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Multinational Enterprise Integration in the Irish Value Chain

Michael O'Grady

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Non-Technical Summary

Multi-national enterprises (MNEs) play a key role in the Irish economy, contributing substantially to output, employment and corporation tax receipts. However, since the 2015 spike in GDP (caused by the relocation of intellectual property to Ireland by foreign MNEs), there has been considerable debate over the "true" contributions of foreign-affiliate firms to the domestic Irish economy.

In this paper, we provide novel evidence on the extent to which MNEs add value to the production process in Ireland. We develop a unique dataset describing the sale and purchase relationships between producers and consumers within the economy, categorized across indigenous and foreign ownership structures. At the NACE sectoral level, we quantify the economic contributions of indigenous and foreign-affiliate firms to the domestic Irish economy, and the participation of these sectors in fostering both inter-industry and intra-industry development.

As a starting point for our analysis, we merge the 2019 CSO Supply and Use Tables for Ireland with Eurostat Annual Enterprise Statistics (AES) and Foreign Control of Enterprises (FCE) datasets, to develop a set of symmetric Input-Output tables for the Irish economy, disaggregated between indigenous firms and foreign controlled enterprises at NACE sector level.

We further refine these tables to account for aspects of MNE activities that are disconnected from the domestic production process. Specifically, we modify the tables to eliminate the interconnections of MNE-affiliate sectors most engaged in intangible R&D services imports, trade in IP assets, and investment spending on transportation leasing. With these adjustments, the modified I-O tables provide a more informative guide to sectoral interconnections and value-added growth in the domestic economy, similar to the use of GNI* for measuring aggregate economic growth.

With our tables constructed, we generate network maps of the domestic economy for 2019, showing the interconnections between indigenous and foreign-affiliate sub-sectors, which represent the dependence between industries for the sale and purchase of intermediate goods for production purposes. The maps also present a visual representation of the effects of distortionary globalization activities, and the impact of removing these effects from the modified form of the I-O tables.

To quantify the value of the various industrial sectors to the aggregate domestic economy, we use the modified I-O tables to generate a number of importance measures, accounting for the size of a sub-sector's inputs and output, the interconnectedness with other sub-sectors, and the value-added element of their activities. Our measures include input and output multipliers (measuring the way in which supply and demand changes in one sector of the domestic economy drives production across all other sectors), key-sector analysis (identifying specific sectors whose economic activity exerts a greater-than-average influence at an aggregate level activity) and field of influence estimates (measuring the effect of exogenous shocks to aggregate productivity on sectoral output growth).

Even accounting for the globalization distortions discussed above, our measures find that foreign-controlled sub-sectors are typically the most interconnected domestic industries, whose activity provides a greater-than-average influence on the wider economy. In particular, the foreign-controlled Energy and Construction sub-sectors are the most heavily interconnected domestic industries in the Irish economy, drawing production inputs from a diverse array of other industries, so that increases in demand for their goods stimulates economic activity across a range of other sectors.

Similarly, the foreign-controlled Mining & Quarrying, Professional Scientific and Technical and Admin & Support services sectors are some of the more supply-driven sub-sectors of the economy. These sub-sectors provide considerable amounts of their output for use as other firms' productive inputs and are heavily integrated in the domestic supply chain.

Finally, we identify the foreign-controlled Energy, Construction and ICT sub-sectors as being the most effective drivers of growth Induced by technological change in the economy. Following an economy-wide technological shock, these firms experience the greatest benefit to their productive capacity; increasing the efficacy with which they combine goods and services inputs to produce output beyond that of other sub-sectors.

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Michael O'Grady*

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Abstract

Foreign MNE affiliates generate and contribute markedly to Irish output, value added, exports, imports and employment, while the majority of corporation tax derives directly from the income of multi-national firms. To better understand the effects of multinational firms in the Irish economy, this paper analyzes the linkages of MNE affiliates in the domestic supply chain. To do so, we construct original symmetric input-output tables at the NACE sector level, extended across ownership structures, with the distortionary effects of globalisation-related activities removed from the data. Using these tables, we estimate a range of analytical measures to determine the strength and direction of economic interconnections across the domestic supply chain, identify the indigenous and MNE controlled sectors whose economic activity exerts the greatest influence on the domestic economy, and estimate which sectors likely benefit most from technological innovation / increased production efficiency at an aggregate level.

JEL Classification: [G15, G01, C34, G23]
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*Central Bank of Ireland, Irish Economic Analysis Division. michael.ogrady@centralbank.ie.
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1 Introduction

The activities of multi-national enterprises (MNEs) in the Irish economy have attracted a substantial amount of domestic and international attention in the last decade, both from a policy perspective and from their distortionary effects on National Accounts statistics.[1] While globalization trends have caused a proliferation in trade, foreign direct investment (FDI) and the international transfer of knowledge and technology over the last three decades, Irish industrial policy has specifically targeted the expansion of these factors since the early 1960s. As a result, foreign-affiliate activity has been embedded in the Irish economy (and concentrated within key manufacturing and services sectors) over a longer time period, and to a greater extent than the vast majority of other globalized countries.

Despite the documented effects of MNE-affiliate enterprises on macroeconomic aggregates and national statistics, there is less evidence available with regard to the linkages between MNE affiliates and indigenous firms, or the direct, indirect and induced effects on output, value added, international trade and employment from MNE activity in Ireland. Typically, policy initiatives that were designed to attract inward investment from MNE affiliates were based not only on the direct fiscal and labour market benefits from their presence, but also on the assumption of positive spillover effects to indigenous SMEs.

With the clustering of large numbers of foreign-controlled MNEs across several key sectors (particularly the pharmaceuticals, basic chemicals and ICT sectors), a narrative has developed since 2015 regarding the dual nature of the Irish economy. This characterization delineates between the FDI-driven, export-oriented MNE element of

[1] https://www.esri.ie/system/files/publications/QEC2015SUM_SA_FitzGerald.pdf

the economy and the more domestically focused, labour-intensive SME component, with the implication that there are limited spillovers that accrue to SMEs from MNEs.[2]

The argument for this viewpoint derives from two main stylized facts: the relative difference in growth rates of sectors dominated by foreign-controlled enterprises versus indigenously dominated sectors, and the relative difference in productivity growth rates between MNEs and SMEs. While some research has found positive productivity spillovers to Irish SMEs resulting from linkages with resident MNEs, the majority of research on the topic finds minimal empirical evidence to support the hypothesis of positive MNE spillovers to indigenous Irish firms.

Instead of attempting to directly estimate positive externalities accruing to the domestic economy from MNE activities, we take a different approach to measuring the economic impact of foreign controlled enterprises on the Irish economy. In this paper, we analyse the domestic economic linkages of MNE affiliates to better understand the role of foreign controlled enterprises in the domestic supply chain. We identify the direct effects of MNEs through output, value added, international trade and employment measures, in addition to the upstream and downstream contributions that MNEs make to the production processes of indigenous firms in other sectors, plus their relationships with consumers via final demand channels.

To achieve these results, we make use of three complimentary datasets on sectoral economic activity in the Irish Economy: the CSO Supply and Use Tables for Ireland, the Eurostat Annual Enterprise Statistics (AES), and the Eurostat Foreign Control of Enterprises (FCE) series. Combining these datasets with sectoral assumptions regarding sales structures and production technologies, we develop a set of symmetric input-output tables (SIOTs) for the Irish economy, disaggregated between indigenous firms

[2] See O'Connor, Enright and Dalton (2014); Papa, Rehill and O'Connor (2018); Di Ubaldo, Lawless and Siedschlag (2018); and Di Ubaldo and Siedschlag (2022).

and foreign controlled enterprises at NACE sector level. We further modify the tables, to remove globalisation-related activities of contract manufacturing and intellectual property transfers, from the MNE-affiliated sub-sectors where this activity is known to occur. These tables provide novel information on the flow of goods and services between and within industries throughout the domestic supply chain, and the extent to which inter-dependencies exist between MNEs and SMEs across industries.[3]

With the tables constructed for 2019, we use this data to provide quantifiable estimates for several policy-relevant analytical measures. First, we generate some measures of the interdependence between the individual sub-sectors and the rest of the economy. Next, we construct linkage measures to determine the sub-sectoral responses to supply and demand shocks, identifying which sectors act as propagators of growth through the domestic supply chain, and which sectors are reliant on demand shocks from other industrial sectors to generate output growth. Finally, we estimate the effects of a change in the level of technology in the domestic economy, identifying which sectors benefit most from an increase in exogenous productivity shocks, i.e. act as conduit between technological innovation and domestic economic growth.

Our results suggest that, even after removing estimates of the distortionary effects of globalisation-related activities of MNE affiliates, a number of foreign-affiliate sub-sectors of the domestic economy act as key drivers of aggregate output growth. In particular, the foreign-controlled Construction sub-sector, the foreign-controlled Energy sub-sector, and the indigenous Construction sub-sector are the most important elements of the economy for generating and propagating growth throughout the domestic supply chain, with the Agriculture sector also identified as being an important industry for the dissemination of supply and demand shocks.

[3] Removing these effects changes the indigenous sub-sectoral multipliers (our simplest measure of supply-chain interconnection) by between 0.1% and 26%, relative to the unadjusted measures.

In contrast, the indigenous Admin & Support and Professional, Scientific & Technical sub-sectors are the weakest market-based sectors for either stimulating inter-sectoral growth from final demand shocks, or for contributing to aggregate growth following production increases in other segments of the economy. The Health and Education sectors are also identified as being weak drivers of supply and demand shocks, although this result was to be expected, given these sectors form the majority of the non-market sector (together with the Public Administration sector) in the I-O tables.

Somewhat surprisingly, neither the foreign-affiliate Manufacturing sector nor the ICT sector are found to be particularly potent or ineffectual at propagating supply and demand shocks, or driving growth following technological innovations to the economy, despite their position as two of the largest sub-sectors in our modified I-O tables. One potential reason for this could be the fact that a substantial proportion of their production is used to generate final demand products for export. Firms still gain value added in the form of increased profits, but the majority of end-users of the goods and services are outside of the domestic economy, hence there is some loss of the full gains from these innovations.[4]

The remainder of the paper is structured as follows. Section 2 presents the development of MNE activity in Ireland since 2015, and the extent to which this activity has become embedded in the economy. Section 3 outlines the process by which we construct our ownership-extended SIOTs, and the assumption needed to create contemporaneous tables and disaggregate across ownership structures. Section 4 presents visualizations of the generated SIOTs in the form of network maps, and some basic statistical properties of the tables. Section 5 presents more detailed analytical work on the extended SIOTs, including input and output multiplier analysis,

[4] Even removing the distortionary globalisation effects from the I-O tables still leaves the foreign-affiliate ICT and Manufacturing sectors as two of the three largest exporting sectors in the tables.

backward and forward linkage estimates and key sector analysis to identify dependence characteristics of MNEs across sectors. Section 6 concludes the paper.

2 MNE Activity and the Irish National Accounts

With the global economic recovery from the twin crises of 2008 and 2012, there was a structural change to the nature of globalization, the effects of which were felt heterogeneously across countries. In Ireland, while FDI flows initially slumped and financial flows retrenched sharply with the decline in cross-border bank lending, several multi-national enterprises took advantage of (i) Ireland's low corporation tax rate, and (ii) the ability to locate intellectual property products (IPPs) anywhere in the world under most international tax laws, to relocate both economic activities and the underlying intellectual property to their Irish subsidiaries.

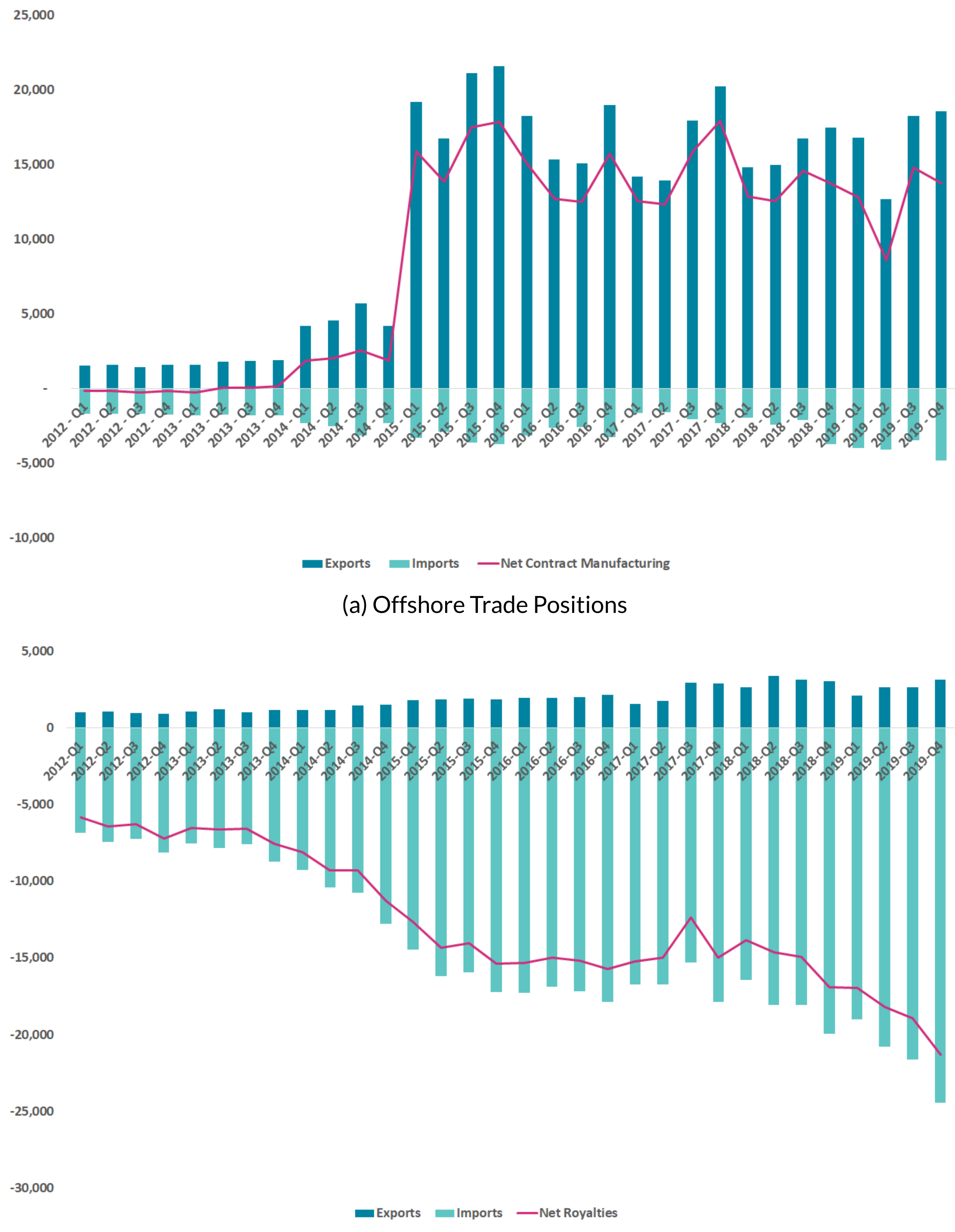
As an added complication, the intellectual property owned by a number of these MNEs was (and continues to be) used in contract manufacturing / goods for processing arrangements. Under these arrangements, Irish-domiciled enterprises involve contract manufacturers, including those resident outside Ireland, to produce final products using the blueprints from the IPPs. The subsequent distribution and sale of these products, organized by the Irish enterprises, results in value added being created in the Irish economy, which also includes income generated by the IPP.

Figure 1a displays the level of contract manufacturing and merchanting activities carried out by companies in Ireland between $2012q1$ and $2019q4$, while Figure 1b shows the value of royalties/licenses and assets trade by Irish domiciled firms over the same period. From these charts, it is evident that a profound change occurred in (primarily MNE-related) Irish offshore trade activities in 2015, precipitated by an inflow of royalties payments in the previous year. Between 2013 and 2014, imports of royalties payments increased by almost 40 per cent, to €43.3 billion, which contributed to the 60 per cent increase in contract manufacturing exports to €18.6 billion. In 2015 further royalties import growth of 48 per cent (€20 billion) combined with increased R&D asset inflows of €30 billion ($+106\%$ on the previous year) to boost contract manufacturing exports by 320 per cent, to €78.6 billion. These offshore exports occurred primarily in the chemical, pharmaceutical, electrical and computer products, and were heavily concentrated among foreign-owned MNEs.

The effect that these asset and IP relocations have had on Irish national accounts statistics is well documented. In 2015 alone, nominal GDP increased by 34.8%, GNI grew by 22.7% and GVA increased by 37.6%. Between 2015 and 2022, compound annual growth rates of 8.8%, 9.8% and 10% have been recorded in GVA, GDP and GNI. Given the inherent difficulties posed by globalisation-related activities in the measurement of national economic activity, the CSO convened the Economic Statistics Review Group (ESRG), whose mandate included the development and expansion of the existing National Accounts and Balance of Payments frameworks, and the creation of new national economic indicators.

In 2016, the ESRG produced a report of its deliberations, which outlined suggestions for several new auxiliary measures of economic activity. Primarily, the group recommended the development of an adjusted level indicator of the size of the economy, derived from GNI but adjusted to account for the retained earnings of re-domiciled firms and depreciation on foreign-owned domestic capital assets. With respect to cyclical indicators, the group suggested developing an adjusted measure of investment (with an associated measure of underlying domestic demand) to account for the impact of IP relocations, contract manufacturing, aircraft leasing and re-domiciled firms. Furthermore, a published disaggregation of GVA into sectors dominated by

Figure 1: Globalization of Irish Trade Flows (€mil), 2012-2019



(a) Offshore Trade Positions

(b) Royalties & License Payments

Source: Author's calculations from CSO National Accounts and Balance of Payments data foreign-owned multi-national enterprises and indigenously dominated sectors was also suggested.

These measures have proven effective in complementing the standard headline indicators of output and investment in the Irish economy, to gauge the dynamics of purely domestic economic activity deriving from indigenous, Irish-resident firms. However, their focus is macroeconomic in nature and as such, makes no attempt to quantify the role and impact of foreign-owned MNEs in the activities of the domestic economy, or the importance of domestic linkages between these MNEs and the rest of the economy. Given the increased focus and importance of economic linkages in understanding the effects of globalization on national economies, and the renewed interest in sectoral analysis of supply chains since the Covid-19 pandemic, we develop a sectoral disaggregation of these effects through the use of IO tables, presented in the next section.

3 Construction of Ownership-Extended I-O Tables

To develop a set of I-O tables that account for the multinational elements of sectoral activity in the Irish economy, two immediate challenges present themselves in the data. Firstly, full sets of domestic Input-Output tables are only produced by the CSO in intervals of five years, and are typically produced with a substantial time lag. Secondly, neither the Input-Output tables themselves, nor the underlying supply and use tables, provide any disaggregation relating to indigenous and foreign-owned MNE affiliate components of the economy, at any hierarchical level of the NACE classification system.

To overcome the first obstacle, we make use of the CSO's Supply and Use Tables (SUTs), which are available annually from 2008. To derive symmetric I-O tables, we need to make a number of assumptions regarding tax rates and trade margins for intermediate goods (at the industry$\times$product level) and the components of final demand. To do so, we leverage the corresponding rates from the most recently available set of I-O tables (the 2015 edition), with robustness checks to confirm that these assumptions do not introduce distortionary effects.

To resolve the disaggregation issue, we incorporate information from the Foreign-Controlled Enterprise Statistics (FATS) series provided by Eurostat into our Input-Output tables. Using data on various sectoral-level indicators (including value-added components, personnel costs and production value), we derive the foreign-controlled MNE share of these indicators, and use them to split the intermediate consumption and value-added columns of our industry-by-industry I-O tables. While this approach is reliant on a number of inferences, the results allow for a more informed analysis of the interlinkages with, and importance to, the domestic economy resulting from MNEs across a number of industrial sectors.[5]

We also discuss the activities of re-domiciled PLCs that have introduced substantial volatility into the national accounts data (primarily through patent changes, capital transfer of international IP assets, and globalization effects on trade channels), and derive a strategy on how to separate these activities from their real contributions to the domestic economy.

[5] Primarily, this approach requires the assumption that indigenous and foreign-controlled firms in the same NACE sector employ the same production technology, so that the use of intermediate consumption goods is proportionate across ownership structures. We also assume that variables from the FATS database act as appropriate proxies for various elements of the I-O tables. Finally, we inherently assume that the sub-sectoral mix of firms in our sectoral aggregates is broadly homogenous across ownership structures, i.e. MNE activity in the ICT sector isn't just confined to the Computer Programming or Telecommunications sub-sector, and is distributed across the sector in a similar way to indigenous firms.

3.1 Development of Contemporary Symmetric Input-Output Tables

Under European statistical regulations, EEA countries are required to produce Input-Output Tables every five years, with most tables published within three years of the end of the reference year. Since 2008, Input-Output Tables have been obliged to use the NACE Rev. 2 classification system, covering 58 product categories across 19 sectors of activity. Under this schedule, Ireland has published total, domestic and imported Input-Output Tables, on a product-by-product basis, for 2005, 2010, 2015 and 2020.[6] Outside of the main I-O tables, the CSO also provides use tables for imported products, use tables for margins, and use tables for taxes minus subsidies on products.

I-O tables are among the richest and most useful data structures for national economic analysis, containing information on aspects of both supply and demand. However, relying on data that can be up to 8 years out of date for insights into the interlinkages between production sectors, relationships between producers and consumers, and the flows of intermediate and final goods and services in the economy can potentially misinform policymakers and researchers. This is particularly true of Ireland, given: the degree to which international capital flows into the economy; the rate at which recent inward migration has expanded the domestic labour force; and the pace at which technological innovation has enhanced production processes in the indigenous and multinational segments of the economy.

As a complement to the official CSO I-O tables, we develop a set of estimated Input-Output Tables, based on the CSO's Supply and Use Tables that are available annually in NACE Rev 2 format since 2008. These tables form the basis of the calculations for generating Symmetric Input-Output Tables, and simply require both series to be

[6] An additional set of tables, off this five-year publication schedule, was produced for the 2011 economy in 2014.

transformed into a common price format.[7] To do so, the only information needed are product$\times$industry-level net taxes and trade margins. While these values are not available annually, tax and trade margin rates for each product$\times$industry combination can be calculated from the most recent SIOTs and applied to the Supply and Use Table, to either convert Supply Tables into producer prices, or Use Tables into basic prices.[8]

There are several benefits to this approach. Primarily, it allows for a more contemporary analysis of linkages between production sectors, and the general equilibrium effects of sectoral expansions and contractions. It permits the development of a time-series of SIOTs, which provides a greater understanding of the dynamics within the Irish economy over the last decade. It also reduces dependency on the official 5-year SIOT release, which may be affected by aberrant economic conditions that cause disruptions to domestic supply chains, e.g. the Covid-19 pandemic effects in 2020. Finally, it gives policymakers an additional tool for examining the effects of globalization on the Irish Economy.

To generate Use Tables for Taxes less Subsidies on Products, we first calculate the net tax rate for each of the 58×58 product-industry combinations, as a share of total use value for that product in the given industry, from the 2015 tables.[9] We then apply this tax rate to the Supply and Use Tables under analysis, either removing the estimated net tax effects on producer prices in the Use Tables, or adding their effects to basic prices in the Supply Tables. As a robustness check, we confirm that this approach does not lead to potential negative values in the estimated SIOTs.

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7 Supply Tables are provided in basic prices, while Use Tables are provided in purchasers' prices.

8 https://www.cso.ie/en/interactivezone/statisticsexplained/nationalaccountsexplained/

9 While 2020 tables are available, we avoid their use to eliminate the risk of contaminating our data with any effects of the Covid-19 pandemic.

Additionally, to estimate the Use Tables for Trade Margins outside of years where official data exists, we calculate the trade margin share as the ratio of trade margins to total use value at producer prices, for each product$\times$industry combination, from the most recently available tables. As trade margins for each industry and final use category must sum to zero in the use table, we apply this ratio to use values in the year under analysis, to estimate trade margin values for all products sectors that are not included in the Distributive Trade Sector (NACE Sector G). Then, we use the cumulative value from this calculation, and apply it proportionally to each NACE Sector G product group in the industry or final use category, with proportions based on the weighted share of trade margins for Sector G products in each industry generated by the individual Sector G product category, i.e.

$$\begin{aligned} TM_{i,j}^{20xx} &= \tfrac{1}{\tau_{i,j}^{2015}} * \Psi_{i,j}^{20xx} && \forall\, i \notin G^{\text{NACE}}, \quad j = 1, \dots, 64 \\ TM_{h,j}^{20xx} &= -(\tfrac{1}{\mu_{h,j}^{2015}}) * (\textstyle\sum_{i=1}^{55} TM_{i,j}^{20xx}) && \forall\, h \in G^{\text{NACE}}, \quad i \notin G^{\text{NACE}} \end{aligned} \tag{1}$$

where i and h are the set of product groups that span the NACE Rev. 2 2-digit classification system, j are the 64 2-digit NACE industries and final use groups, $\tau_{i,j}^{2015}$ is the product$\times$industry trade margin share from the 2015 tables, $\Psi_{i,j}^{20xx}$ are the use values at producer prices for product i in industry j for a given year, $\mu_{h,j}^{2015}$ is the product-level share of trade margins from aggregate Sector G trade margins in industry / final use group j, and G^{NACE} is the set of products and services covered by NACE Rev. 2 Sector G.[10]

As our benchmark case, we run the above procedure on the 2019 Supply and Use Tables, the most recently available tables provided by the CSO prior to the Covid-19 shock of 2020. Given our current interest in the I-O tables is more macroeconomic in nature (e.g. examining the economic impacts of changes to tax structures, or the general

[10] This includes Wholesale Trade, Retail Trade, and Wholesale & Retail Trade and Repair of Vehicles.

equilibrium effects of sectoral contractions), we generate our tables on an industry-by-industry basis, using a fixed product sales structure.[11] However, tables using a product-by-product basis and/or an industry sales structure can also be generated, for further research on more microeconomic topics (e.g. productivity analysis or estimating the effects of new production technologies) beyond the scope of our work.

3.2 Extension of Input-Output Tables across Ownership Structures

With our system for generating contemporaneous I-O tables in place, the next stage in our approach requires the separation of NACE sectors into their indigenous and multinational sub-components. This process is more challenging than the previous step, as there is limited data available from the CSO on the proportion of MNE activity at the NACE sectoral level, and no data that directly relates to the values in the supply and use tables.

Instead, we leverage information on business activities at the NACE level from two distinct datasets developed by Eurostat. The Annual Enterprise Statistics (AES) database for special aggregates of activities provides data on a range of economic indicators for structural business statistics at the member-state level. Data are available from 2010, encompasses the total business economy of the reporting country (NACE sectors B-N), and provides aggregate information on activity in each sector over a set of 33 variables. Similarly, the Foreign Control of Enterprises Statistics (FATS) database provides data on the activities of multinational enterprises, resident in European member states, across a set of economic indicators. Data are available from 2008, also covers the NACE sectors classified under the total business economy (with the exception of Financial & Insurance

[11] See the "Eurostat Manual of Supply, Use and Input-Output Tables" for a more detailed discussion of the costs and benefits from product-by-product vs industry-by-industry I-O tables, and the implicit trade-offs from technology and sales structure assumptions.

activities), and covers a set of 23 variables that overlap strongly with the series present in the AES database.

Merging the two Eurostat databases, we return 13 distinct variables that are common to both groups: Number of Enterprises; Value Added Plus Total Purchases of Goods and Services; Turnover or Gross Premiums; Production Value; Value Added at Factor Cost; Gross Operating Surplus; Total Purchases of Goods and Services; Resale Goods; Personnel Costs; Gross Investment in Tangible Goods; Persons Employed; Unpaid Persons Employed; and Employees.

Using this data, we can obtain ratios of the share of each variable accounted for by foreign-controlled enterprises, at the NACE sector level. To disaggregate the columns of the IO table across ownership structures, we need information on seven row vector categories: Total Inputs, Imports, Value Added, Net Product Taxes and Subsidies, and Total Intermediate Consumption, which can be proxied for using the variables from our merged Eurostat database.

For total inputs, we proxy for the breakdown of ownership shares using "Value Added Plus Total Purchases of Goods and Services". The "Value Added at Factor Cost" variable can act as a proxy for our value added row, while "Total Purchases of Goods and Services" proxies for the net product taxes and subsidies row.

For our imports and total intermediate consumption rows, we only need to solve for one of the rows, with the remaining row being identified residually through the system of equations. We make use of the fact that MNE affiliates are more integrated into global value chains, and are thus more likely to import final-use goods and services than indigenous firms, by choosing a proxy that maximizes the MNE share of the imports row for a given sector. If proxying for the imports row using "Total Purchases of Goods and Services" maximizes the MNE share, we apply this weighting to imports, and let the total intermediate consumption row be determined residually. Otherwise, we use "Total

Purchases of Goods and Services" as a proxy for the total intermediate consumption row, and let the imports row be calculated as the residual value.

However, we still need to assign weightings to the components of the Value Added and Intermediate Consumption matrices. For intermediate consumption, we have suitable proxy variables for both the compensation of employees row (Personnel Costs) and operating surplus (Gross Operating Surplus). Given we know the share of Value Added, we assume the shares of Consumption of Fixed Capital and Non-Product Taxes less Subsidies are the same within industry-ownership structures, which allows for the values in each row to be determined residually.

With regard to intermediate consumption, we have no prior information or additional data sources that can inform our estimation of the disaggregation of intermediate product purchases across ownership structures. As a result, we apply the technology assumption from the product$\times$product IO table transformation, and assume that each industry has its own specific method of production, irrespective of the product mix. Thus, between the indigenous and MNE affiliate firms in a given NACE sector, we maintain a fixed-proportion share across all rows in the intermediate product matrix. While our assumption regarding the structure of the intermediate product matrix may be an over-simplification of real-world production processes, there is no currently available data that would allow us to generate a more plausible breakdown of the elements of the intermediate consumption matrix in our ownership-extended IO tables.[12]

[12] As noted in the Eurostat manual of Supply, Use and Input-Output tables, two distinct firms producing identical products may have quite different input structures, depending on the degree of reliance on purchase of semi-fabricated products, outsourcing of certain activities, whether it owns or rents capital equipment and buildings, and the degree of vertical integration of the various production processes. However, there is no way to completely eliminate institutional characteristics from symmetric Input-Output Tables. As institutional structures change over time, it is obvious that the interpretation of an Input-Output Table as a description of a technical production system is inherently constrained by design.

With the Intermediate Consumption, Value Added and Total Input blocks of the expanded I-O Table constructed, the only remaining element that still needs to be estimated is the matrix of Final Demand. Here, proxying for the ownership shares across rows is a little more difficult, as the Eurostat data do not correspond as directly to the final demand categories. For Private and Government Consumption, we assume that there is an association with employment shares and proxy using Total Persons Employed. For Gross Fixed Capital Formation and Changes in Inventories, we use the share of Gross Investment in Tangible Goods as our proxy variable. Finally, with the other four final demand variables determined, and the requirement for Total Output to be equal to Total Inputs (due to the symmetric nature of the I-O Tables), export shares are determined residually.

Our completed ownership-extended I-O table consists of a 32×32 Intermediate Consumption matrix, a 4×32 Value-Added matrix, a 6×32 matrix of Final Demand, and 1×32 vectors of Net Product Taxes, Imports, Total Inputs and Total Outputs.

3.3 Removal of Globalisation-Based Distortions from the Ownership-Extended I-O Tables

As discussed in Section 2, the presence of contract manufacturing activity across several MNE affiliated sub-sectors of the Irish economy introduces considerable bias into the supply and use table data. As a result of this distortion, estimates of the interconnections between these MNE sectors and other segments of the economy will also be biased, overstating the effects of the sector on the domestic economy. So long as merchanting and contract manufacturing activity is present in the data, estimates of industrial connectivity (e.g. backward and forward linkages, field of influence values, importance coefficients), multiplier analysis (including output, input, income, and employment multipliers), and general equilibrium effects of sectoral expansions and contractions will be measured with error.

To attempt to minimize the effects of IP transfer, merchanting and contract manufacturing, we modify the extended I-O tables using an approach similar to the method of Timoney (2023). From CSO data on the capital stock of fixed assets and domestic physical capital formation, we know that there are four sectors whose onshoring of intellectual property since 2015 have caused discrete level shifts in the national capital stock data: Manufacturing, Information, Communications & Technology, Administrative & Support services, and Professional, Scientific & Technical services. This IP onshoring causes a corresponding increase in the operating surplus component of Value Added, resulting from the ownership of the goods produced under license via contract manufacturing arrangements. Outputs produced under these arrangements have a high import content, limited linkages to economic activity within the Irish economy, and are typically exported to third-party countries, so inputs and output rarely interact with the domestic supply chain.

Additionally, there is considerable research devoted to the existence and characteristics of "factoryless goods producers" (FGPs); firms that do not manufacture themselves, but are heavily involved in the production of goods nonetheless. While FGPs do not supply the raw material inputs to the production process, they do supply substantial service inputs in the form of technology, know-how, and product design. In addition, the FGP may be monitoring the quality of material inputs through selection or pre-approval of certain material input providers. Under Revision 4 of the International Standard Industrial Classification of All Economic Activities, "a principal who completely outsources the transformation process but does not own the input materials is in fact buying the completed good from the contractor with the intention to resell it. Such an activity is classified in Wholesale and Retail Trade, specifically according to the type of sale and the specific type of good sold".

The problem, as it relates to the I-O tables, is that production is aggregated at the sectoral level (or the 2-digit divisional level in the Supply and Use Tables). Intermediate consumption goods from sector i purchased by firms from industry j are aggregated into a single value, so that the data do not differentiate between €100 of physical goods located in Ireland, and €100 of IPP that are used in the manufacture of goods abroad, whose ownership and profits are booked in Ireland. While the raw material will combine with other physical goods and services located in Ireland, domestic labour and production technologies to produce output, the IPP will combine with completely different input materials, using foreign labour and production processes, none of which is recorded in the Irish I-O tables. However, any modelling of the production process will assume that domestic intermediates use domestic inputs and IPP in a perfectly substitutable way. This issue is discussed further in Appendix A.

Given these activities are conducted almost exclusively by foreign-controlled enterprises, and take place within the five NACE sectors listed above, we modify the IO tables to remove their distortionary effects in the following process:

- In the intermediate consumption matrix, we proportionately scale the $5 \times 5 = 25$ elements representing MNE $\rightarrow$ MNE activities between the five sectors where data distortions are known to occur, to match indigenous sub-sector usage shares.

- In the value-added matrix, we nullify the gross operating profit element of the five columns representing MNE activity in these five sectors. We also constrain the consumption of fixed capital to be proportionate to the equivalent indigenous sub-sector.

- In the Imports vector (which contains imports that are consumed as final demand, i.e. unmodified in the production process), we nullify the five values that relate to the MNE activity in the five NACE sectors.
- In the final demand matrix, we proportionately scale the Gross Fixed Capital Formation and Exports rows, for the five MNE-owned NACE sectors, so that the I-O table remains symmetric.

Implementing these modifications in the 2019 tables results in a 30% reduction in aggregate intermediate consumption, a 41% reduction in aggregate Value Added, a 56% reduction in aggregate final demand imports, a 47% reduction in GFCF and a 63% reduction in exports. Combined, these adjustments lead to a 40.3% reduction in output, which is a close approximation to the 41% reduction in Irish GDP in 2019 (representing globalization effects from IP transfers and depreciation, and redomiciled PLC income) from the calculation of the more appropriate measure of domestic economic output, GNI*.

4 Input-Output Table Visualizations

As discussed above, the primary function of the Input-Output tables is to describe the sale and purchase relationships between consumers and producers within an economy. Even condensed to the NACE sector level, there are $1,440$ individual data points within the tables. This makes it difficult to provide a concise numerical representation of these relationships, while retaining important information regarding the scale and scope of economic linkages.

Instead, graphical demonstrations typically better explain the concept of large network linkages than the data tables. To this end, we present two of the more common I-O table visualizations in this section: 3-dimensional histograms and network maps. 3-dimensional histograms are useful for identifying which pairs of sales-purchases relationships are the strongest within the I-O tables. Network maps are typically less granular, but show the importance of each sector within the entire economic network, in addition to the broader supply chain configuration and topology.

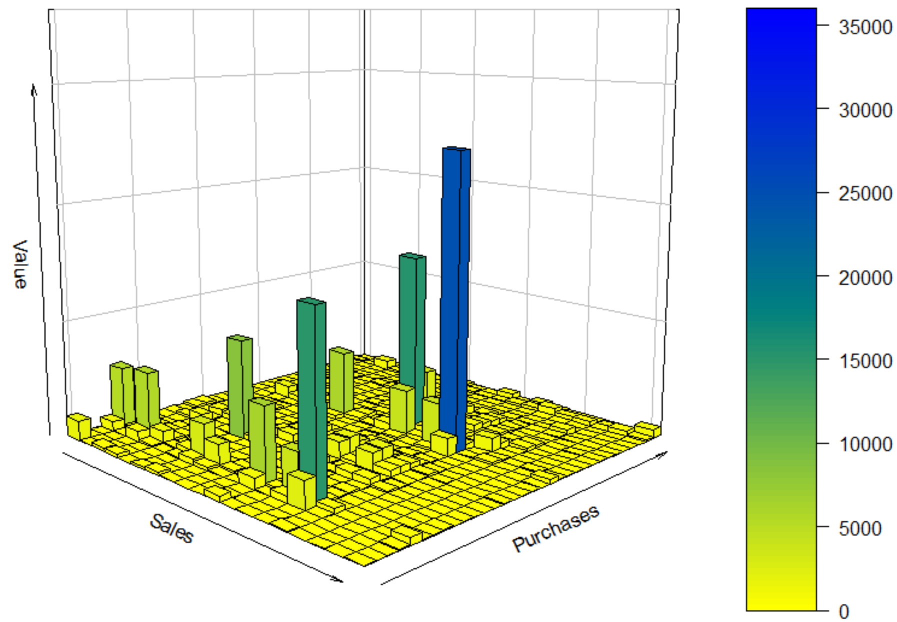
4.1 3-D Histograms of Intermediate Consumption

Figure 2 presents the sales of goods and services for intermediate consumption in the production process of each industry. For ease of comparison, we differentiate the sales of indigenous firms (a) and foreign-controlled enterprises (b) across separate charts, to elucidate the differences in sales patterns between the two ownership structures. The most striking difference across the charts is that indigenous firms have more linkages across sectors, but foreign affiliates are responsible for more of the high-value linkages. This is evidenced by the fact that the median value of industry-to-industry sales in indigenous sub-sectors is larger than in foreign-affiliate sub-sectors (€23.3m vs €17.5m), but foreign-affiliate firms' sales account for 12 of the 20 largest industry-to-industry connections in the intermediate consumption tables.[13] Overall, the total value of sales of intermediates is almost identical between indigenous sub-sectors (€190.68 billion) and their foreign affiliate counterparts (€190.44 billion).

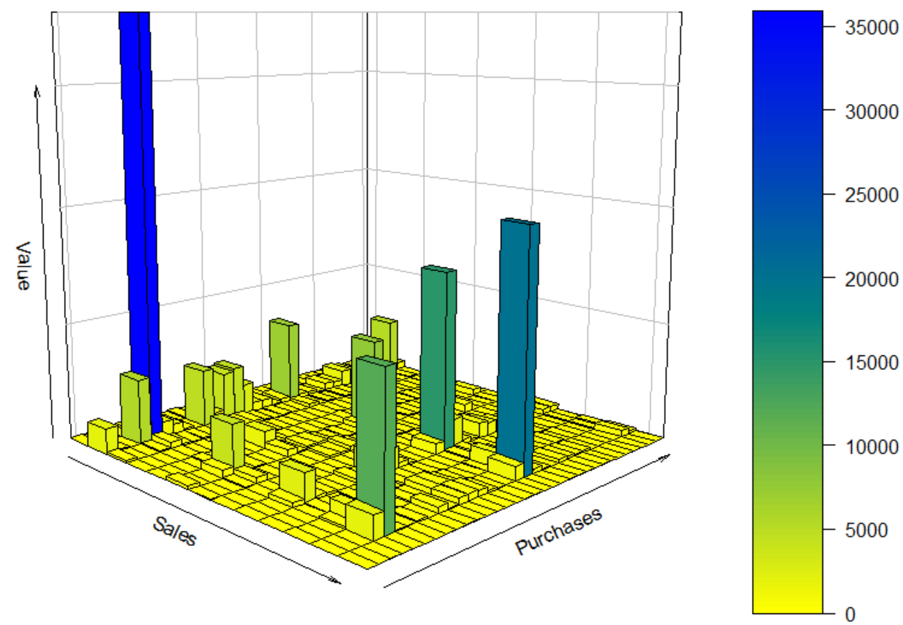
However, there is a much greater skew with regard to the purchases of production intermediates across ownership structures. As shown in Figure 3, foreign affiliate firms account for 14 of the top-20 industry-to-industry connections in the intermediate consumption tables, with the mean value of the industry-to-industry purchases of MNEs (€563.4m) more than double the corresponding value of purchases by indigenous firms

[13] These 20 values represent the largest 2% of intermediate sales-purchases relationships in the 2019 I-O tables.

Figure 2: Total Purchases of Intermediate Goods and Services, 2019



(a) Indigenous Firm Sales



(b) Foreign Affiliate Sales

Source: Author's calculations from CSO Supply & Use Tables, and Eurostat AES & FCE data.

(€241.4m). These 14 connections account for 45% of total intermediate consumption in the economy, with the remaining six large purchases by indigenous segments accounting for an additional 11% of total intermediate consumption. With respect to total purchases across all sectors, indigenous industries accounted for 38.5% (€146.8 billion) of purchases, while foreign-affiliate industries were responsible for 61.5% (€234.4 billion) of total intermediate purchases. Somewhat unsurprisingly, the manufacturing and ICT industries accounted for the majority (85%) of these MNE affiliate purchases.

4.2 Network Mapping of Extended I-O Tables

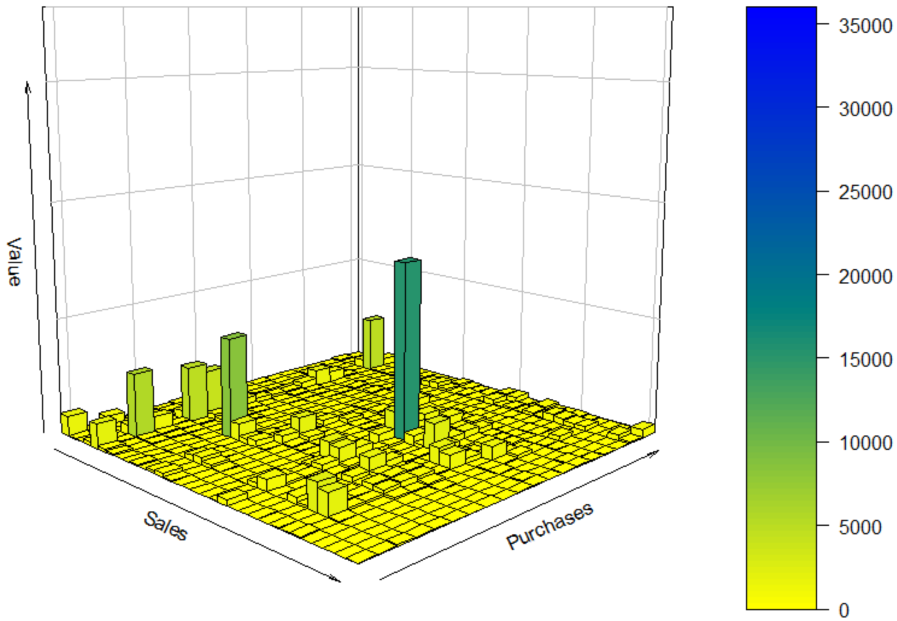
With respect to I-O Table analysis, a network map is a representation of the sectors in the supply chain network, the interconnections that represent sales and purchases flows between these sectors, and their topological layout. Figure 4 presents such a mapping for the 2019 ownership-extended I-O tables.[14]

Each of the 32 industry-ownership sectors is represented by a circle (node). The darker, inner portion of the node represents total intermediate consumption, while the lighter, outer portion of the circle represents total inputs. The lines between nodes (edges) represent the cumulative value of intermediate consumption flows between both sectors. Sectors are labelled using their NACE sector level, with I and F used to denote whether the ownership structure relates to indigenous firms or foreign-controlled enterprises, respectively. For the benefit of legibility, only the largest 10% of edges are presented in the map.

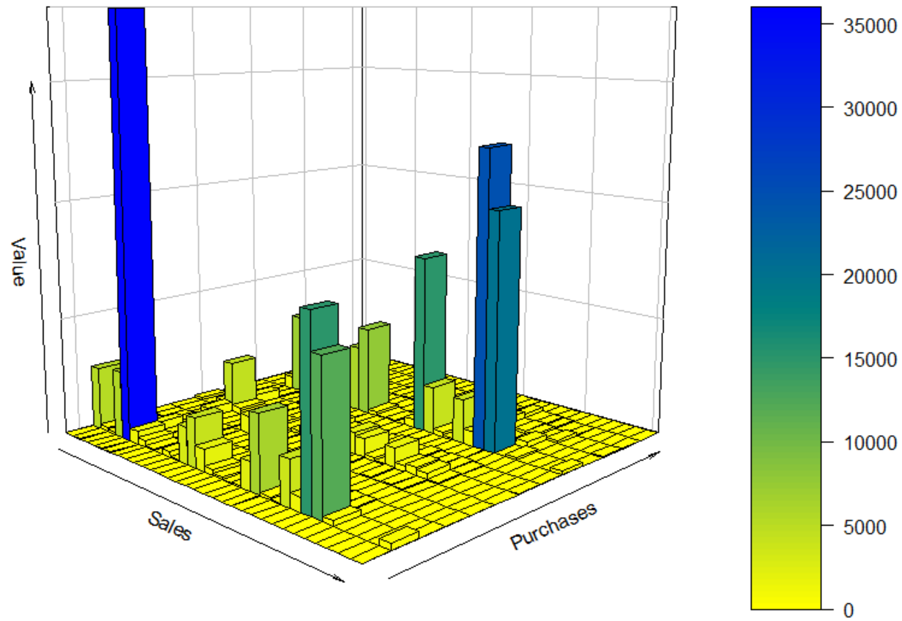
From the graph, it is clear that the foreign-controlled manufacturing and ICT sectors are important within the Irish economy: both sectors have large inner and outer nodes, a high number of connections to other sectors, and several of the largest

[14] The layout of the map is derived using a variant of the Kamada-Kawai approach, which uses a stress-minimization algorithm to determine the optimal positioning of nodes in the graph.

Figure 3: Total Sales of Intermediate Goods and Services, 2019



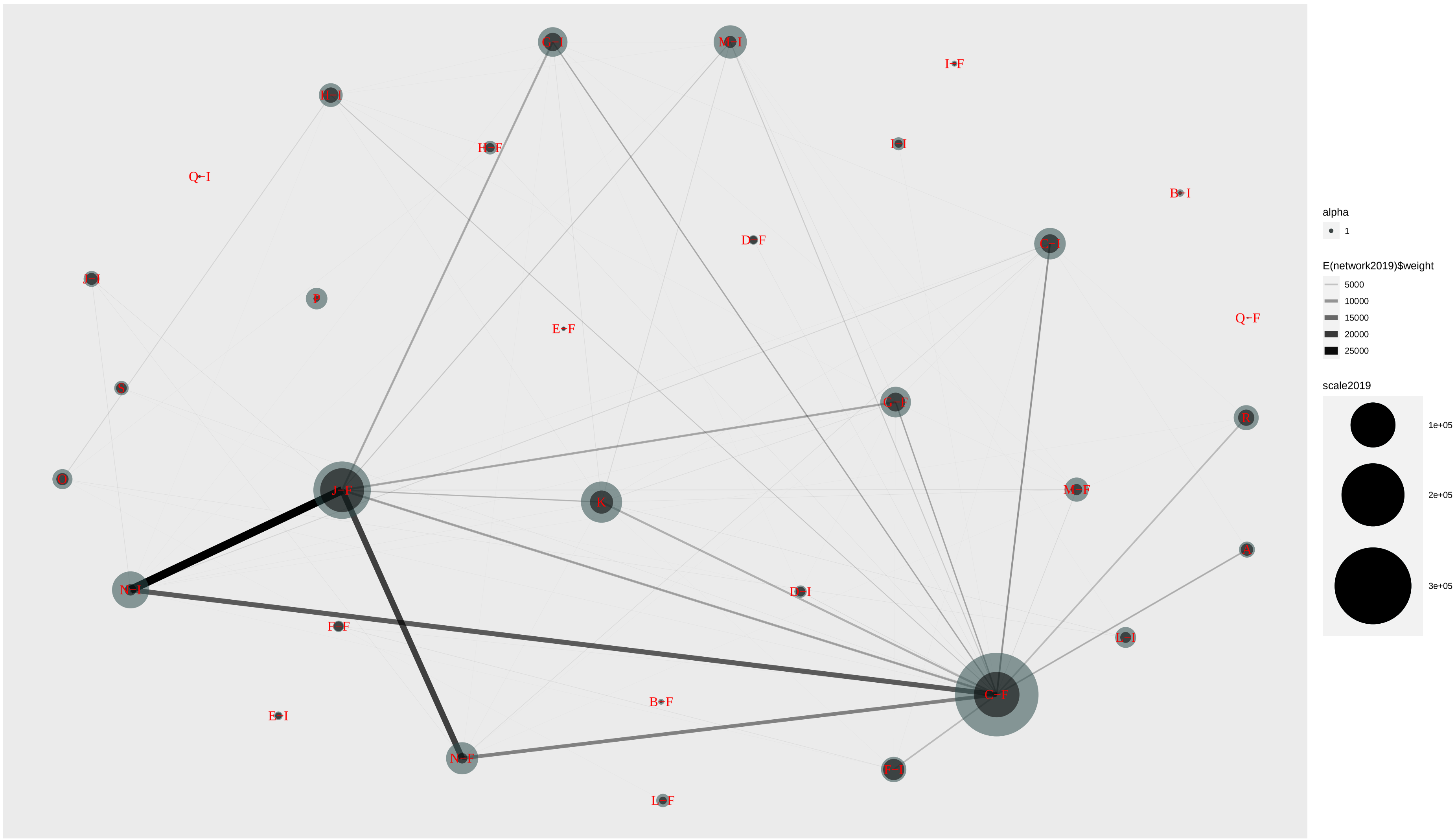
(a) Indigenous Firm Purchases



(b) Foreign Affiliate Purchases

Source: Author's calculations from CSO Supply & Use Tables, and Eurostat AES & FCE data.

Figure 4: Network Map of the Irish Economy by NACE Sector and Ownership Structure



Source: Author's calculations from CSO Supply & Use Tables, and Eurostat AES & FCE data.
Legend: A = Agriculture, B = Mining & Quarrying, C = Manufacturing, D = Energy, E = Water & Waste Management, F = Construction, G = Wholesale & Retail Trade, H = Transport & Storage, I = Accomodation & Food Service, J = Information & Communication Technology, K = Finance, L = Real Estate, M = Professional, Scientific & Technical, N = Administration & Support, O = Public Administration & Defence, P = Education, Q = Repair of Computers & Household Goods, R = Health, S = Arts & Other Service Activities.

edges between any two nodes in the network. Both sub-sectors depend heavily on connections between the indigenous and foreign-affiliate Administrative and Support Service Activities sectors (N-I and N-F), indigenous and foreign-affiliate Wholesale and Retail Trade sectors (G-I and G-F), the indigenous Construction sector (F-I), the indigenous Professional, Scientific and Technical sector (M-I) and the Financial sector (K).

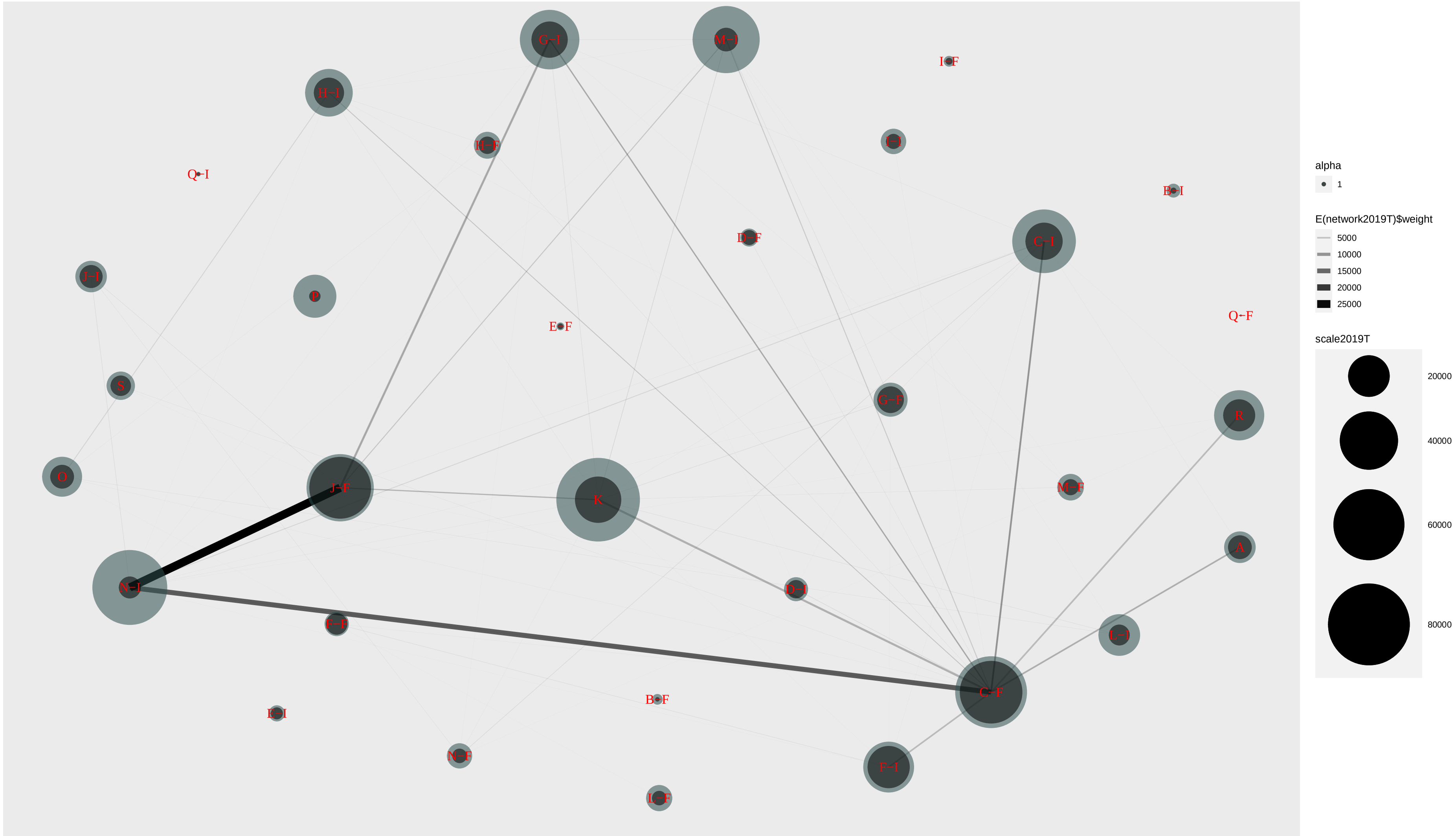
There is also a strong linkage between both sectors, primarily through foreign affiliate manufacturing sales to the foreign-affiliate ICT sector. The foreign-controlled manufacturing sector alone has over 19 large linkages with other sectors, showing the scale of the sector within the economy, the diverse mix of products required in its own production processes and the reliance of other industries for intermediate manufacturing goods.

4.3 Network Mapping of Extended I-O Tables, excluding Globalisation Effects

Having modified the extended I-O tables to account for the globalisation effects resulting from IP asset inflows, depreciation of capital in IP assets, and factoryless goods production, we are theoretically closer to a set of tables that are more representative of the relations of production within the domestic Irish economy. Figure 5 presents the revised network map with the globalisation effects removed from the data.

The main effects of removing globalisation effects from the data are readily seen in the updated network map. Primarily, the modification to both the Manufacturing and ICT MNE sub-sectors contracts their overall scale to the point where their output value is broadly similar to the financial sector. Additionally, the modification to the value-added components of the foreign-controlled Administrative & Support and PST sub-

Figure 5: Network Map of the Irish Economy excluding Globalisation Effects, 2019



Source: Author's calculations from CSO Supply & Use Tables, and Eurostat AES & FCE data.
Legend: A = Agriculture, B = Mining & Quarrying, C = Manufacturing, D = Energy, E = Water & Waste Management, F = Construction, G = Wholesale & Retail Trade, H = Transport & Storage, I = Accomodation & Food Service, J = Information & Communication Technology, K = Finance, L = Real Estate, M = Professional, Scientific & Technical, N = Administration & Support, O = Public Administration & Defence, P = Education, Q = Repair of Computers & Household Goods, R = Health, S = Arts & Other Service Activities.

sectors brings their ratio of intermediate consumption-to-output more in line with their indigenous counterparts, as well as other sub-sectors of the economy.

By trimming the MNE cross-sectoral linkages, we remove some of the largest interconnections in the intermediate consumption matrix. The links between foreign affiliate Manufacturing, ICT and Administration and Support Service sub-sectors are now removed from the network map, so that their strongest connections are now with the indigenous Administrative and Support Service sub-sector and the Financial sector. Without contract manufacturing and IP effects skewing the data, the importance of indigenous-MNE connections becomes more evident, including those between the foreign-controlled Manufacturing sub-sector and the indigenous Health, Agriculture and Construction sub-sectors.

5 Sectoral Analysis

With the basic structure and visualizations of the I-O tables complete, we turn to more analytical uses of the I-O tables in this section. For much of our preliminary analysis, it is useful to compare some sectoral characteristics from 2019 to the ownership-extended 2015 tables, to show how industry dynamics have reshaped the Irish economy over the period.

We also present more complex analytical measures of sectoral interdependence and importance, using the extended I-O Tables with the distortionary effects of globalisation activities (discussed in Section 3.3) removed from the data. These measures, including input and output multipliers, forward and backward linkages, and field of influence analysis, provide important estimates on the direct and indirect economic contributions of various industries to the domestic Irish economy, and the roles played by each industry in promoting inter and intra-industry development.

5.1 Intermediate Consumption, Value Added and Output Growth Analysis

As a first measure of sectoral dynamics, we plot growth rates of intermediate consumption, value added, and total output for the 32 industry groupings in the extended I-O tables (Figure 6). From Figure 6a, there is an obvious trend in increased MNE activity across all sectors, with intermediate consumption growth higher in each of the 13 MNE-affiliated sectors then their indigenous counterparts. Of these 13 MNE sectors, 9 recorded intermediate consumption growth rates above 65%, with only 3 indigenous sectors recording growth rates above this threshold. Contrastingly, the largest declines were observed in indigenous sectors: the indigenous ICT (J-I), Education (P) and Repairs (Q-I) industries all recorded intermediate consumption growth below -40%.

Similar patterns are observed in the growth of sectoral value added (Figure 6b), with four of the five highest value-added growth rates recorded in MNE sub-sectors: MNE sub-sectors of the Water & Waste Management (E-F), Real Estate Services (L-F), Construction (F-F) and Repairs (Q-F) industries all registered value added growth rates above 50% between 2015 and 2019. Agriculture (A) was the only indigenous sector to register value-added growth above 35%.

Finally, the total output growth rates across sub-sectors are presented in Figure 6c. Again, the chart substantiates the narrative of positive, homogenous conditions across MNE sub-sectors, while indigenous economic performance was more diverse. Nine of the ten strongest performing sub-sectors were MNE controlled, with output growth ranging from 60% (Water & Waste Management) to 275% (Professional, Scientific & Technical services). The construction sub-sector was the only indigenous industry to register comparable (64.4%) growth, primarily due to the remnants of the housing market crash and its associated effects on residential construction, which were still present in the 2015 data. Contrastingly, most sub-sectors that recorded output declines were in the indigenous element of the economy, with the largest contractions in the indigenous Mining & Quarrying, ICT and Repair sub-sectors.[15]

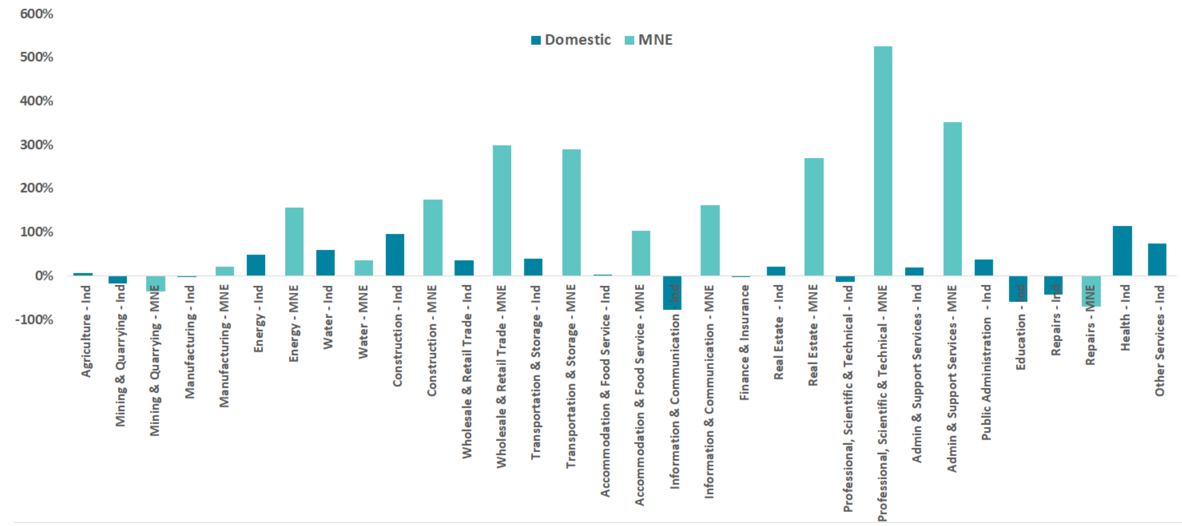
While sectoral growth rates are useful in identifying absolute changes in sectoral size between two periods, it is also useful to examine compositional changes in the aggregate economy. Appendix B presents relative changes in the sectoral shares of intermediate consumption, value added and total output, over the 2015-2019 period.

5.2 Multiplier, Key Sector and Field of Influence Analysis

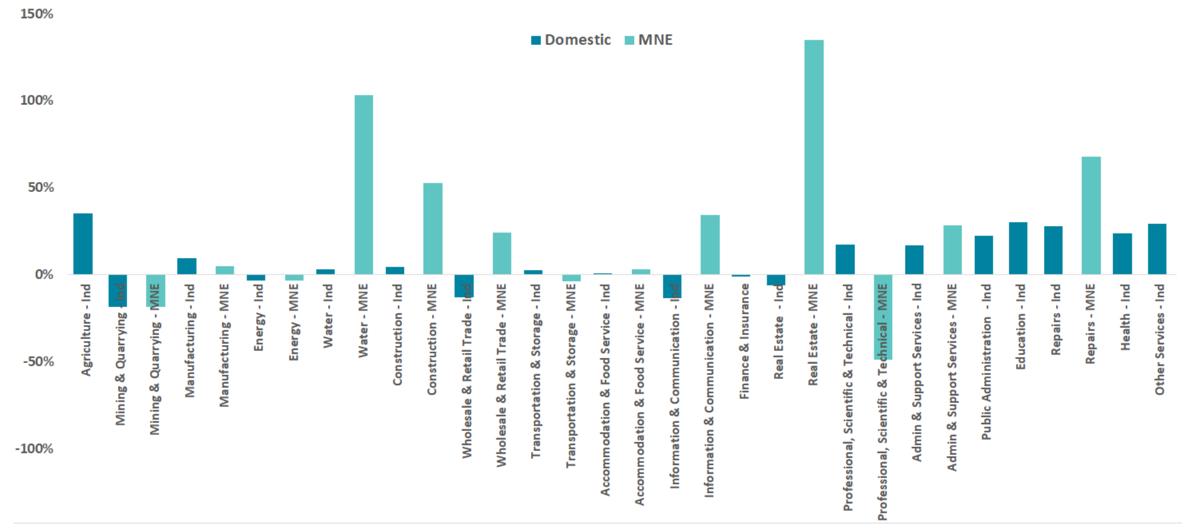
With our I-O table more representative of true domestic economic linkages, we turn our attention to analyzing the relative strength of these relationships. The first set of measures that we estimate for the domestic economy are input-output multipliers, which provide insights into the way in which changes in one sector of the domestic economy affect all other sectors. Next, we calculate backward and forward linkages, using them to perform key-sector analysis, identifying the sectors whose productive activity exerts a greater-than-average influence on the aggregate economy. Finally, we conduct a field of influence analysis, designed to estimate the effect of an exogenous shock to aggregate productivity (or the aggregate level of technology in the economy) on sectoral output growth.

15 The decline in indigenous ICT services is noteworthy, give the marked success of MNEs in the sector. Whether this contraction is due to Irish firms being unable to compete for market share with foreign subsidiary firms, or MNE acquisitions of indigenous firms is pertinent to the discussion spillovers/ economic benefits that derive from MNE clusters. Unfortunately, it is not possible to determine the drivers of this contraction from either the CSO or Eurostat data.

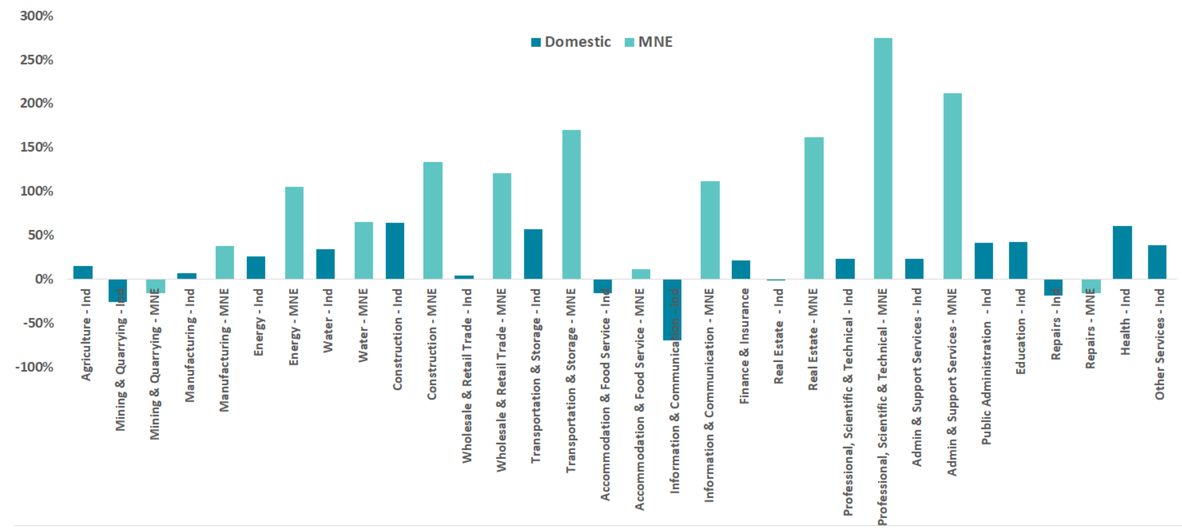
Figure 6: Components of Industry-Ownership Absolute Growth, 2015-2019



(a) Intermediate Consumption Growth Rates



(b) Value Added Growth Rates



(c) Total Output Growth Rates

Source: Author's calculations from CSO Supply & Use Tables, and Eurostat AES & FCE data.

5.2.1 Input-Output Multipliers

Input-output multipliers are used to determine the economic effects of an exogenous change in final demand for the output of a specific industry. As a result, they provide a measure of the interdependence between an individual sector and the rest of the economy.[16]

Output multipliers are defined as the total output produced by all industries in response to a unit increase in final demand for an industry's output. Formally, output multipliers can be represented as

$$\boldsymbol{O}_i^{mult} = \Sigma_j L_{ij} \tag{2}$$

where L_{ij} is the Leontief inverse matrix, and Σ_j are the column sums from the Leontief inverse matrix L_{ij}.[17] Multiplying a change in demand for an individual industry's output by that industry's output multiplier generates an estimate of the aggregate effects on total output throughout the economy.

In contrast, input (or supply) multipliers multiplier measures the rate of change of total input values throughout all sectors of the economy, with respect to the value-added contribution of a given sector, i.e the push influence of change of primary input on the economy. Similar to output multipliers, input multipliers can be calculated as the sum

[16] Input-Output multipliers represent good first-order approximations to the macroeconomic effects of microeconomic shocks, particularly under Cobb-Douglas production and consumption functions, with constant sales shares. However, in the presence of nonlinearities, or other functional forms where shocks have larger second-order impacts, input-output multipliers may not accurately represent the change in aggregate output in response to an idiosyncratic economic shock. In this case, richer modelling approaches, such as the non-parametric general equilibrium model of Baqaee and Farhi (2019), will better reflect aggregate outcomes.

[17] The Leontief inverse matrix is a core mathematical object in Input-Output Analysis. The matrix represents the value of gross output from Sector i that is produced to satisfy demand for an additional unit of output from Sector j.

over columns from the Ghoshian matrix

$$\boldsymbol{I}_i^{mult} = \Sigma_j G_{ij} \tag{3}$$

where L_{ij} is the Ghoshian inverse matrix, and Σ_j are column sums from the Ghoshian inverse matrix L_{ij}.[18]

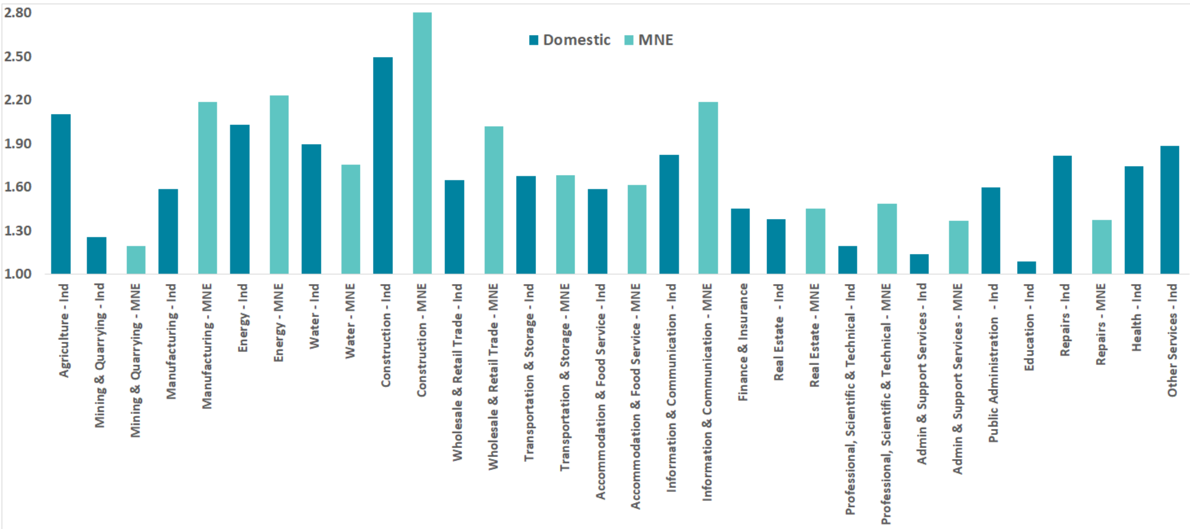
Figure 7 presents estimates of the input and output multipliers across indigenous and foreign-controlled industry sub-sectors. From Figure 7a, the largest "pull effects" in the domestic economy come from foreign-controlled enterprise sectors. Of the industries with an output multiplier greater than 2, five are in MNE controlled sub-sectors (Manufacturing, Energy, Construction, Wholesale & Retail Trade, and ICT), while three are in indigenous sub-sectors (Agriculture, Energy and Construction). Correspondingly, the sub-sectors with the lowest output multipliers are all indigenous (Education, Admin & Support and PST services). Average output multipliers for the indigenous sub-sectors of the economy are estimated to be 1.651. Without the removal of globalization effects from the tables, this estimate increases to 1.947. This differential provides some quantification of the bias introduced by these effects into the I-O tables.

From the input multiplier estimates, results are somewhat more consistent across sectors. There is an even split between the indigenous (Agriculture, Mining & Quarrying, Energy and Admin & Support) and multi-national (Mining & Quarrying, Energy, PST and Admin & Support) sub-sectors with an input multiplier above 2. Likely due to the non-market based nature of the sectors, the Education and Health sectors are estimated to have the lowest input multipliers (≤ 1.15). Across indigenous and MNE sectors, the largest differential between multiplier estimates is in the Manufacturing sector,

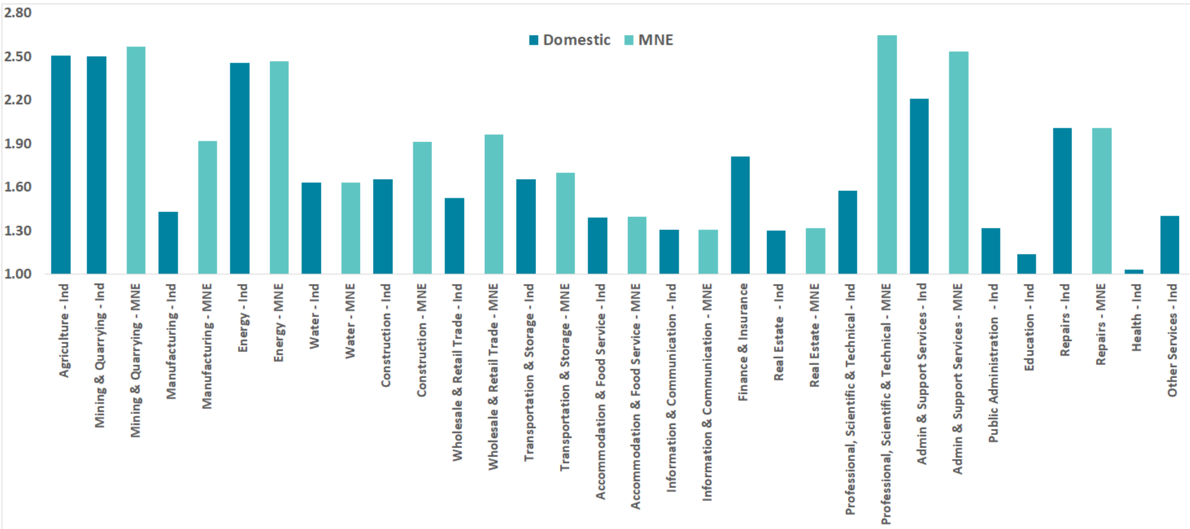
[18] The Ghoshian inverse matrix reflects the requirements for the use of product i in industry j necessary to produce one additional unit of output from industry j.

with €1 of inputs in MNEs producing over €0.5 more output than in indigenous firms. Similar to output multipliers, the average indigenous input multiplier with globalization effects removed from the data (1.675) is considerably lower than the estimates from the unadjusted tables (1.969).

Figure 7: Sub-Sectoral Input and Output Multipliers, 2019



(a) Output Multipliers



(b) Input Multipliers

Source: Author's calculations from CSO Supply & Use Tables, and Eurostat AES & FCE data.

5.2.2 Linkage and Key Sector Analysis

With values of our Leontief and Ghoshian matrices estimated, the next analytical measures we derive from the extended I-O tables are forward and backward linkages. In an Input-Output modelling framework, a change in production across a sector has two kinds of effects on other sectors in the economy: a change in both the level of supply and the level of demand. When industry i increases its production, there is increased demand for inputs from enterprises across other $j \neq i$ industries. Similarly, an increase in production across other industries leads to additional output required from firms in industry i, to supply the inputs needed to meet higher levels of demand.

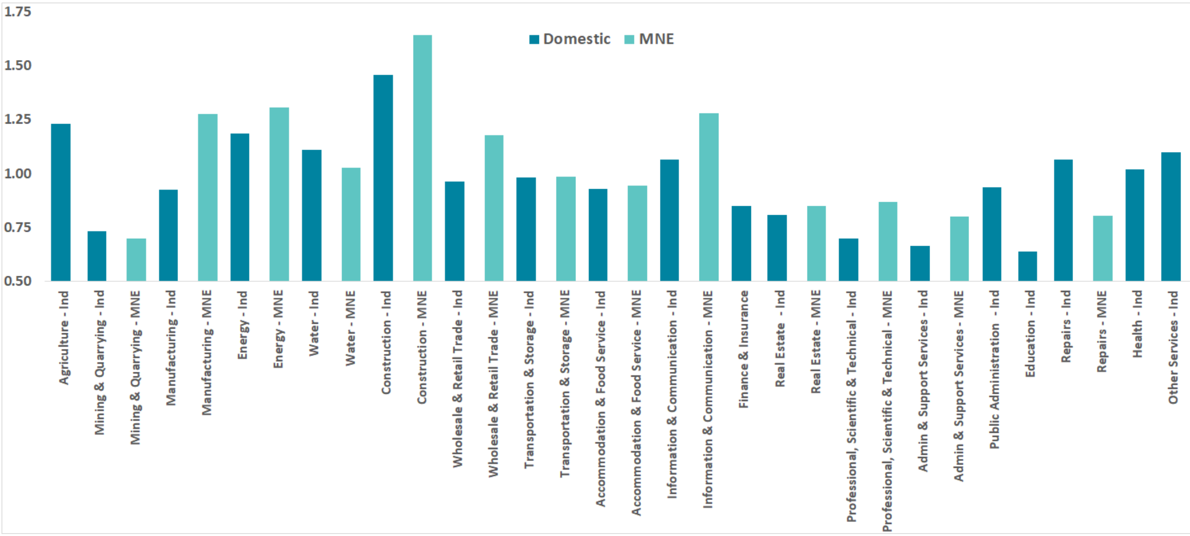
An industry with relatively greater backward linkages is more beneficial to the economy, as it can generate larger increases in aggregate production from a given change in its output. In contrast, an industry with relatively higher forward linkages than other industries is has greater dependence on supply-chains, as its production is more responsive to changes in the output of other industries. In keeping with Rasmussen (1956), formulae for backward and forward linkages can be expressed as

$$BL_j = \frac{\Sigma_{i=1}^{n} L_{ij}}{\frac{1}{n}\Sigma_{j=1}^{n}\Sigma_{i=1}^{n} L_{ij}} \tag{4}$$

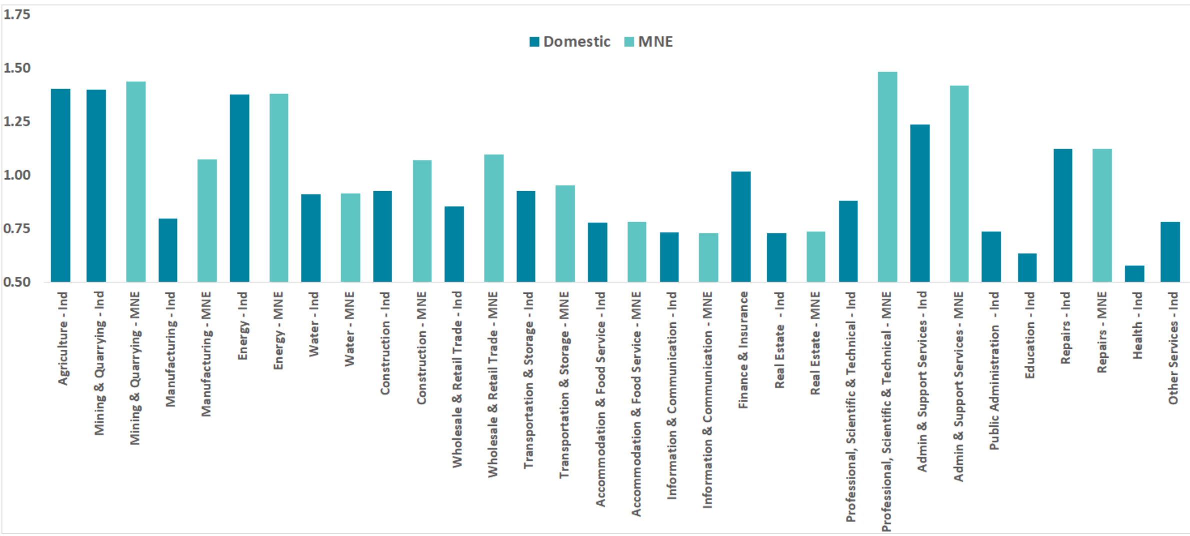
$$FL_i = \frac{\Sigma_{j=1}^{n} G_{ij}}{\frac{1}{n}\Sigma_{j=1}^{n}\Sigma_{i=1}^{n} G_{ij}} \tag{5}$$

where L and G are the Leontief and Ghoshian inverse matrices. Under the Rasmussen measure of backward and forward linkages, a typical interpretation is that industries with $BL_j > 1$ generate above-average increases in economic activity for a given change in their output. Similarly, an industry with $FL_i > 1$ generates an above-average growth response to a given production increase in the rest of the economy. Sub-sectoral estimates for backward and forward linkage values are presented in Figure 8.

Figure 8: Sub-Sectoral Backward and Forward Linkages, 2019



(a) Backward Linkages



(b) Forward Linkages

Source: Author's calculations from CSO Supply & Use Tables, and Eurostat AES & FCE data.

With respect to the backward linkage values in Figure 8a, 14 of the 32 sub-sectors are estimated to be "above average". While 8 of these 14 sub-sectors are indigenous, only the indigenous Construction sector has a backward linkage value greater than 1.25; in contrast, four MNE sectors (Manufacturing, Energy, Construction and ICT) have a BL_i estimate above this value. Of the sub-sectors with below-average backward linkages, the indigenous Mining & Quarrying, PST, Admin & Support, and Education sectors, together with the foreign-controlled Mining & Quarrying sector, all have BL estimates below 0.75.

Forward linkages estimates (Figure 8b) show a much different pattern to the backward linkages. While 14 sub-sectors are again found to be "above average", six of these sub-sectors are populated by indigenous enterprises, three of which (Agriculture, Mining & Quarrying and Energy) have FL estimates above 1.25. Among MNE controlled sub-sectors, Mining & Quarrying, Energy, PST and Administration & Support services are estimated to have a $FL_i \geq 1.25$. Both the Health (0.576) and Education (0.636) sectors were identified as industries with input dependencies substantially below all other sub-sectors of the Irish economy.

Finally, in this section, we use the linkages estimated above to perform key-sector analysis. Key-sector analysis aims to identify specific sectors whose economic activity exerts a greater-than-average influence at an aggregate level. Thus, the most important industrial sectors are defined as those that have the potential to generate substantial growth and, in turn, stimulate economic development across other sectors of the economy. Under this definition, sectors with both BL and FL values greater than 1 are considered to be key sectors in driving growth, being dependent on both inter-industry demand and supply. Conversely, sectors with BL and FL values below 1 are viewed as ancillary or independent sectors. Sectors with a backward linkage (forward linkage) greater than unity are considered to be dependent on inter-industry supply (inter-industry demand). Figure 9 presents the results of the key-sector analysis for the 2019 Irish economy.

Figure 9: Key Sector Analysis of Irish Economy, excluding Globalisation Effects, 2019

Source: Author's calculations from CSO Supply & Use Tables, and Eurostat AES & FCE data.

From Figure 9, there are seven sub-sectors in the economy that are classified as being key sectors: Agriculture (A), MNE Manufacturing (C-F), the indigenous and MNE Energy industries (D-I and D-F), the MNE Wholesale & Retail Trade sub-sector, the MNE construction sub-sector and the indigenous Repairs (R-I) sector.[19] In contrast, the Education (P) sectors is the most independent sector, with neither backward nor forward linkage values greater than 0.65: no sector has a lower backward linkage value, and only the Public Administration (Q) sector has a lower forward linkage value.

19 Among the identified key sectors, the indigenous Repairs sub-sector is an outlier, accounting for less than 0.02% of aggregate output. Thus, the size of a given sector must be taken into account when considering the benefits of policy decisions (e.g. industrial targeting or industry-level incentives), and not purely the relative linkages.

5.2.3 Field of Influence Analysis

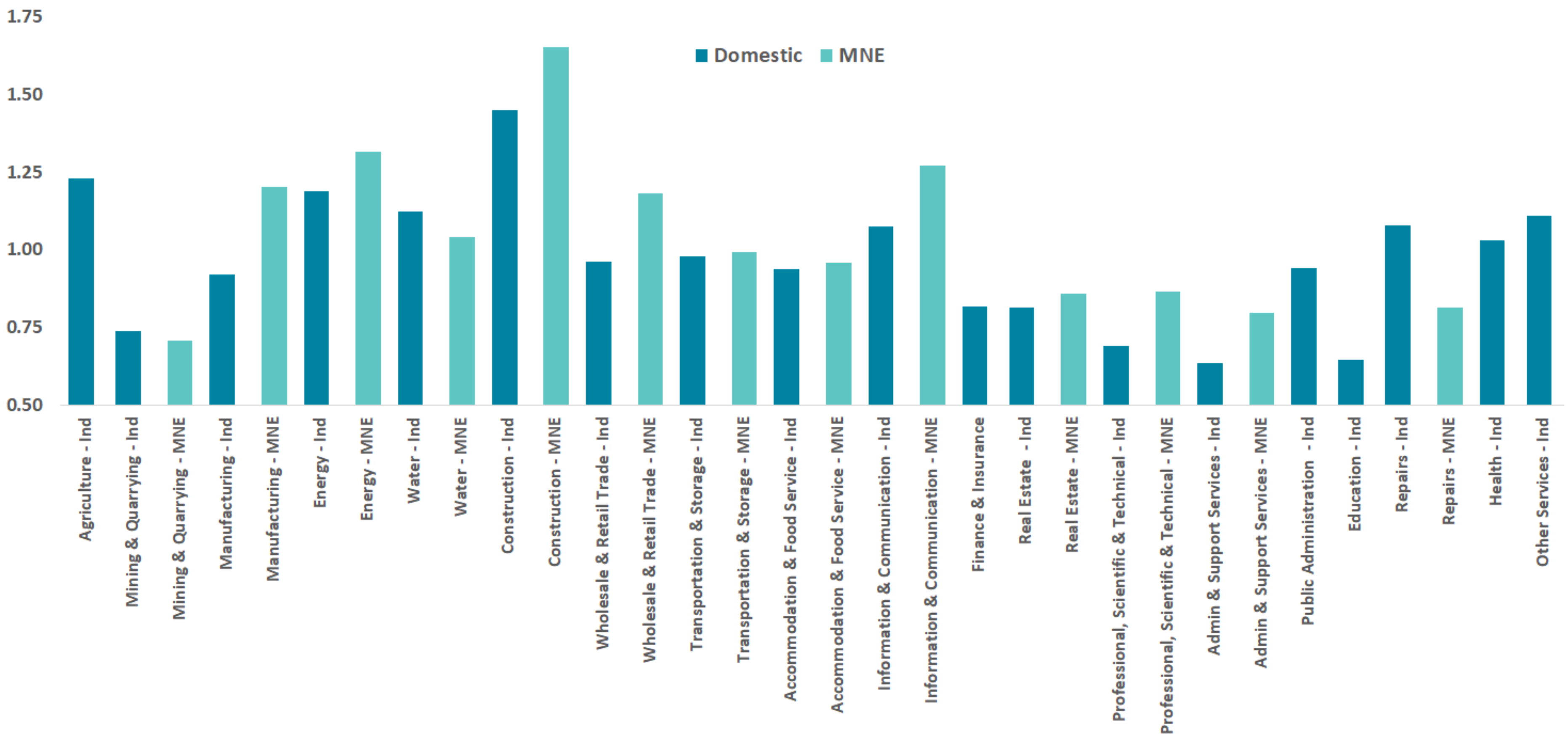
Our final analytical measure that we calculate for the trimmed I-O tables are the sectoral field of influence estimates. A full derivation of the field of influence measure, f_{c_j}, is provided in Appendix C.

The "field of influence" (FOI) measure was originally created by Hewings, Sonis and Jensen (1988) to overcome the inability of input-output models to incorporate innovations from technological change into coefficient matrices. Under the field of influence approach, technological change is represented as the competition for inputs that results following the dissemination of new technology.[20] The competitive process can be modelled as a Markov or logistic process, with the effect of this competition leading to changes in the coefficient structure of the I-O table. Formally, this effect is measured as changes in the intermediate coefficients' matrix of an I-O table on the Leontief inverse.

Results from the field of influence estimates are provided in Figure 10. Given the strong linkages previously identified in the key sector analysis, it is unsurprising that the sub-sectors that generate the largest change in output from an innovation to the Input-Output tables are; Agriculture (1.23), foreign-controlled Energy (1.31), indigenous (1.45) and foreign controlled (1.65) Construction, and foreign-controlled ICT (1.27). Similarly, the sectors with the lowest field of influence values are; indigenous Professional, Scientific & Technical services (0.69), indigenous Administration & Support services (0.64), and Education Services (0.64).

[20] From economic point of view, this approach can be used to analyze the effect of technological change, improvements in efficiency, changes in product lines, changes in the structure and complexity of an economy over time, and any number of other causal changes to an economy through the I-O tables.

Figure 10: Field of Influence Analysis of Irish Economy, excluding Globalisation Effects, 2019



Source: Author’s calculations from CSO Supply & Use Tables, and Eurostat AES & FCE data.

5.3 Summary of Analytical Results

Table 1 presents a summary of the main findings from our six analytical measures discussed in Section 5.

Subject to the caveats discussed above, estimates suggest that the foreign-controlled Construction sub-sector, the foreign-controlled Energy sub-sector, and the indigenous Construction sub-sector are the three most interconnected domestic industries, whose activity provides a greater-than-average influence on the wider economy. All three sectors draw production inputs from a diverse array of other industries, so that increases in demand for their goods stimulates economic activity across a range of other sectors. The analysis also suggests that, to a lesser degree, the Agriculture sector is also an important driver of growth in the economy, drawing resources for production from a number of other sectors in addition to providing raw materials used in production throughout the economy.

In contrast, the Education and Health sectors rank among the lowest industries in terms of stimulating economic growth. Neither sector draws heavily from other sectors in response to increased demand for their services, nor are other sectors depend on their services for increasing production in response to positive demand shocks. However, these sectors do not provide market-based services, so their relatively low performance in driving economic growth is not surprising. Of the sectors that do provide market-based services, the indigenous Admin & Support sub-sector and the indigenous Professional, Scientific & Technical sub-sector are among the lowest ranking sectors according to our measures; both sub-sectors having weak backwards and forwards linkages, while neither industry acts as a strong catalyst for converting broad-based productivity innovations into economic growth.

Table 1: Summary of Analytical Results

	Highest Ranked Sectors	Lowest Ranked Sectors
Input Multiplier	Construction (MNE) Construction (IND) Energy (MNE)	Education Admin & Support Services (IND) Professional, Scientific & Technical (IND)
Output Multiplier	Professional, Scientific & Technical (MNE) Mining & Quarrying (MNE) Admin & Support Services (MNE)	Health (IND) Education Real Estate Activities (IND)
Backward Linkages	Construction (MNE) Construction (IND) Energy (MNE)	Education Admin & Support Services (IND) Professional, Scientific & Technical (IND)
Forward Linkages	Professional, Scientific & Technical (MNE) Mining & Quarrying (MNE) Admin & Support Services (MNE)	Health (IND) Education Information & Communication Technology (MNE)
Key Sector	Construction (MNE) Energy (MNE) Agriculture (IND)	Education Professional, Scientific and Technical (IND) Admin & Support Services (IND)
Field of Influence	Construction (MNE) Construction (IND) Energy (MNE)	Education Admin & Support Services (IND) Professional, Scientific & Technical (IND)

Source: Author's calculations from CSO Supply & Use Tables, and Eurostat AES & FCE data.

6 Conclusion

Since 2015, interpreting structural changes in the development of the Irish economy has proven to be increasingly challenging, due to the expanded role of multinational enterprises in the domestic production process and the growing levels of international trade integration. The large-scale movement of intellectual property assets, the trade classification of goods and services manufactured offshore, and the legal presence of redomiciled PLCs in Ireland have combined to introduce distortions into most standard statistical measures of economic development, including: output, financial flows, capital accumulation, trade and value-added. While a number of additional measures have been constructed to provide a more appropriate quantification of domestic economic activity, several official series still do not have supplementary counterparty measures, to identify or eliminate these distortionary effects from the underlying data.

In this paper, we develop such counterparty measures for the domestic Input-Output tables, and their underlying Supply and Use tables. Using the unadjusted CSO Supply and Use Tables for Ireland, together with Eurostat Annual Enterprise Statistics (AES) and Foreign Control of Enterprises (FCE) series, we develop a set of symmetric input-output tables (SIOTs) for the Irish economy, disaggregated between indigenous firms and foreign controlled enterprises at NACE sector level. We further modify the tables, to remove globalisation-related activities of contract manufacturing and intellectual property transfers, from the MNE-affiliated sub-sectors where this activity is known to occur. These tables provide novel information on the flow of goods and services throughout the domestic supply chain, and show the extent to which inter-dependencies exist between MNEs and SMEs across industries.

As our benchmark case, we run the above procedure on the 2019 Supply and Use Tables, the most recently available tables provided by the CSO prior to the coronavirus pandemic of 2020. Our results suggest that, even after removing estimates of the distortionary effects of globalisation-related activities of MNE affiliates, several foreign-affiliate sub-sectors of the domestic economy are identified as being key drivers of aggregate output growth. In particular, the foreign-controlled Construction sub-sector, the foreign-controlled Energy sub-sector, and the indigenous Construction sub-sector are the most important elements of the domestic economy for both generating and propagating growth throughout the domestic supply chain, with the Agriculture sector also identified as being an important industry for the dissemination of supply and demand shocks.

The present paper sets up a template, and there is much that can be done subsequent to this work. For example, the ownership-extended I-O tables are well suited to analysing the effects of exogenous macroeconomic shocks at a sub-macroeconomic level. The OECD's attempts to develop a global minimum tax framework under the Base Erosion and Profit Shifting (BEPS) project is specifically designed to exercise taxing rights on a portion of MNE residual profits, and could change the investment and location decisions of foreign-affiliate enterprises at a global level. Given the ownership-extended I-O tables explicitly distinguish between indigenous and MNE activity, the tables are well-suited to identify the effects of changes in MNE activity on domestic output, employment and tax levels.

Similarly, with the rapid development of Artificial Intelligence (AI) technologies in the last few years, there is much debate about its potential to revolutionise entire product markets and industries. Conceptualising shocks to the economy from AI-uptake as either supply-side shocks (through productivity and jobs impacts from both replacement automation and augmenting AI), or as demand-side shocks (through AI integration into existing products), it is possible to trace the effects of these aggregate shocks through the various sub-sectors of the economy using the ownership-extended IO tables.

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Appendix A. IPP and Biases in Supply-Chain Analysis

Consider a production function for the aggregate output of Sector i in the economy. With 19 aggregate NACE industries, the general form of the production function can be represented as

$$Y_i = \alpha_i \cdot F_i\left(l_i, \{k_{i,j}\}_{j=A}^{S}\right) \quad \forall \ j = A \ldots S \tag{6}$$

Applying a simple Cobb-Douglas functional form of production within each sector, Equation 11 becomes

$$Y_i = \alpha_i \cdot l_i^{\beta_l} \cdot \prod_{j=A}^{S} k_{i,j}^{\beta_j} \quad \forall \ j = A \ldots S \tag{7}$$

Now, assume that a factoryless goods producer (FGP) enters the market, importing IP assets in the form of intra-sector intermediates, $\breve{k}_{fgp,i}$, and contracts a foreign firm to produce goods abroad using this IP. Output is exported abroad to a third-party country, with profits accruing back to the FGP, who has no other associations with production in the domestic economy. The measure of intra-sector intermediates in the economy now becomes $(k_{i,i} + \breve{k}_{fgp,i}) = \hat{k}_{i,i}$. Representing the measure of output derived from the contract manufacturing process as $\breve{Y}_i$, so that total output in Sector i is given by $(Y_i + \breve{Y}_i) = \hat{Y}_i$, the equation for the new level of output from Sector i is given by

$$\hat{Y}_i = \left(\alpha_i \cdot l_i^{\beta_l} \cdot \prod_{j=A}^{S} k_{i,j}^{\beta_j}\right) + \alpha_i^* \cdot F_i^*(\breve{k}_{fgp,i}, l_i^*, \{k_{fgp,j}^*\}_{j=A}^{S}) \quad \forall \ j = A \ldots S \tag{8}$$

Embedded in α_i^* is the foreign technology production process by which the IP assets of the FGP combine with labour and additional raw material from the foreign firms manufacturing process to generate output. When the output of the domestic economy is estimated using the same functional form of Equation 11, the estimate of $\hat{Y}_i$ becomes

$$\hat{Y}_i = \hat{\alpha}_i \cdot l_i^{\hat{\beta}_l} \cdot \left(\prod_{j=A}^{S} k_{i,j}^{\hat{\beta}_j}\right) \cdot \breve{k}_{fgp,i}^{\hat{\beta}_{fgp}} \quad \forall \ j = A \ldots S \tag{9}$$

Assuming $\hat{\beta}_{fgp}$ to be non-zero, the properties of Cobb-Douglas production functions imply that $\left(\sum_j \hat{\beta}_j + \hat{\beta}_j\right) < \left(\sum_j \beta_j + \beta_j\right)$, $\alpha_i \neq \hat{\alpha}_i$ (except under a singular solution), and $\beta_l \neq \hat{\beta}_l$ (again, only under a unique solution to the equation).

Estimation problems arise when considering the effects of technology or sector-specific shocks. Consider a technology shock in the domestic economy that improves the production process in Sector i. Under the true production function, Eq(13), $\frac{\delta \breve{Y}_i}{\delta \alpha_i} = 0$. However, under the representation in Equation (14), $\frac{\delta \breve{Y}_i}{\delta \alpha_i} > 0$, even though domestic production technology does not influence the production of goods under contract manufacturing structures.

Similarly, the presence of globalisation effects will potentially bias the estimation of sectoral linkages, including linkages between sectors that do not directly engage in contract manufacturing. Consider two indigenous sectors: F-I (Construction) and J-I (ICT Services). Both sectors trade intermediate consumption goods between each other. The measurement of direct linkage between these indigenous sectors in the I-O tables is unaffected by the presence of MNEs in other sectors. Thus, to understand the direct impact of a shock in F-I on J-I, we can use the values from the I-O tables.

However, a shock to the Construction sector will have both indirect and induced impacts on ICT services, via other sectors. If the indigenous Construction sector has linkages to foreign-controlled PST services (M-F), the Construction shock will increase foreign-affiliate PST services output $($so that $\frac{\delta \hat{Y}_{M-F}}{\delta \hat{Y}_{F-I}} > 0)$, which in turn requires intermediate goods (for products that are not produced under contract manufacturing arrangements using IPP) from the indigenous ICT services sector $($so that $\frac{\delta \hat{Y}_{J-I}}{\delta \hat{Y}_{M-F}} > 0)$.

The magnitude of this indirect shock to the indigenous ICT services sector is determined by the total size of the foreign-affiliate PST sector, and its total purchases of inter-industry and intra-industry intermediates. Using values from the unadjusted I-O tables (which contain IPPs that are not used in domestic production) would identify a spuriously significant propagation channel in the Irish economy, leading to incorrect inferences regarding the change in indigenous ICT activity resulting from shocks to the indigenous Construction sector.

Appendix B. Relative Growth Analysis

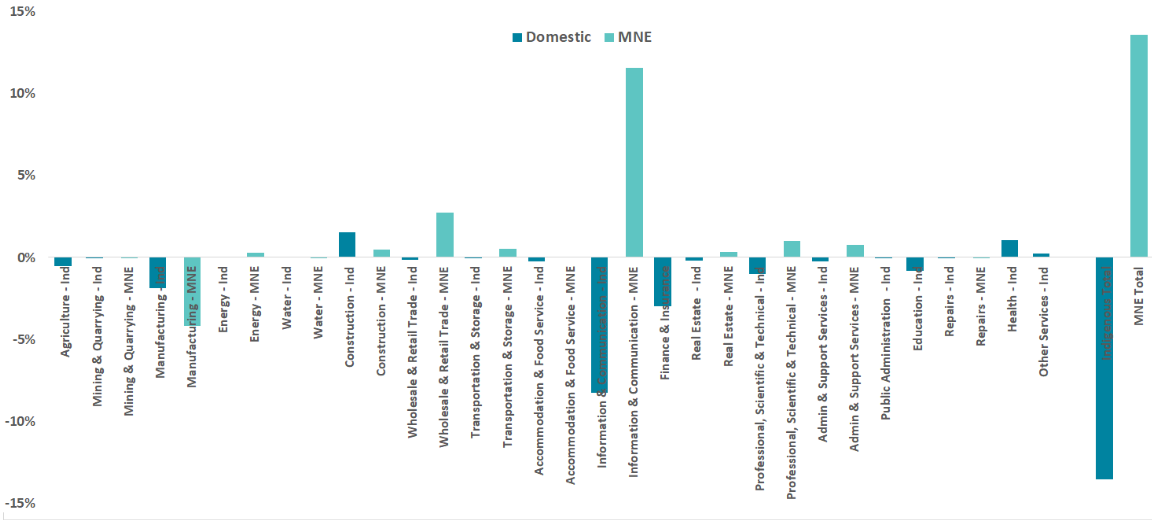
Figure 11 presents changes in the sub-sectoral share of economy-wide measures of intermediate consumption, value added, and total output. These values show the change in relative importance of a sub-sector to the economy, as well as the change in the overall weight of indigenous versus MNE activity in the domestic supply chain.

From Figure 11a the increase in the relative scale of MNE activities in the Irish economy, and the distortionary effects of contract manufacturing, are readily observable. From 2015 to 2019, the foreign-controlled element of the ICT industry increased their share of aggregate intermediate consumption by 13.4%, to 60.8% of total production process inputs. Alone, the MNE-owned ICT and Manufacturing sub-sectors accounted for over half (50.9%) of intermediate input purchases, up from 43.8% in 2015. Foreign-controlled elements of the Wholesale and Retail Trade (+2.8%), Administrative and Support Services (+0.8%) and Professional, Scientific and Technical (+1%) sectors also increased their share of aggregate intermediate consumption over the 2015-2019 period.

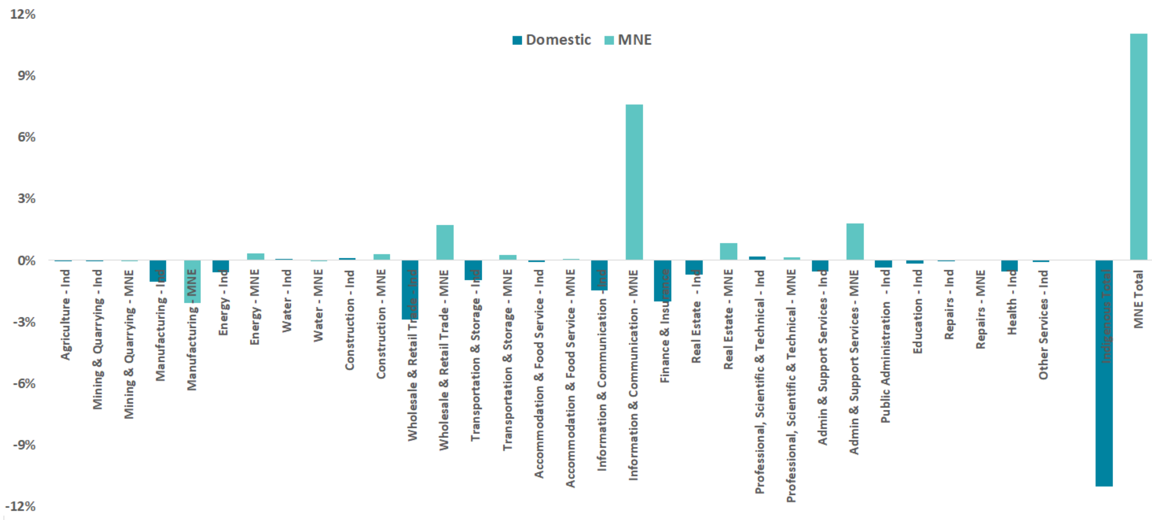
Contributions to the value-added element of the economy were similarly skewed, with foreign-controlled enterprises accounting for 54.9% of total valued added in 2019, an increase of 11%. Despite declining 2.1% over the 2015-2019 period, the MNE-owned manufacturing sector remained the largest contributor to value added (30.5%), with ICT increasing its share by 6.4 percentage points to 14% of aggregate value added. Among indigenous sub-sectors, the Construction and Professional, Scientific & Technical industries were the only sectors to increase their relative contributions to value added, respectively accounting for 2.3% (+0.1 percentage points) and 3.9% (+0.2 percentage points) of total value added.

Unsurprisingly, foreign-controlled enterprises accounted for the majority of total output in 2019, increasing their economy-wide share from 44.6% in 2015 to 57.8% in 2019. Again, Manufacturing and ICT focused foreign-controlled enterprises were the largest contributors to output, combining for a 45% share of total economy output in 2019; an increase of 5 percentage points over 2015 values. In the indigenous segments of the economy, only the Health (+0.1p.p.) and Construction (+0.5p.p) sub-sectors saw their share of output increase between 2015 and 2019.

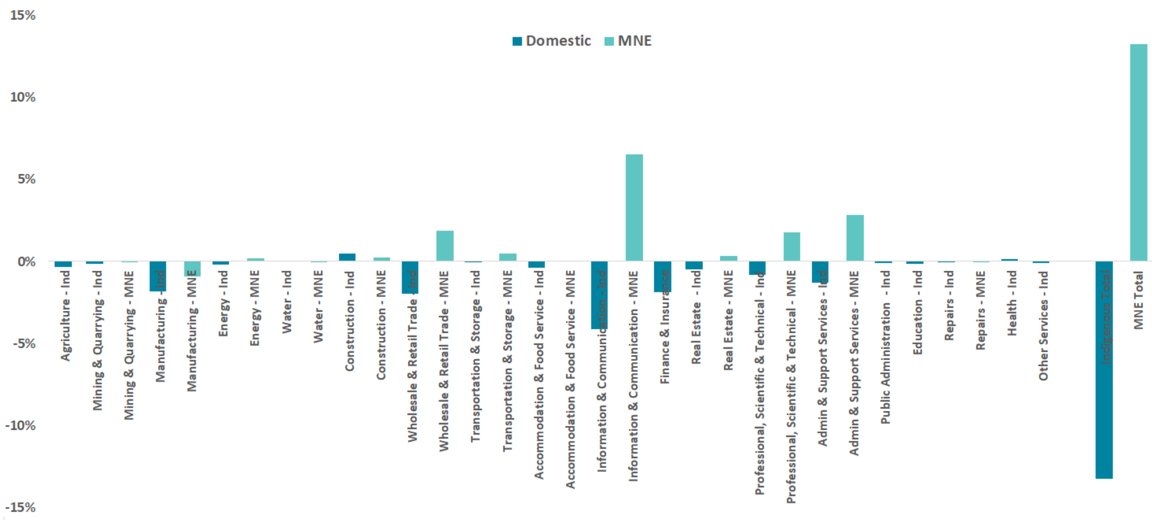
Figure 11: Components of Industry-Ownership Relative Growth, 2015-2019



(a) Intermediate Consumption Growth Rates



(b) Value Added Growth Rates



(c) Total Output Growth Rates

Source: Author's calculations from CSO Supply & Use Tables, and Eurostat AES & FCE data.

Appendix C. Field of Influence Estimation

Let $\boldsymbol{A} = (a_{ij})$ be the $n \times n$ matrix of intermediate coefficients, let $\boldsymbol{E} = (e_{ij})$ be a matrix of incremental changes in the intermediate coefficients, and let $\boldsymbol{B_0} = (\boldsymbol{I} - \boldsymbol{A})^{-1}$ and $\boldsymbol{B_t} = \boldsymbol{B}(\boldsymbol{E}) = (\boldsymbol{I} - \boldsymbol{A} - \boldsymbol{E})^{-1}$ be the Leontief inverses before and after the technological change.

The ratio of determinants of the Leontief inverses before and after changes is the polynomial of the incremental changes, e_{ij}, represented as

$$\boldsymbol{Q}(\boldsymbol{E}) = \frac{det\boldsymbol{B_0}}{det\boldsymbol{B_t}} = 1 - \sum_{j_1 i_1} b_{j_1 i_1} e_{j_1 i_1} + \sum_{k=2}^{n} (-1)^k \sum_{i_r \neq i_s, j_r \neq j_s} B_{0r} \begin{pmatrix} j_1 & \cdots & j_k \\ i_1 & \cdots & i_k \end{pmatrix} e_{i_1 j_1} e_{i_2 j_2} \cdots e_{i_k j_k} \tag{10}$$

where $B_{0r} \begin{pmatrix} j_1 & \cdots & j_k \\ i_1 & \cdots & i_k \end{pmatrix}$ is a determinant of order k that includes the components of the Leontief inverse $\boldsymbol{B}_0$ from the ordered set of columns $i_1, i_2 \cdots i_k$, and rows $j_1, j_2 \cdots j_k$.

A fundamental formula between the Leontief matrices is

$$\boldsymbol{B_t} = \boldsymbol{B}(\boldsymbol{E}) = \boldsymbol{B_0} + \frac{1}{\boldsymbol{Q}(\boldsymbol{E})} \left[\sum_{k=2}^{n} \sum_{i_r \neq i_s, j_r \neq j_s} \boldsymbol{F} \begin{pmatrix} j_1 & \cdots & j_k \\ i_1 & \cdots & i_k \end{pmatrix} e_{j_1 i_1} e_{j_2 i_2} \cdots e_{j_k i_k} \right] \tag{11}$$

where the "field of influence" matrix $\boldsymbol{F} \begin{pmatrix} j_1 & \cdots & j_k \\ i_1 & \cdots & i_k \end{pmatrix}$ of the incremental changes $e_{j_1 i_1}, \ldots, e_{j_k i_k}$ includes the components

$$f_{ij} \begin{pmatrix} j_1 & \cdots & j_k \\ i_1 & \cdots & i_k \end{pmatrix} = (-1)^k \left[\boldsymbol{B_{0r}}(\cdot) - b_{ij} \boldsymbol{B_{0r}}(\cdot) \right] \quad i, j = 1, \ldots, n \tag{12}$$

From these equations, it is possible to identify sets of coefficients, which can be differentiated from the rest of the matrix, on the basis of their analytical importance (typically between 10% and 20% of all coefficients).

For the first-order field of influence, we can represent the industry-level effects of a technological change by the equation

$$f_{c_j} = \boldsymbol{i}' \left(\sum_{i \neq j} \boldsymbol{F}(i, j) \right) \boldsymbol{i} \tag{13}$$

which can be normalized by the sum of all individual sub-sectoral effects and multiplied by n, to yield

$$\tilde{f}_{c_j} = n \frac{\boldsymbol{i}' \left(\sum_{i \neq j} \boldsymbol{F}(i,j) \right) \boldsymbol{i}}{\boldsymbol{i}' \left(\sum_{j=1}^{n} \sum^{i \neq j} \boldsymbol{F}(i,j) \right) \boldsymbol{i}} \tag{14}$$

where $\frac{1}{n} \sum_{i \neq j} \tilde{f}_{c_j} = 1$. Thus, a field of influence value higher than unity implies that the effect of a given degree of technological change in sector j is higher than average, by the extent of the distance of the FOI value from unity.

T: +353 (0)1 224 6000
www.centralbank.ie
publications@centralbank.ie

Bosca PO 559, Baile Átha Cliath 1, Éire
PO Box 559, Dublin 1, Ireland