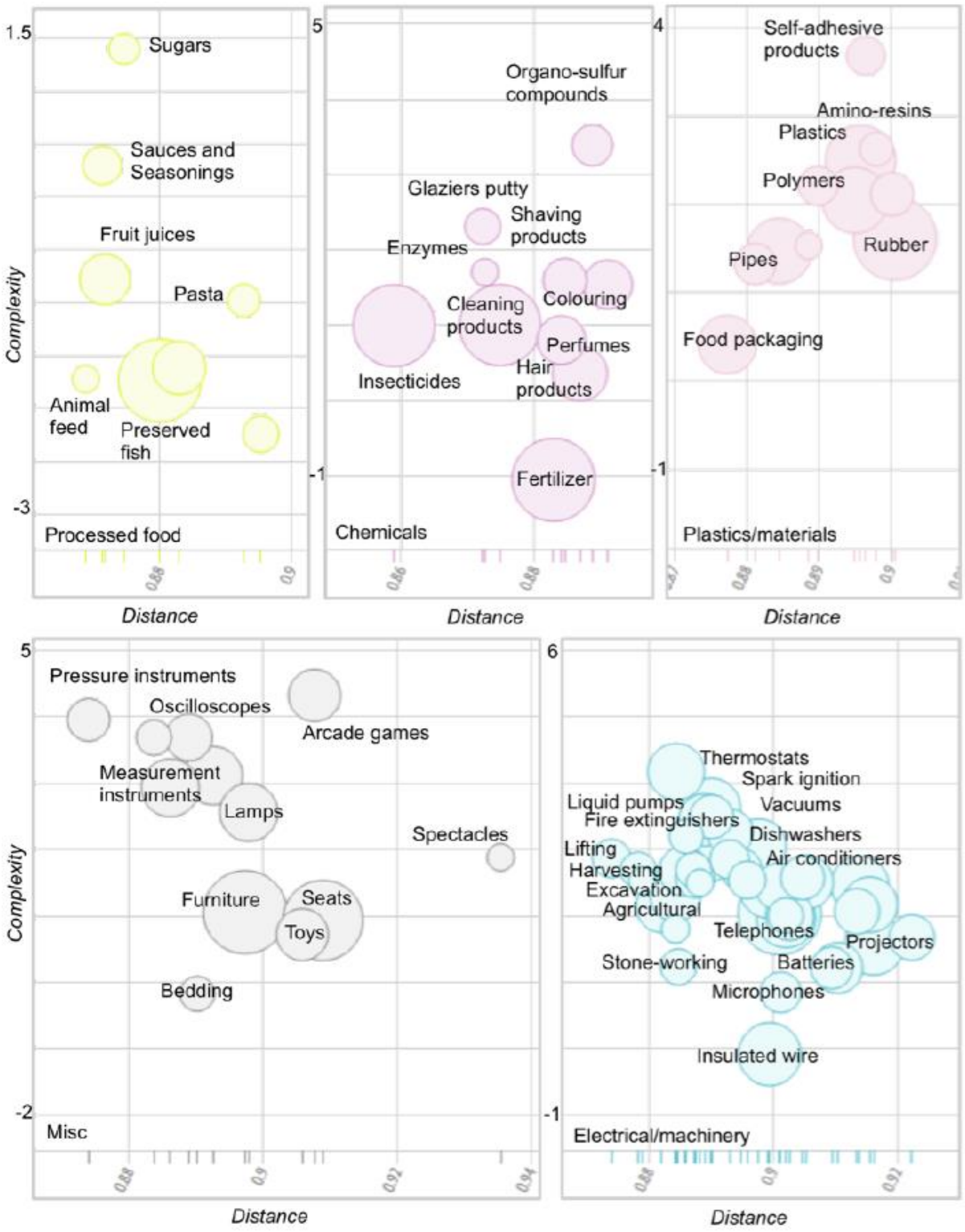

Figure 11: Zooming in on individual sectors, we can identify some potential products for diversification. For example there are a number of processed food products at near distance to Ireland's current Product Space. At a significantly higher complexity level, we observe that - in general – the more complex a product is in the chemicals and pharmaceuticals sector, the more distant it is. Interestingly, we observe the converse relationship for electronic/machinery products where very high complexity products are located at close proximity. These strategic industries include various measurement instruments, pumps (liquid and fire extinguishers) and a range of machinery including lifting, harvesting, excavation, agricultural and stone-working machinery. [Source: The Atlas of Economic Complexity, with artistic and text overlays by Author.]

HS4	Name	Sector	PCI	RCA
1301	Insect Resins	Vegetable Products	-3.159	1.038579
1518	Inedible Fats & Oils	Vegetable Products	1.789	1.081046
709	Other Vegetables	Vegetable Products	-1.634	1.088605
1212	Locust Beans	Vegetable Products	-1.779	1.1795
1004	Oats	Vegetable Products	1.349	1.251943
1104	Processed Cereals	Vegetable Products	-.086	1.499132
1502	Bovine, Sheep & Goat Fat	Vegetable Products	.678	2.743429
1503	Lard	Vegetable Products	2.072	11.0104
2605	Cobalt Ore	Mineral Products	-2.171	1.021077
2501	Salt	Mineral Products	-.589	1.204291
2523	Cement	Mineral Products	-1.039	1.324323
2607	Lead Ore	Mineral Products	-2.187	1.670436
2519	Magnesium Carbonate	Mineral Products	1.084	2.759546
2608	Zinc Ore	Mineral Products	-1.557	6.01981
2703	Peat	Mineral Products	.947	6.357962
4102	Sheep Hides	Raw Hides, Skins, Leather, & Furs	-1.97	2.134955
4101	Equine & Bovine Hides	Raw Hides, Skins, Leather, & Furs	-.889	3.071927
5802	Terry Fabric	Textiles	-.545	1.207559
5503	Unprocessed Synthetic Staple Fibers	Textiles	.953	2.841571
1905	Baked Goods	Foodstuffs	.018	1.195164
1704	Confectionery Sugar	Foodstuffs	-.49	1.255705
1806	Chocolate	Foodstuffs	1.03	1.26345
1601	Sausages	Foodstuffs	.911	1.332852
2309	Animal Food	Foodstuffs	.688	1.489556
2202	Flavored Water	Foodstuffs	.091	1.499612
1603	Animal Extracts	Foodstuffs	.733	1.6621
2101	Coffee & Tea Products	Foodstuffs	-.599	2.529913
2403	Processed Tobacco	Foodstuffs	-.163	3.257975
2208	Hard Liquor	Foodstuffs	.054	4.412035
1602	Other Prepared Meat	Foodstuffs	.789	4.435578
2203	Beer	Foodstuffs	.51	4.724258
2106	Other Edible Preparations	Foodstuffs	1.06	5.33331
2206	Other Fermented Beverages	Foodstuffs	1.773	9.06234
1901	Malt Extract	Foodstuffs	.981	10.07684
401	Milk	Animal & Animal Products	-.14	1.176767
511	Other Inedible Animal Products	Animal & Animal Products	.16	1.194979
303	Non-fillet Frozen Fish	Animal & Animal Products	-2.587	1.247562
203	Pig Meat	Animal & Animal Products	2.098	1.286056
210	Preserved Meat	Animal & Animal Products	1.438	1.353036
510	Pharmaceutical Animal Products	Animal & Animal Products	-.854	1.434703
102	Bovine	Animal & Animal Products	-.333	1.684484
403	Fermented Milk Products	Animal & Animal Products	.881	1.695112
302	Non-fillet Fresh Fish	Animal & Animal Products	-1.78	1.722604
202	Frozen Bovine Meat	Animal & Animal Products	-.355	1.799927
402	Concentrated Milk	Animal & Animal Products	-.432	2.290068
205	Horse Meat	Animal & Animal Products	.031	2.773813
103	Pigs	Animal & Animal Products	2.252	2.787294
406	Cheese	Animal & Animal Products	.613	3.282073
404	Whey	Animal & Animal Products	1.584	3.397846
206	Edible Offal	Animal & Animal Products	.298	3.562011
204	Sheep & Goat Meat	Animal & Animal Products	-.903	4.731306
201	Bovine Meat	Animal & Animal Products	.425	9.669322
405	Butter	Animal & Animal Products	1.264	10.71069
101	Horses	Animal & Animal Products	.361	15.52435
7001	Glass Scraps	Stone / Glass	.961	1.293565
7116	Pearl Products	Stone / Glass	.921	3.98458
7105	Precious Stone Dust	Stone / Glass	2.631	11.17053

Table 1: Industries exported with RCA in 2012 - sorted by1H2S 2-digit sector, and then by RCA level from low to high.

HS4	Name	Sector	PCI	RCA
4410	Particle Board	Wood & Wood Products	1.306	1.006762
4907	Postage Stamps	Wood & Wood Products	-1.265	1.454512
4911	Other Printed Material	Wood & Wood Products	1.311	1.54186
4411	Wood Fiberboard	Wood & Wood Products	.895	1.797523
7504	Nickel Powder	Metals	1.932	1.633661
8309	Metal Stoppers	Metals	.981	2.420552
7802	Scrap Lead	Metals	-1.075	3.090667
7804	Lead Sheets	Metals	-.808	4.976325
3921	Other Plastic Sheetings	Plastics / Rubbers	1.557	1.164639
3912	Cellulose	Plastics / Rubbers	2.884	3.433189
3506	Glues	Chemicals & Allied Industries	1.923	1.048144
2918	Carboxylic Acids	Chemicals & Allied Industries	1.371	1.074937
3005	Bandages	Chemicals & Allied Industries	2.042	1.154691
3502	Water Soluble Proteins	Chemicals & Allied Industries	1.889	1.19748
3301	Essential Oils	Chemicals & Allied Industries	-1.074	1.475846
2924	Carboxyamide Compounds	Chemicals & Allied Industries	2.222	1.935501
3504	Peptones	Chemicals & Allied Industries	2.357	2.007883
3304	Cosmetic Products	Chemicals & Allied Industries	1.014	2.253765
3215	Ink	Chemicals & Allied Industries	2.686	2.351688
2843	Precious Metal Compounds	Chemicals & Allied Industries	1.24	2.500813
3101	Animal or Vegetable Fertilizers	Chemicals & Allied Industries	.227	2.822005
3001	Glands & Other Organs	Chemicals & Allied Industries	2.082	3.10981
2935	Sulfonamides	Chemicals & Allied Industries	2.843	3.196348
3203	Vegetable or Animal Dyes	Chemicals & Allied Industries	1.444	3.636772
3822	Laboratory Reagents	Chemicals & Allied Industries	2.779	3.805268
2921	Amine Compounds	Chemicals & Allied Industries	2.276	5.150117
2850	Hydrides & other anions	Chemicals & Allied Industries	3.254	5.162922
2932	Oxygen Heterocyclic Compounds	Chemicals & Allied Industries	2.1	5.194946
3823	Industrial Fatty Acids, Oils & Alcohols	Chemicals & Allied Industries	2.19	5.241478
2818	Aluminium Oxide	Chemicals & Allied Industries	-.876	5.956333
2941	Antibiotics	Chemicals & Allied Industries	2.647	5.992982
3004	Packaged Medicaments	Chemicals & Allied Industries	2.122	7.067108
2922	Oxygen Amino Compounds	Chemicals & Allied Industries	2.242	7.786514
3002	Human or Animal Blood	Chemicals & Allied Industries	2.552	7.930344
3306	Dental Products	Chemicals & Allied Industries	.401	7.952086
3606	Pyrophoric Alloys	Chemicals & Allied Industries	1.653	8.316469
3006	Other Pharmaceuticals	Chemicals & Allied Industries	2.337	8.992134
2931	Other Organo-Inorganic Compounds	Chemicals & Allied Industries	2.593	9.161278
2937	Hormones	Chemicals & Allied Industries	2.837	11.97433
3501	Casein	Chemicals & Allied Industries	1.006	12.58528
3003	Unpackaged Medicaments	Chemicals & Allied Industries	1.262	16.19355
2934	Nucleic Acids	Chemicals & Allied Industries	2.753	28.83466
3302	Scented Mixtures	Chemicals & Allied Industries	.397	38.66038
2933	Nitrogen Heterocyclic Compounds	Chemicals & Allied Industries	2.359	41.7979

Table 2: Industries exported with RCA in 2012 - continued.

HS4	Name	Sector	PCI	RCA
8473	Office Machine parts	Machinery / Electrical	2.476	1.007414
8527	Radio Receivers	Machinery / Electrical	2.184	1.026046
8542	Integrated Circuits	Machinery / Electrical	2.651	1.112748
8531	Audio Alarms	Machinery / Electrical	2.138	1.379459
8418	Refrigerators	Machinery / Electrical	1.382	1.490847
8525	Broadcasting Equipment	Machinery / Electrical	1.947	1.553461
8471	Digital Disk Drives	Machinery / Electrical	2.232	1.57007
8469	Typewriters	Machinery / Electrical	1.466	1.61601
8427	Fork-Lifts	Machinery / Electrical	3.443	1.756606
8434	Dairy Machinery	Machinery / Electrical	2.085	1.876806
8443	Industrial Printers	Machinery / Electrical	3.368	1.956788
8426	Cranes	Machinery / Electrical	1.11	2.266474
8523	Data Storage	Machinery / Electrical	2.25	3.025502
8519	Sound Recording Equipment	Machinery / Electrical	2.776	3.253418
8524	Gramophone Records	Machinery / Electrical	2.901	12.16269
9033	Measuing Instrument Parts	Miscellaneous	1.87	1.030967
9608	Pens	Miscellaneous	1.941	1.107957
9614	Smoking Pipes	Miscellaneous	.793	1.117323
9012	Non-optical Microscopes	Miscellaneous	3.602	1.434057
9603	Brooms	Miscellaneous	.364	2.229265
9027	Chemical Analysis Instruments	Miscellaneous	2.862	2.325371
9019	Physical Therapy Instruments	Miscellaneous	2.841	3.338614
9018	Medical Instruments	Miscellaneous	2.336	5.036821
9001	Optical Fibers	Miscellaneous	2.665	6.629953
9021	Orthopedic Appliances	Miscellaneous	2.24	12.30969

Table 3: Industries exported with RCA in 2012 – continued

HS4	Name	Sector	PCI	Year
6701	Bird Skins w/ Feathers	Footwear / Headgear	.689	2012
802	Other Nuts	Vegetable Products	-1.747	2000
703	Onions	Vegetable Products	-2.541	2002
1521	Waxes	Vegetable Products	-1.993	2004
804	Tropical Fruits	Vegetable Products	-3.086	2005
807	Melons	Vegetable Products	-2.353	2005
1207	Other Oily Seeds	Vegetable Products	-3.569	2006
1106	Legume Flours	Vegetable Products	-1.084	2006
1522	Fat & Oil Residues	Vegetable Products	-.948	2006
1204	Linseed	Vegetable Products	.724	2006
1007	Sorghum	Vegetable Products	-1.451	2007
1510	Olive Oil	Vegetable Products	-1.209	2009
809	Pitted Fruits	Vegetable Products	-1.171	2010
2502	Iron Pyrites	Mineral Products	-.545	2001
2707	Coal Tar Oil	Mineral Products	-.062	2002
2612	Uranium & Thorium Ore	Mineral Products	-3.027	2004
2708	Pitch Coke	Mineral Products	.505	2005
2509	Chalk	Mineral Products	-.041	2006
2617	Other Ores	Mineral Products	-2.871	2007
2619	Slag Dross	Mineral Products	.405	2007
2508	Clays	Mineral Products	.398	2008
2621	Other Slag & Ash	Mineral Products	1.39	2008
2504	Graphite	Mineral Products	1.363	2008
2705	Non-Petroleum Gas	Mineral Products	-.029	2008
2510	Calcium Phosphates	Mineral Products	-2.46	2008
2701	Coal Briquettes	Mineral Products	-.422	2009
2529	Feldspar	Mineral Products	-.401	2009
2513	Pumice	Mineral Products	-1.24	2011
2614	Titanium Ore	Mineral Products	-1.678	2012
4108	Chamois Leather	Raw Hides, Skins, Leather, & Furs	-.631	2004
4304	Artificial Fur	Raw Hides, Skins, Leather, & Furs	.291	2011
5005	Silk Waste Yarn	Textiles	.105	2000
5502	Artificial Filament Tow	Textiles	2.896	2002
5302	Hemp Fibers	Textiles	1.155	2003
5208	Light Pure Woven Cotton	Textiles	-1.177	2004
5003	Silk Waste	Textiles	-1.342	2005
5908	Textile Wicks	Textiles	.201	2007
5905	Textile Wall Coverings	Textiles	3.045	2009
5605	Metallic Yarn	Textiles	1.585	2009
5108	Non-Retail Animal Hair Yarn	Textiles	-.129	2012
5307	Jute Yarn	Textiles	-.801	2012
2305	Ground Nut Meal	Foodstuffs	-1.216	2011
503	Horse Hair	Animal & Animal Products	.406	2000
410	Other Edible Animal Products	Animal & Animal Products	-1.022	2005
507	Raw Bones	Animal & Animal Products	-3.276	2006
6906	Ceramic Pipes	Stone / Glass	2.305	2001
7118	Coin	Stone / Glass	1.308	2001
4703	Sulfate Chemical Woodpulp	Wood & Wood Products	1.193	2002
4601	Plaiting Products	Wood & Wood Products	-1.765	2011

Table 4: Industry appearances 2000-2012 - sorted by HS 2-digit sector, and then by year of appearance.

HS4	Name	Sector	PCI	Year
7203	Iron Reductions	Metals	.647	2003
8213	Scissors	Metals	2.823	2003
7305	Other Large Iron Pipes	Metals	1.893	2004
7405	Copper Alloys	Metals	1.844	2005
7316	Iron Acnhors	Metals	1.175	2007
7905	Zinc Sheets	Metals	.673	2008
7206	Iron Ingots	Metals	-.058	2008
8106	Bismuth	Metals	.538	2008
8108	Titanium	Metals	2.481	2009
7227	Steel Bars	Metals	2.186	2009
3911	Petroleum Resins	Plastics / Rubbers	2.603	2004
2810	Boron	Chemicals & Allied Industries	.291	2001
2840	Borates	Chemicals & Allied Industries	1.438	2002
2927	Diazo, Azo or Aoxy Compounds	Chemicals & Allied Industries	2.521	2004
2908	Phenol Derivatives	Chemicals & Allied Industries	2.34	2006
2845	Other Isotopes	Chemicals & Allied Industries	1.998	2007
3802	Activated Carbon	Chemicals & Allied Industries	.899	2007
2847	Hydrogen peroxide	Chemicals & Allied Industries	1.235	2008
2837	Cyanides	Chemicals & Allied Industries	1.292	2009
3404	Waxes	Chemicals & Allied Industries	3.139	2010
2817	Zinc Oxide & Peroxide	Chemicals & Allied Industries	.407	2011
8904	Tug Boats	Transportation	.655	2000
9104	Dashboard Clocks	Miscellaneous	3.127	2001
9110	Incomplete Movement Sets	Miscellaneous	.966	2001
9301	Military Weapons	Miscellaneous	.202	2004
8603	Self-Propelled Rail Transport	Transportation	4.107	2004
8901	Cruise Ships	Transportation	.782	2005
8606	Railway Freight Cars	Transportation	.984	2005
9111	Watch Cases & Parts	Miscellaneous	2.478	2006
9113	Watch Straps	Miscellaneous	1.064	2007
9307	Bladed Weapons & Accessories	Miscellaneous	1.116	2008
9305	Weapons Parts & Accessories	Miscellaneous	2.71	2010
8608	Railway Track Fictures	Transportation	2.815	2011
8605	Railway Passenger Cars	Transportation	2.74	2011

Table 5: Industry appearances 2000-2012 - continued.

HS4	Name	Sector	PCI	Year
6501	Hat Forms	Footwear / Headgear	-.932	2009
1506	Other Animal Fats	Vegetable Products	2.158	2001
1205	Rapeseed	Vegetable Products	1.508	2004
1504	Fish Oil	Vegetable Products	-.195	2005
801	Coconuts, Brazil Nuts & Cashews	Vegetable Products	-5.787	2005
1519	Stearic Acid	Vegetable Products	.366	2005
1505	Wool Grease	Vegetable Products	.51	2009
1209	Sowing Seeds	Vegetable Products	-.733	2010
1522	Fat & Oil Residues	Vegetable Products	-.442	2011
2514	Slate	Mineral Products	1.225	2000
2619	Slag Dross	Mineral Products	1.51	2002
2515	Marble, Travertine & Alabaster	Mineral Products	-1.466	2005
2702	Lignite	Mineral Products	-.41	2006
2606	Aluminium Ore	Mineral Products	-2.339	2008
2514	Slate	Mineral Products	.161	2012
4111	Leather Sheets	Raw Hides, Skins, Leather, & Furs	.557	2000
4304	Artificial Fur	Raw Hides, Skins, Leather, & Furs	.765	2001
4206	Articles of Gut	Raw Hides, Skins, Leather, & Furs	.059	2004
5209	Heavy Pute Woven Cotton	Textiles	-.723	2000
5406	Retail Artificial Filament Yarn	Textiles	.806	2000
5404	Synthetic Monofilament	Textiles	2.248	2000
5207	Retail Cotton Yarn	Textiles	-2.541	2002
5809	Metallic Fabric	Textiles	1.433	2003
5305	Coconut & Other Vegetable Fibers	Textiles	-3.499	2004
5605	Metallic Yarn	Textiles	1.81	2004
5106	Non-Retail Carded Wool Yarn	Textiles	.776	2004
5108	Non-Retail Animal Hair Yarn	Textiles	-1.748	2005
5103	Wool or Animal Hair Waste	Textiles	-.263	2006
5609	Other Articles of Twine & Rope	Textiles	-.35	2007
5104	Garnetted Wool or Animal Hair	Textiles	1.481	2007
5808	Braids	Textiles	.476	2007
5509	Non-Retail Synthetic Staple Fibers Yarn	Textiles	-.407	2007
5406	Retail Artificial Filament Yarn	Textiles	.203	2009
5110	Horsehair Yarn	Textiles	.586	2011
5408	Artificial Filament Yarn Woven Fabric	Textiles	1.825	2012
5106	Non-Retail Carded Wool Yarn	Textiles	1.136	2012
1802	Cocoa Shells	Foodstuffs	-3.692	2002
1802	Cocoa Shells	Foodstuffs	-6.799	2009
2003	Processed Mushrooms	Foodstuffs	.835	2009
2207	Alcohol > 80% ABV	Foodstuffs	-1.186	2010
2006	Sugar Preserved Foods	Foodstuffs	-.207	2010
508	Coral & Shells	Animal & Animal Products	-1.905	2010
502	Pig Hair	Animal & Animal Products	.389	2010
106	Other Animals	Animal & Animal Products	-2.364	2011
7018	Glass Beads	Stone / Glass	1.126	2001
7003	Cast or Rolled Glass	Stone / Glass	.783	2003
7115	Other Precious Metal Products	Stone / Glass	2.423	2004
6901	Bricks	Stone / Glass	-.902	2010
6905	Roofing Tiles	Stone / Glass	.899	2011
7003	Cast or Rolled Glass	Stone / Glass	.866	2011
6904	Ceramic Bricks	Stone / Glass	-.626	2011
4702	Dissolving Grades Chemical Woodpulp	Wood & Wood Products	2.166	2005
4704	Sulfite Chemical Woodpulp	Wood & Wood Products	2.198	2005
4815	Paper Floor Coverings	Wood & Wood Products	1.461	2005
4906	Architectural Plans	Wood & Wood Products	2.166	2008
4808	Corrugated Paper	Wood & Wood Products	.881	2009

Table 6: Industry disappearances 2000-2012 - sorted by HS 2-digit sector, and then by year of disappearance.

HS4	Name	Sector	PCI	Year
8112	Other Metals	Metals	1.82	2001
7505	Nickel Bars	Metals	3.108	2002
8005	Tin Foil	Metals	1.638	2007
7416	Copper Springs	Metals	.978	2007
7414	Endless Copper Wire Bands	Metals	.384	2007
8305	Metal Office Products	Metals	2.233	2007
7903	Zinc Powder	Metals	-.284	2007
7406	Copper Powder	Metals	1.668	2008
7413	Stranded Copper Wire	Metals	1.023	2010
4004	Scrap Rubber	Plastics / Rubbers	.809	2002
4007	Rubber Thread	Plastics / Rubbers	-1.13	2012
2809	Phosphoric Acid	Chemicals & Allied Industries	-.929	2002
3803	Tall Oil	Chemicals & Allied Industries	2.225	2003
2814	Ammonia	Chemicals & Allied Industries	-1.019	2003
2822	Cobalt Oxides & Hydroxides	Chemicals & Allied Industries	1.688	2005
3806	Rosin	Chemicals & Allied Industries	1.349	2005
2817	Zinc Oxide & Peroxide	Chemicals & Allied Industries	.756	2005
3809	Dyeing Finishing Agents	Chemicals & Allied Industries	2.774	2005
2820	Manganese Oxides	Chemicals & Allied Industries	.381	2006
2929	Other Nitrogen Compounds	Chemicals & Allied Industries	3.141	2008
3818	Disc Chemicals for Electronics	Chemicals & Allied Industries	3.773	2012
2839	Silicates	Chemicals & Allied Industries	.724	2012
3208	Nonaqueous Paints	Chemicals & Allied Industries	1.018	2012
8513	Portable Lighting	Machinery / Electrical	.509	2002
8435	Fruit Pressing Machinery	Machinery / Electrical	.33	2002
8437	Mill Machinery	Machinery / Electrical	1.443	2007
8520	Dictation Machines	Machinery / Electrical	1.105	2009
8482	Ball Bearings	Machinery / Electrical	3.01	2009
8478	Tobacco Processing Machines	Machinery / Electrical	1.648	2011
9701	Paintings	Miscellaneous	3.761	2001
9011	Microscopes	Miscellaneous	1.993	2002
9003	Spectacle Frames	Miscellaneous	3.426	2002
8802	Planes, Helicopters, and/or Spacecraft	Transportation	1.195	2003
9203	Pipe Organs	Miscellaneous	1.494	2003
9618	Mannequins	Miscellaneous	1.815	2005
8712	Bicycles	Transportation	.25	2005
8801	Non-powered Aircraft	Transportation	1.342	2007
9501	Wheeled Toys	Miscellaneous	.327	2007
9507	Fishing & Hunting Equipment	Miscellaneous	-.527	2009
9017	Drafting Tools	Miscellaneous	2.453	2011
8902	Fishing Ships	Transportation	-.833	2012

Table 7: Industry disappearances 2000-2012 - continued.

HS4	Name	Sector	PCI	Distance	Gain	Max RCA
6603	Umbrella & Walking Stick Accessories	Footwear / Headgear	1.785	.615	.172	.916
6601	Umbrellas	Footwear / Headgear	2.159	.631	.142	.138
1210	Hops	Vegetable Products	1.294	.604	.164	.101
1109	Wheat Gluten	Vegetable Products	2.463	.614	.248	.388
2706	Tar	Mineral Products	1.126	.617	.131	.277
2618	Granulated Slag	Mineral Products	1.827	.618	.228	.277
2708	Pitch Coke	Mineral Products	1.521	.629	.173	.257
2525	Mica	Mineral Products	1.592	.631	.12	.06
5602	Felt	Textiles	1.556	.584	.165	.68
5909	Hosepiping Textiles	Textiles	2.469	.601	.3	.3
5906	Rubber Textile Fabric	Textiles	2.218	.603	.287	.19
5907	Coated Textile Fabric	Textiles	2.345	.608	.289	.142
5905	Textile Wall Coverings	Textiles	2.694	.612	.351	.112
5903	Plastic Coated Textile Fabric	Textiles	2.463	.612	.338	.175
5408	Artificial Filament Yarn Woven Fabric	Textiles	1.825	.615	.178	.208
5606	Gimp Yarn	Textiles	1.746	.618	.22	.145
5902	Polyamide Fabric	Textiles	1.266	.622	.047	.074
5904	Linoleum	Textiles	2.059	.623	.269	.465
5405	Artificial Monofilament	Textiles	2.261	.629	.285	.099
5507	Processed Artificial Staple Fibers	Textiles	1.368	.631	.22	.368
5516	Artificial Fabrics	Textiles	1.159	.631	.086	.06
5605	Metallic Yarn	Textiles	2.777	.632	.323	.372
5006	Retail Silk Yarn	Textiles	1.631	.632	.133	.211
5502	Artificial Filament Tow	Textiles	3.577	.633	.37	.057
5001	Silkworm Cocoons	Textiles	2.317	.633	.207	.753
5007	Silk Fabrics	Textiles	1.785	.657	.143	.084
2003	Processed Mushrooms	Foodstuffs	1.926	.646	.113	.394
208	Other Meat	Animal & Animal Products	1.1	.586	.082	.751

Table 8: Potential strategic industries - sorted by HS 2-digit sector, and then distance to Ireland's current location in the Product Space.

HS4	Name	Sector	PCI	Distance	Gain	Max RCA
6911	Porcelain Tableware	Stone / Glass	1.112	.595	.061	.168
6807	Asphalt	Stone / Glass	1.233	.598	.13	.238
7005	Float Glass	Stone / Glass	1.221	.602	.071	.133
7118	Coin	Stone / Glass	1.861	.602	.174	.459
7003	Cast or Rolled Glass	Stone / Glass	1.39	.605	.134	.496
6902	Refractory Bricks	Stone / Glass	1.942	.615	.212	.069
6913	Ornamental Ceramics	Stone / Glass	1.104	.616	.055	.295
6906	Ceramic Pipes	Stone / Glass	1.71	.624	.186	.533
7107	Silver-Clad Metals	Stone / Glass	1.984	.625	.378	.666
7018	Glass Beads	Stone / Glass	1.923	.626	.234	.539
6814	Mica	Stone / Glass	2.293	.631	.248	.065
7016	Glass Bricks	Stone / Glass	1.859	.631	.235	.169
7110	Platinum	Stone / Glass	2.833	.632	.31	.671
7002	Glass Balls	Stone / Glass	2.918	.635	.332	.612
7014	Signaling Glassware	Stone / Glass	3.717	.636	.433	.14
6907	Unglazed Ceramics	Stone / Glass	1.183	.647	.063	.154
7006	Glass With Edge Workings	Stone / Glass	2.465	.651	.228	.207
7004	Blown Glass	Stone / Glass	5.274	.652	.318	.252
4805	Other Uncoated Paper	Wood & Wood Products	1.79	.579	.159	.353
4905	Maps	Wood & Wood Products	1.978	.595	.216	.488
4810	Kaolin Coated Paper	Wood & Wood Products	1.85	.609	.221	.083
4807	Composite Paper	Wood & Wood Products	1.313	.612	.167	.454
4904	Sheet Music	Wood & Wood Products	2.645	.614	.317	.825
4806	Vegetable Parchment	Wood & Wood Products	3.248	.616	.339	.426
4801	Newsprint	Wood & Wood Products	2.129	.617	.244	.12
4704	Sulfite Chemical Woodpulp	Wood & Wood Products	1.86	.618	.2	.392
4814	Wallpaper	Wood & Wood Products	2.188	.618	.246	.061
4701	Mechanical Wood Pulp	Wood & Wood Products	1.797	.625	.138	.109
4702	Dissolving Grades Chemical Woodpulp	Wood & Wood Products	1.83	.625	.11	.154
4504	Agglomerated Cork	Wood & Wood Products	1.86	.628	.239	.281
4809	Carbon Paper	Wood & Wood Products	1.693	.628	.141	.192
4502	Debacked Cork	Wood & Wood Products	1.973	.633	.089	.1

Table 9: Potential strategic industries - continued.

HS4	Name	Sector	PCI	Distance	Gain	Max RCA
8301	Padlocks	Metals	2.121	.59	.184	.376
8310	Metal Signs	Metals	1.944	.591	.208	.93
8308	Other Metal Fasteners	Metals	1.643	.593	.204	.202
7320	Iron Springs	Metals	2.817	.595	.341	.074
7217	Iron Wire	Metals	1.175	.597	.074	.125
7607	Aluminium Foil	Metals	2.209	.598	.241	.094
7606	Aluminium Plating	Metals	1.779	.598	.201	.169
7412	Copper Pipe Fittings	Metals	2.643	.601	.312	.164
7904	Zinc Bars	Metals	1.635	.602	.083	.151
8307	Flexible Metal Tubing	Metals	2.38	.603	.285	.208
7411	Copper Pipes	Metals	1.622	.606	.177	.054
8303	Safes	Metals	2.32	.609	.258	.178
8202	Hand Saws	Metals	2.733	.609	.325	.064
7222	Other Stainless Steel Bars	Metals	2.483	.609	.308	.766
7226	Flat-Rolled Iron	Metals	2.766	.61	.35	.188
7304	Iron Pipes	Metals	1.403	.613	.125	.069
8007	Other Tin Products	Metals	1.408	.614	.147	.719
7506	Nickel Sheets	Metals	2.454	.615	.341	.138
7418	Copper Housewares	Metals	1.59	.615	.147	.179
7205	Iron Powder	Metals	1.757	.617	.244	.255
7228	Other Steel Bars	Metals	2.01	.617	.281	.12
7224	Steel Ingots	Metals	1.894	.618	.151	.216
7319	Iron Sewing Needles	Metals	1.793	.619	.236	.498
7220	Flat-Rolled Stainless Steel	Metals	2.921	.619	.37	.063
8104	Magnesium	Metals	2.799	.62	.261	.091
8108	Titanium	Metals	2.624	.621	.336	.164
7409	Copper Plating	Metals	1.224	.622	.201	.102
7229	Steel Wire	Metals	2.924	.623	.333	.254
8211	Knives	Metals	2.063	.623	.252	.508
7227	Steel Bars	Metals	2.333	.625	.34	.061
7218	Stainless Steel Ingots	Metals	2.13	.626	.246	.105
7603	Aluminium Powder	Metals	1.97	.627	.188	.249
8305	Metal Office Products	Metals	2.376	.628	.232	.249
7219	Large Flat-Rolled Stainless Steel	Metals	3.01	.629	.341	.114
7406	Copper Powder	Metals	2.298	.63	.264	.499
8103	Tantalum	Metals	1.957	.63	.209	.058
7225	Flat Flat-Rolled Steel	Metals	3.008	.631	.35	.052
8213	Scissors	Metals	2.326	.632	.295	.113
8306	Bells	Metals	1.081	.633	.168	.086
7405	Copper Alloys	Metals	1.281	.639	.188	.074
8005	Tin Foil	Metals	4.312	.647	.282	.632
8102	Molybdenum	Metals	2.728	.648	.362	.084
8106	Bismuth	Metals	2.133	.65	.085	.211
7906	Zinc Pipes	Metals	1.569	.65	.078	.414
8111	Manganese	Metals	1.294	.655	.066	.115
7417	Copper Stovetops	Metals	1.134	.684	.01	.927

Table 10: Potential strategic industries - continued.

HS4	Name	Sector	PCI	Distance	Gain	Max RCA
2811	Other Inorganic Acids	Chemicals & Allied Industries	1.932	.588	.207	.247
3505	Dextrins	Chemicals & Allied Industries	2.095	.598	.229	.193
3206	Other Coloring Matter	Chemicals & Allied Industries	2.498	.599	.292	.136
3706	Motion-picture film, exposed & developed	Chemicals & Allied Industries	1.598	.603	.141	.256
2901	Acyclic Hydrocarbons	Chemicals & Allied Industries	1.381	.604	.155	.218
3403	Lubricating Products	Chemicals & Allied Industries	2.84	.606	.384	.226
3810	Metal Pickling Preparations	Chemicals & Allied Industries	3.141	.606	.403	.644
3807	Wood Tar, Oils & Pitch	Chemicals & Allied Industries	1.798	.607	.248	.498
2826	Fluorides	Chemicals & Allied Industries	1.078	.608	.134	.067
3811	Antiknock	Chemicals & Allied Industries	1.559	.61	.233	.111
2912	Aldehydes	Chemicals & Allied Industries	2.059	.611	.267	.122
2915	Saturated Acyclic Monocarboxylic Acids	Chemicals & Allied Industries	1.921	.612	.197	.973
3815	Reaction & Catalytic Products	Chemicals & Allied Industries	2.46	.613	.361	.107
3814	Organic Composite Solvents	Chemicals & Allied Industries	1.48	.613	.181	.581
3813	Fire Extinguishers Preparations	Chemicals & Allied Industries	2.534	.614	.259	.37
3213	Artistry Paints	Chemicals & Allied Industries	1.861	.614	.241	.238
2909	Ethers	Chemicals & Allied Industries	1.41	.615	.145	.981
2902	Cyclic Hydrocarbons	Chemicals & Allied Industries	1.506	.615	.114	.061
3801	Artificial Graphite	Chemicals & Allied Industries	2.214	.616	.262	.327
3601	Propellant Powders	Chemicals & Allied Industries	2.384	.616	.303	.479
3812	Prepared Rubber Accelerators	Chemicals & Allied Industries	2.59	.617	.32	.074
2849	Carbides	Chemicals & Allied Industries	1.381	.617	.117	.209
3404	Waxes	Chemicals & Allied Industries	1.741	.619	.217	.134
2842	Other Inorganic Acids Salts	Chemicals & Allied Industries	2.06	.619	.235	.69
2919	Phosphoric Esters & Salts	Chemicals & Allied Industries	2.416	.623	.333	.405
3701	Photographic Plates	Chemicals & Allied Industries	3.223	.625	.375	.055
3804	Wood Pulp Lyes	Chemicals & Allied Industries	1.984	.626	.242	.133
2821	Iron Oxides & Hydroxides	Chemicals & Allied Industries	1.958	.628	.265	.25
2903	Halogenated Hydrocarbons	Chemicals & Allied Industries	3.121	.633	.341	.68
3207	Prepared Pigments	Chemicals & Allied Industries	2.238	.634	.304	.204
2813	Nonmetal Sulfides	Chemicals & Allied Industries	1.63	.635	.178	.123
2913	Aldehyde Derivatives	Chemicals & Allied Industries	2.756	.637	.259	.66
3702	Photographic Film	Chemicals & Allied Industries	3.687	.646	.311	.217
2831	Dithionites & Sulfoxylates	Chemicals & Allied Industries	2.127	.658	.144	.18

Table 11: Potential strategic industries - continued.

HS4	Name	Sector	PCI	Distance	Gain	Max RCA
8535	High-voltage Protection Equipment	Machinery / Electrical	1.849	.585	.131	.379
8405	Water & Gas Generators	Machinery / Electrical	2.294	.59	.248	.237
8417	Industrial Furnaces	Machinery / Electrical	1.812	.59	.127	.655
8466	Metalworking Machine Parts	Machinery / Electrical	2.987	.597	.354	.335
8478	Tobacco Processing Machines	Machinery / Electrical	1.757	.598	.231	.625
8410	Hydraulic Turbines	Machinery / Electrical	1.318	.6	.097	.269
8459	Drilling Machines	Machinery / Electrical	1.773	.6	.209	.482
8483	Transmissions	Machinery / Electrical	3.1	.6	.37	.124
8451	Textile Processing Machines	Machinery / Electrical	2.356	.601	.275	.076
8462	Forging Machines	Machinery / Electrical	2.482	.603	.307	.151
8482	Ball Bearings	Machinery / Electrical	2.907	.604	.36	.164
8442	Print Production Machinery	Machinery / Electrical	3.151	.605	.376	.403
8464	Stoneworking Machines	Machinery / Electrical	2.294	.606	.273	.226
8512	Electrical Lighting & Signalling Equipment	Machinery / Electrical	2.433	.607	.264	.152
8420	Rolling Machines	Machinery / Electrical	2.61	.609	.329	.281
8453	Leather Machinery	Machinery / Electrical	1.452	.61	.194	.345
8480	Metal Molds	Machinery / Electrical	2.776	.61	.325	.201
8406	Steam Turbines	Machinery / Electrical	2.875	.611	.378	.179
8465	Woodworking machines	Machinery / Electrical	2.556	.611	.297	.104
8455	Metal-Rolling Mills	Machinery / Electrical	2.074	.612	.257	.092
8439	Papermaking Machines	Machinery / Electrical	1.992	.612	.276	.182
8454	Casting Machines	Machinery / Electrical	2.244	.615	.257	.676
8456	Laser-Removal Machines	Machinery / Electrical	2.991	.615	.379	.345
8545	Carbon-based Electronics	Machinery / Electrical	2.172	.617	.246	.483
8450	Household Washing Machines	Machinery / Electrical	2.01	.618	.203	.21
8529	Broadcasting Accessories	Machinery / Electrical	2.73	.619	.248	.437
8477	Rubberworking Machinery	Machinery / Electrical	3.334	.622	.421	.131
8448	Knitting Machine Accessories	Machinery / Electrical	2.791	.624	.351	.309
8460	Metal Finishing Machines	Machinery / Electrical	3.248	.625	.378	.283
8461	Metalworking Machines	Machinery / Electrical	3.331	.627	.371	.135
8449	Felt Machinery	Machinery / Electrical	3.113	.628	.422	.081
8458	Metal Lathes	Machinery / Electrical	3.125	.628	.361	.059
8446	Looms	Machinery / Electrical	2.477	.634	.318	.256
8445	Textile Fiber Machinery	Machinery / Electrical	2.457	.638	.311	.475
8452	Sewing Machines	Machinery / Electrical	1.764	.64	.244	.179
8513	Portable Lighting	Machinery / Electrical	1.78	.642	.122	.441
8447	Knitting Machines	Machinery / Electrical	1.654	.646	.282	.096
8444	Artificial Textile Machinery	Machinery / Electrical	3.718	.653	.373	.264

Table 12: Potential strategic industries - continued.

HS4	Name	Sector	PCI	Distance	Gain	Max RCA
8608	Railway Track Fictures	Transportation	1.757	.587	.195	.539
9306	Explosive Ammunition	Miscellaneous	1.635	.587	.123	.558
9028	Utility Meters	Miscellaneous	1.533	.588	.085	.118
9508	Fairground Amusements	Miscellaneous	1.752	.589	.174	.264
8903	Yachts	Transportation	1.91	.592	.176	.552
8607	Locomotive Parts	Transportation	2.207	.593	.267	.135
8701	Tractors	Transportation	2.507	.596	.306	.101
8704	Delivery Trucks	Transportation	1.279	.597	.126	.123
8708	Vehicle Parts	Transportation	2.677	.599	.314	.168
9305	Weapons Parts & Accessories	Miscellaneous	2.581	.601	.305	.093
8703	Cars	Transportation	2.196	.605	.308	.074
9029	Recolution Counters	Miscellaneous	2.813	.605	.308	.15
8707	Vehicle Bodies	Transportation	2.571	.607	.295	.11
9618	Mannequins	Miscellaneous	1.247	.613	.125	.5
9703	Sculptures	Miscellaneous	1.127	.614	.264	.797
9301	Military Weapons	Miscellaneous	1.353	.615	.184	.056
8906	Other Sea Transportaion	Transportation	1.357	.616	.085	.061
9303	Other Firearms	Miscellaneous	2.467	.618	.294	.497
9606	Buttons	Miscellaneous	1.225	.618	.206	.202
8713	Wheelchairs	Transportation	2.279	.618	.26	.274
9017	Drafting Tools	Miscellaneous	3.24	.619	.41	.23
8605	Railway Passenger Cars	Transportation	2.355	.619	.321	.17
9104	Dashboard Clocks	Miscellaneous	1.503	.62	.255	.069
8604	Railway Maintenance Vehicles	Transportation	1.217	.62	.176	.076
9107	Time Switches	Miscellaneous	2.096	.621	.217	.747
9209	Musical Instrument Parts	Miscellaneous	3.087	.621	.423	.374
9607	Zippers	Miscellaneous	1.425	.624	.194	.108
8606	Railway Freight Cars	Transportation	1.252	.627	.117	.415
9113	Watch Straps	Miscellaneous	1.071	.627	.14	.133
9109	Clock Movements	Miscellaneous	2.193	.629	.211	.7
9307	Bladed Weapons & Accessories	Miscellaneous	1.281	.63	.14	.096
8601	Electric Locomotives	Transportation	1.368	.63	.184	.456
9002	Mirrors & Lenses	Miscellaneous	2.611	.632	.215	.17
9613	Lighters	Miscellaneous	1.831	.632	.158	.08
9302	Handguns	Miscellaneous	1.775	.635	.165	.136
8901	Cruise Ships	Transportation	1.355	.635	.064	.119
9205	Wind Instruments	Miscellaneous	2.862	.637	.303	.143
9111	Watch Cases & Parts	Miscellaneous	2.708	.637	.174	.685
8603	Self-Propelled Rail Transport	Transportation	2.388	.638	.364	.128
9617	Vacuum Flask	Miscellaneous	2.059	.639	.14	.073
9105	Other Clocks	Miscellaneous	2.442	.642	.215	.339
9202	String Instruments	Miscellaneous	2.227	.643	.217	.125
9110	Incomplete Movement Sets	Miscellaneous	2.49	.644	.157	.219
9114	Other Clocks & Watches	Miscellaneous	2.616	.644	.219	.156
9207	Electric Musical Instruments	Miscellaneous	2.951	.645	.279	.194
8711	Motorcycles	Transportation	2.223	.648	.229	.15
9102	Watches	Miscellaneous	2.245	.651	.25	.073
9013	LCDs	Miscellaneous	3.8	.655	.182	.071

Table 13: Potential strategic industries - continued.

Appendix References

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VOTE OF THANKS PROPOSED BY EOIN O'LEARY,[1] UNIVERSITY COLLEGE CORK

I would like to thank the Society for inviting me to second the vote of thanks on this very worthwhile and interesting paper. Neave should be complimented for being one of the first to offer a detailed application of the complexity framework to Ireland.[2] For my part, in my book published last March, which Neave cites, I pointed to possible advancements in the area of product space (O'Leary, 2015: 185). I should add that Neave was already engaging in her work by the time I was writing my book. I was therefore very glad to see this paper and am particularly pleased to be invited to respond to it.

My comments are in three sections. I begin with some general comments on the paper in the context of my own work, and continue with more detailed comments on the theory and method used by the author. This is followed by some thoughts on the findings.

General Comments

This paper analyses the evolution of Ireland's merchandise exports since 1995 using the economic complexity framework (Hidalgo, Klinger, Barabasi and Hausman, 2007). It observes a higher level of specialisation than would be suggested by Ireland's level of GDP per capita. It identifies a dual structure within the economy, with domestic and foreign-owned exporters exhibiting distinctly different characteristics. In the latter case, there is a recent consolidation and reduction in complexity level by foreign-owned businesses producing high-technology pharmaceutical and electronics products. This contrasts with a dynamic and growing pattern for businesses producing food products, likely to be domestically owned. According to Neave, these businesses may be well positioned for continued expansion of Ireland's indigenous activities into more complex goods.

These results in many respects resonate with my own work which has increasingly pointed to the existence of a dual economy in Ireland. In my last co-authored paper to the Society, I reported an intriguing result that despite indigenous businesses spending considerably less per worker on R&D, these businesses are significantly more likely than foreign-owned businesses to introduce new innovative products (Doran, Jordan and O'Leary, 2013). Subsequent work on Irish innovation has pointed to the innovation activities of foreign-owned businesses being largely self-contained within the corporations to which they belong, with little likelihood that external interaction by Irish-based subsidiaries increases the likelihood that they will innovate. This contrasts with indigenous businesses where there is stronger evidence that external interaction is important for innovation (Doran and O'Leary, 2014).

In my book I have argued that apart from low tax, which has clearly been hugely important, other factors have played a role in offering foreign-owned businesses in the pharmaceutical and ICT sectors sustainable advantages from operating out of Ireland. Assistance from IDA Ireland and government departments in the provision of locations with net urbanization economies for foreign-assisted businesses is likely to have been important. These advantages include the availability of a general pool of skilled labour and appropriate infrastructural facilities to meet their needs. A further strength has been strong connectivity of these businesses with other units in the corporations to which they belong in support of productivity enhancement. The skills of the Irish-based management and workforce in successfully up-grading these large businesses, often over a number of decades, have also been a positive and under-researched feature. However, the main weakness has been the lack of linkages from these businesses to others in the Irish economy which has meant that a critical mass of internationally competitive indigenous businesses, in the pharmaceutical, ICT or related sectors has failed to emerge since the 1970s.

As regards indigenous manufacturing I show that the food processing sector, broadly defined, is our only internationally competitive manufacturing sector.[3] While this sector has stronger linkages into the Irish economy, which have contributed to its sustainability, it has a number of significant weaknesses. While there are a small number of large successful businesses such as Kerry, Glanbia and ABP, there are also a very large number of small low productivity businesses. I argue that there is a lack of entrepreneurial vibrancy in the sector due to the over-emphasis on commodity production, the dominance of the EU's 'beggar-thy-neighbour' Common Agricultural Policy, and the destructive effects of industry rent-seeking. Despite a strong export performance, these weaknesses have contributed to a failure to realize potential and have undermined the sustainability of the

[1] I would like to thank my colleague Dr Eleanor Doyle for sharing her thoughts on this paper.
[2] The only other study on Ireland in this field that I am aware of is by Brady, Doyle and Noonan (2013), who focus on comparing Ireland and Finland since 2000.
[3] Although compared to this paper I was operating at a much higher level of aggregation.

sector (O'Leary, 2015: 166-7). This conclusion clearly differs from Neave's more up-beat conclusions about this sector. I will return to this later.

I would also re-iterate that the 'elephant in the room' remains the absence of data on the nature and extent of capabilities in the Irish labour force, which is so important for linkages. This has more to do with the skills acquired 'on the job' that worker's formal education qualifications (Kavanagh and Doyle, 2003). Data are therefore needed at the levels of the firm and the individual worker that will allow us to trace skills commonalities across firms, sectors and even places. This kind of research is being carried out by evolutionary economic geographers for Scandinavian countries (see for example, Timmermans and Boschma, 2014). Without these data we will continue 'grasping at straws' in relation to the key questions of linkages and relatedness.

The author is up-front in stating that her analysis is confined to merchandise exports. The techniques being used requires access to the extremely detailed and standardized internationally available merchandise trade statistics. Services exports are excluded from the analysis. The policy response to Neave's finding of a recent consolidation and reduction in the complexity level by the foreign-owned businesses in high-technology pharmaceuticals and electronics sectors might be to point to the growing presence of foreign-owned high-technology businesses in internationally traded services sectors such as business services and software. This would miss the point. Neave's results are extremely interesting in and of themselves. While internationally traded services are becoming increasingly important, manufacturing is still vital. These results offer fascinating insights into how our manufacturing sectors are performing relative to those in other developed countries. There is no reason that I see in principle why the product space technique could not be applied to traded services. Unfortunately, international data on traded services is far too aggregated, lacking the granularity of the merchandise trade data.

Neave states in her paper that the problem of the overstatement of value-added due to transfer pricing by Irish-based multi-nationals does not significantly affect the export data, on which her analysis greatly depends. I have doubts about this statement, although I note that Neave offered more qualification on this point in her presentation tonight. The practice of transfer pricing results in the over-valuation of exported output (and indeed often the undervaluation of imports) in the categories in which these businesses are dominant. For example, for *Chemicals and related products* the share of merchandise exports increased enormously from 19% in 1995 to a massive 60% in 2012 (O'Leary, 2015: 74). This category of products is clearly related to the chemical and pharmaceutical industry, where it is widely known that inflated productivity levels are substantially affected by transfer pricing. I show that adjusting for transfer pricing might reduce the Irish productivity level in this sector by up to 50% in 2007 (O'Leary, 2015: 43). This anomaly in Irish export data has the knock-on effect that the export shares of categories dominated by indigenous businesses are dwarfed by comparison. For example, the decline registered in the export share of *Total food and live animals,* which includes food processing, is over-stated as a result. There is little that can be done about this as the task of adjusting Irish trade data for transfer pricing is particularly difficult. However, I would argue that more caution is warranted in interpreting the results. For example, measures of revealed comparative advantage for Ireland are biased as a result.

The Findings

The paper contains a very large number of interesting network maps based on different ways of applying the algorithm. I will concentrate on a few.

In Figure 5 we see that in 2013 Ireland occupied two distinct regions of the product space. These are a cluster of high complexity mainly foreign-owned chemical, pharmaceutical and electrical products on the left-hand periphery and a separate cluster of mainly domestic food and agricultural products on the centre-right. The presence of food products in highly connected central areas of the Product Spaces implies that Irish firms and industries producing these products have many options for diversification in terms of the capabilities they already possess. Bearing in mind my earlier observations about this sector, I would add that these options should be seen as opportunities, which I think concurs with Neave's conclusion presented tonight. I have argued above that the food processing industry has not reached its potential. The implication from Neave's results is that opportunities exist if the long-standing problems that have undermined the industry can be addressed. In contrast, the peripheral nature of some of the foreign-owned industries implies that spill-overs may be limited due to their highly specialised nature. These results provide further evidence suggestive of the self-contained nature of these industries, with little linkages to other industries.

In Figure 6 it is shown that Ireland's level of diversity of products exported (as measured by the revealed comparative advantage measure) has been declining over the past two decades from a relatively low level in the mid-1990s. Only Norway had a similarly low level, and it also declined. Other comparator countries, including

Denmark, Austria, Finland, Sweden, Hong Kong, Singapore and Israel, all had higher levels to begin with, which they maintained until 2012. This pattern, combined with what is referred to as a worrying trend in Figure 11, of declining complexity in product appearances coupled with increasingly complexity of disappearances (mostly in pharmaceutical and electrical products), is suggestive of increasing risk associated with Ireland's strategy of industrialization by invitation. This result should be of interest to policymakers charged with Ireland's on-going economic development strategy.

In this regard I have argued that there has been an absence of long-term strategic planning by Irish policymakers. It has been more a case of crisis management in the late 1950s and the late 1980s, before the Celtic Tiger period, to backing a winning formula since (O'Leary, 2015). Was it always the plan that the IDA pipeline would be as important today as it was in the 1980s? Neave questions the sustainability of our foreign-assisted internationally competitive industries due to them not being fully integrated into Ireland's capability base. This adds to other concerns around the sustainability of reliance by policymakers on tax advantages to attract multi-nationals. There is an urgent need in my view for long-term policymaking that is genuinely strategic.

I will conclude by congratulating the author on her meticulous and innovative work which should be used and developed further for Ireland by economists and policymakers. In doing so I would like to commend this very interesting paper to you and second the vote of thanks to Neave.

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DISCUSSION

Frank Barry: This is an interesting and thought-provoking paper, on which I have three comments. Though I didn't realise it at first, all three comments work in the direction of making the findings less worrying than might at first sight appear to be the case. The first point is that the huge scale of Ireland's services exports means that the analysis is missing a much larger part of the canvas in its portrait of Ireland than of most other countries. A lot of spillovers from the foreign-owned manufacturing sector in Ireland actually show up in services. My first example of this comes from my study of the origins of the indigenous-owned software sector, which is perhaps the leading indigenous high-tech sector. The diversity of foreign-owned manufacturing sectors in Ireland was an important factor in its emergence, since the customised and niche software products these firms required were at that time largely non-tradable. My second example comes from a paper with Chris Van Egeraat in the *ESRI Quarterly Economic Commentary* in 2008 entitled "The Decline of the Computer Hardware Sector: How Ireland Adjusted". We showed that as hardware production migrated, most of the hardware firms remained here, transitioning their operations into (better paid) services activities such as sales, technical support, software, R&D, logistics etc.

A second point is that Ireland seems to have very little difficulty in drawing in from abroad whatever skilled workers new MNCs might require – be it Italian-speaking software engineers or whatever. It is a high-wage English-speaking environment and seems to be trendy (a la Richard Florida) for the present at least. The constraints assumed in the paper might be less binding for economies like Ireland with very internationally-open labour markets.

My final point is addressed to the finding that Irish income per capita is high relative to the apparent complexity of the industrial structure. Comparing us to East Asian or other distant economies overlooks the income premium we derive from geographic proximity to the world's richest markets (as shown by Redding and Venables, 'Economic Geography and International Inequality' in the *Journal of International Economics* 2004).

Gerry Wrynn: On an issue highlighted by the speaker, namely that the ICT sector in Ireland is dominated by Multinational companies I would point out that there are dynamic and fast growing indigenously owned companies that have emerged in recent years, supported by Agencies like Enterprise Ireland and benefitting from the Stare financed Research Centres and Technology Centres. However there has been a tendency for such companies to be acquired by cash-rich multinationals seeking emerging technologies and those companies thereby then join the multinational cohort. This phenomenon has contributed to the fact that total exports by Irish owned companies have been stagnant at about 10% and Enterprise Ireland must constantly nurture new companies to replace those lost to the multinational sector just to maintain that proportion. I also mention that employment in the manufacturing sector had been rising steadily, with this week's CSO QNHS data showing a gain of about 19,000 jobs since the Forfas Manufacturing Strategy was published three years ago, a Strategy in respect of which Dr Celine Mc Hugh, who had replied to tonight's paper, had been a key driving force.

Patrick Quill: I congratulate Neave on an excellent example of 'big data' being used to arrive at product groups with similar input structure. I would also suggest that the same methodology might not transfer to services. Linkages between products may be more readily observed in the goods case, because the input structure of goods is more complex than that of services. This can be illustrated by viewing the input-output tables, where the first quadrant (goods) is quite packed, whereas the fourth (services) quadrant is sparse and mainly diagonal.

John FitzGerald: This paper represents a novel way of presenting important data on the Irish economy. The necessity of concentrating on the goods market and excluding the services sector from the analysis because of data issues is a significant restriction. With the move from producing tradable goods to tradable services, even within individual firms, this is a significant restriction. The best way of dealing with this is to consider other available evidence before reaching conclusions on the economy and its comparative advantage. The spillover effects of foreign firms may be important. The transfer of management skills through movement of personnel from the MNE sector is pretty important. In a number of key sectors there is limited domestic value added, after profit repatriations. Tis needs to be taken into account. The Netherlands Central Planning Bureau have done valuable research looking at trade in value added. This approach might prove useful.