

IRELAND'S INPUT-OUTPUT FRAMEWORK – WHERE ARE THE REGIONS?



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Input-output models have been developed, modified and studied extensively around the world since Leontief's pioneering work in the late 1930s. This article considers Ireland's Input-Output framework including the methodological approach and the assumptions required to produce consistent tables. This article also outlines the basic principles that are essential in the development of a Multi-Regional Input-Output (MRIO) model and specifies some of the main options available to regionalise the national Input-Output tables. We conclude that an MRIO model would significantly add to the ability to produce evidence-based policy in Ireland at local and regional level. Institutional support across all levels of Government is required to maximise fully the potential of such a regional model.

Introduction

Policy-makers, researchers, community groups, industry officials and others are often interested in the economic impact of specific sectors on the economy. Economic impact models are used frequently to analyse the impact of sector expansion, firm closure and regulatory changes on the economy. Economic impact analysis models are based, most commonly, on adaptations of the Input-Output framework (Siegel & Johnson, 1993). The Input-Output framework was developed by Professor Leontief in the late 1930s, and focused on the interdependence of industries in an economy by analysing inter-industry flows for a specific geographical area (Leontief, 1936).

The Input-Output (I-O) framework represents inter-industry relationships that exist within the different sectors of an economy in a statistical or accounting format. It is a simple general equilibrium model based on the flows of goods/services between the different sectors of the economy. Industries produce goods/services for consumption by other industries, households and the public sector while simultaneously consuming other sectors' goods/services (e.g. raw materials from other industries, labour from households and public goods supplied by governments and local authorities). The basis of the I-O approach is that production of an 'output' requires 'inputs'. The flow of goods and services or the linkages between the different sectors in an economy lead to the notion of feedback loops and multipliers. The basic multiplier effect refers to the boost to the local economy generated by money spent in the locality as opposed to money leaking to the wider economy. Input-Output tables measure the intensity of multipliers in an economy by analysing upstream linkages (inputs into the production process) and downstream linkages (selling output) in an economy.

Leontief's basic model has been extended in many ways since the 1930s and now provides a wide variety of economic analysis models. The I-O framework has, for example, also been extended to incorporate social, environmental and energy issues. In 2007, a working paper by the Economic and Social Research Institute (ESRI) demonstrated an environmental Input-Output model for Ireland for the year 2000, with a focus on selected emissions (O'Doherty & Tol, 2007) while in 2015, Grealis and O'Donoghue from NUI Galway produced a preliminary report on the development and uses of a bio-economy Input-Output model. According to Miller & Blair (2009), extensions to the I-O framework are considered, mostly, to deal with data availability/limitations and increasing methodological complexity such as incorporating additional information on



economic activity (over time and space) and connecting I-O models to other economic analysis tools.

Under European Union Regulation, Ireland is required to produce National Input-Output tables every five years. The latest National Input-Output tables, describing year 2011, was published by the Central Statistics Office in December 2014 and uses the NACE¹ Rev. 2 classification of economic activity. Ireland's Input-Output framework is based on the revised European System of Accounts methodology and the United Nations' Handbook of Input-Output Tables. It is important that we understand the methodology in use, and the assumptions required to produce consistent tables before considering options to regionalise Input-Output tables. A discussion of the options available to regionalise the national Input-Output tables to a higher level of spatial disaggregation (NUTS 3 or county level) and the potential benefits which are likely to arise will be a useful exercise for the authors, other interested researchers and policy-makers alike.

This article introduces the basic fundamentals of I-O tables, and discusses the assumptions of Ireland's Input-Output framework. It introduces the basic principles of regional I-O tables and considers the potential benefits of such models. The article then considers the methods available to regionalise National Input-Output tables and concludes with a discussion on a shared-service proposal to facilitate the continued development and use of a Multi-Regional Input-Output (MRIO) model.

Input-Output Models: The Fundamentalsⁱⁱⁱ

Input-output models are simple but powerful representations of the structures of national and regional economies. They are based on data regularly collected by governments to produce national accounting indicators such as gross domestic product, national income, and balance of trade. I-O models combine these data to produce tables that reflect the interrelationships among national or regional businesses, households, governments, non-governmental organisations, and the rest of the world. The resulting models are then used to produce estimations of changes in income, production, consumption, saving, imports and exports given any of

a wide range of 'what if' scenarios. These estimations are used to predict the economic consequences of policy changes, natural disasters, and changes in trade patterns, for example, by governments. Businesses use I-O models to describe their importance to their regional economy, or to predict changes in demand for their products. Researchers use I-O to test theories about technological change, income distribution, and a variety of other questions.

I-O models are fundamentally mathematical systems based on the equation of money flows to and from businesses, households and governments. The basic structure of an input-output model for n business sectors can be represented as follows:

$$(I - A)x = f$$

and solving for x using standard matrix algebra:

$$x = (I - A)^{-1}f$$

where:

- x is a vector of gross output
- A is an $n \times n$ input-output coefficient matrix
- I is the Identity matrix ("1" in the diagonal, "0" in all other fields)
- $(I - A)^{-1}$ is an inverse of a square matrix (also known as the Leontief inverse)
- f is a vector of final demand.

Final demand is the sum of purchase by governments and buyers outside the region. Making a number of assumptions (see section below), it is possible to measure regional economic impacts as a result of changes in final demand (Δf) and expressed as changes in gross output (Δx) in each sector. The basic I-O equation is solved mathematically by inverting the $(I-A)$ matrix. The resulting Leontief inverse $(I - A)^{-1}$ shows change in output in each sector due to a unit change in final demand. The Leontief inverse is used as a multiplier matrix providing two types of multipliers - Type I & Type II (see Table 1).

Table 1: Composition of Multipliers

Type I Multipliers	Type II Multipliers
Final-demand change + Direct impacts + Indirect impacts	Final-demand change + Direct impacts + Indirect impacts + Induced impacts
<hr/> Total impact	<hr/> Total impact

(Source: Authors, 2016)

Type I measures the impact of the increase in a product as producers respond to the increased final demand (direct effect) and as producers purchase inputs from other sectors (indirect effect). Type II measures the direct, indirect and induced impacts. Induced impact relates to the subsequent spending of income received by economic agents through the direct and indirect impact. The I-O model would need to be closed with respect to households (moving the household sector into the interrelated endogenous sectors) to generate the induced impact. Using these multipliers from the Leontief inverse, Input-Output tables are important tools in economic impact analysis.

The first set of I-O tables for Ireland, referring to year 1964, were published by the Central Statistics Office in 1970 (MacFeely, 2011). Ireland's Input-Output framework is set out under the European System of Accounts (ESA, 2008) and consists of Supply & Use tables and Symmetric Input-Output tables. Ireland, similar to many other countries, also publish tables showing estimates for the coefficients of domestic product flows and the Leontief inverse of domestic flows with multipliers for other inputs.

The Supply and Use system was designed to better handle secondary production in the I-O Framework (UN, 1999). A 'supply table' details the supply of goods and services by domestic industries as well as imports of goods and services from abroad. The supply table is a product-by-industry table with rows corresponding to products and columns corresponding to industries and imports. Industries are classified according to the product that translates into the largest share of its output, its principal product. An industries' principal product is

shown in the diagonal cells while secondary products are shown in the off-diagonal cells. The 'use table' details the use of goods and services by use (domestic industry and final demand) and is also a product-by-industry table with products and components of Gross Value Added in the rows and the categories of use in the columns.

The main aggregates in the CSO's supply and use tables are consistent with Ireland's National Accounts data. The CSO populates the supply and use tables with data from other state institutions and its many business surveys; Census of Industrial Production^{iv}, Building and Construction Inquiry^v and the Annual Services Inquiry^{vi}. Given the variety of sources used to construct supply and use tables, it is reasonable to expect that the tables may not balance initially. A process called the RAS technique (Stone, 1961) is often employed to balance the tables. The RAS process calculates differences in receipts and expenditures for each sector and distributes the difference proportionately across receipts and expenditures until the matrices are balanced (with the national accounts and the corresponding column/row totals in the supply table are equal to the column/row totals in the use table). Since changes in one sector affect the balance in other sectors, RAS must iteratively make several rounds of adjustments until stable estimates are found. This is important as the supply and use tables are the building blocks of the I-O framework, and form the basis for the transformation of the data contained in the supply and use tables to an Input-Output table. The transformation process depends on the assumption made in relation to the treatment of secondary production in the production process.

Input-Output Models: Assumptions & Application

The Eurostat Manual of Supply, Use and Input-Output Tables and in the UN Handbook of Input-Output Table Compilation and Analysis provide a comprehensive discussion on the four basic assumptions used to transform supply and use tables into symmetric input-output tables^{vii}. The assumptions relate to the treatment of secondary production/by-products in the production process. The four main assumptions used are (i) Product Technology Assumption; (ii) Industry Technology Assumption; (iii) Fixed Industry Sales Structure; and (iv) Fixed Product Sales Structure Assumption. A



symmetric Input-Output table can be a product-by-product or industry-by-industry matrix and, as such, the assumptions chosen are based on the desired final arrangement of the matrix. The two models based on the technology assumption generate product-by-product I-O tables with homogenous products in rows and homogenous branches of productions in the columns. The remaining two models are based on the fixed sales structure assumption and generate industry-by-industry I-O tables with products provided by industries in the rows and industries in the columns (Eurostat, 2008).

The *Product Technology Assumption* supposes that the input structure (inputs used) of each product is the same regardless of the industry where it is being produced. This Assumption is the most commonly used method to transform supply and use tables into symmetric I-O tables. However, the transformation using the Product Technology Assumption may produce negative elements in the technical coefficients matrix that are "improbable or even impossible" (ESA, 2010).

The *Industry Technology Assumption* supposes that an industry's principal and secondary products are produced using the same input structure. This Assumption is the less preferred option in generating product-by-product I-O tables. However, the Industry Technology Assumption (ITA) is preferable to the Product Technology Assumption for two limited reasons – the ITA is applicable to rectangular I-O tables, and it always generates positive elements.

The *Fixed Industry Sales Structure Assumption* supposes that each industry has its own sales structure irrespective of the mix of products it produces. The firms will supply their products (principal and secondary) in the same proportions to buyers. This strong assumption is, generally, considered unrealistic (Eurostat, 2008) and thus is rarely used to transform asymmetric supply and use tables into symmetric I-O tables.

Finally, the *Fixed Product Sales Structure Assumption* supposes that every product has its own specific sales structure regardless of the industry involved. This assumption does not yield negatives elements and has

been used by several European Union Member States (for example Denmark, Netherlands, Finland) to complete the transformation process.

Essentially, the choice of model will depend on the desired final tables, product-by-product or industry-by-industry tables, and the advice and procedures provided by international organisations on generating I-O tables. Many of these organisations seem to agree that the Fixed Product Sales Structures Assumption and the Product Technology Assumption are preferable (Eurostat, 2008; UN, 1999). Ireland's Supply and Use tables are transformed to a Symmetric Input-Output table using the Product Technology Assumption. The Supply and Use tables to Symmetric Input-Output table transformation process use a series of 'intermediate' tables. The 'intermediate' tables include a use table converted to basic prices from purchases' prices and domestic & imported use tables that articulate the assumptions made regarding the production of secondary production (Product Technology Assumption in Ireland's case).

A condensed version of Ireland's 2011 Input-Output table is presented in Table 2. Ireland's published I-O table is a product-by-product symmetric table valued at basic prices and closed with respect to households. Product-by-product refers to the fact that the I-O table shows the use of products in the production of other products, it allows for a simultaneous examination of inputs (columns) and outputs (rows) and is symmetric in that the sum of the columns will equal the sum of the rows. The basic price is the price retained by the producer (price received minus tax due plus any subsidy received). Households are considered exogenous in Ireland's National I-O table and, as per Table 1, the multipliers derived from the I-O table are Type I.

Table 2: 2011 Symmetric Input-Output table of domestic product flows €m

Products	Products						Total inter-industry	Cons and GFCF	Exports	€m Total Outputs
	Agriculture (1-3)	Manufacturing (5-39)	Construction (41-43)	Distribution (45-61)	Business services (62-82)	Other services (84-97)				
Agriculture,	1,162	3,448	28	73	1	19	4,731	1,444	1,102	7,277
Manufacturing	591	4,154	1,462	1,331	491	890	8,919	4,948	84,464	98,331
Construction	60	325	1,032	344	139	212	2,113	7,442	0	9,555
Distribution	365	4,859	456	5,105	3,919	1,035	15,740	24,457	27,945	68,142
Business services	196	1,744	723	6,935	18,508	3,599	31,705	18,617	53,128	103,450
Other services	22	167	135	664	1,431	3,935	6,355	37,815	447	44,618
Total Intermediate consumption	2,398	14,697	3,836	14,453	24,489	9,690	69,562	94,724	167,086	331,373
Imports	2,653	45,988	3,092	16,382	29,801	3,801	101,717	30,681	0	132,398
Product taxes less subsidies	134	381	171	1,033	1,498	684	3,901	10,949	0	14,851
Total	5,185	61,066	7,099	31,868	55,788	14,175	175,181	136,354	167,086	478,621
COE	586	8,792	3,791	16,596	16,004	24,306	70,076			
GOS	3,296	27,792	-1,360	19,130	31,242	6,313	86,413			
Other taxes less subsidies	-1,790	681	25	547	417	-176	-297			
Value added	2,092	37,265	2,456	36,273	47,663	30,442	156,192			
Total inputs (= total outputs)	7,277	98,331	9,555	68,142	103,450	44,618	331,373			

(Source: CSO, 2014)

The I-O table can be separated into three main components:

- Inter-industry transactions – the blue shaded area of Table 2 – represents the flows of goods and services produced and consumed by the different sectors in Ireland. This component is also called “intermediate demand” with rows describing the distribution of a producer’s output and columns describing the composition of inputs required by an industry to produce its output;
- Final demand sector – the green shaded area in Table 2 – represents the sales by sector to the ultimate consumers (households, investors,

government, and exports) for final consumption or use; and

- Factors of production – the pink shaded area in Table 2 – represent the value added rows of non-industrial inputs to production (i.e. labour, taxes etc.).

The Leontief inverse calculated using the National I-O table includes output multipliers and direct and indirect multipliers for other inputs used in the production cycle. The direct plus indirect multipliers for other inputs show how the additional €1 of final demand was spread across imports, taxes less subsidies, compensation of employees, consumption of fixed capital and net



operation profit. There is no duplication in the direct plus indirect multipliers for other inputs and each product column will sum to 1. The output multipliers show how much direct plus indirect (and induced if households are endogenous) output is required across all domestic products per €1 of final demand of each product sector. Output multipliers are based on gross outputs rather than value added of products and thereby the estimate includes a duplication of output. For example, in the 2011 Leontief Inverse estimates for Ireland, each €1 of final demand in the “agriculture, forestry and fishing” sector requires €1.459 worth of output to be produced in order to satisfy the increased final demand. The output multiplier of €1.459 (in gross terms) includes €1.194 worth of domestically produced output in the “agriculture, forestry and fishing” sector, €0.053 worth of domestically produced output in the “wholesale trade” sector, €0.021 worth of output in the domestically produced “food & beverages and tobacco products” and tiny amounts of other domestically produced goods and services. The duplication occurs due to the interrelationship between products and costs of production that are absorbed into the value of each product. Value added, on the other hand, excludes the value of inputs included in the value of the gross output.

I-O models are widely used to estimate the full consequences of changes in exports, changes in final demand by household, change in government purchases, changes in investment patterns, new firms or business closures, natural disasters, and many other scenarios. With appropriate care, I-O models can be used to estimate the full consequences of technological change, labour and resource shortages, and other exogenous structural changes in regional economies.

To illustrate the usefulness of multipliers, a hypothetical case of a firm in the “food & beverages and tobacco products” sector, exporting an additional €1 million worth of produce is considered. To assess the impact of this firm’s additional exports we can estimate the effect on output to meet this additional final demand by applying the appropriate multiplier for the sector concerned. Multiplying the direct impact (€1 million) by the Type I output multiplier for the “Food & beverages and tobacco products” sector group (1.456) gives

a total of direct plus indirect impacts of €1.456 million. Subtracting the initial direct impact gives the additional indirect impact throughout the Irish economy as €0.456 million. Other types of multipliers can also be calculated for income, Gross Value Added, and employment enriching the economic impact analysis. This is a simple illustration highlighting the usefulness of output multipliers at the aggregate sector and national level. Imagine, therefore, the usefulness of multipliers at a more disaggregated sectoral or geographical level.

Regional Input-Output Models: The Fundamentals

There are two features related to regional economies that necessitate a distinction between national and regional input-output models (Miller & Blair, 2009). The first specific feature relates to the structure of production of the respective regions. The structure of the economy in a particular region may or may not be similar to the structure of the economy at the national level. Milk production in the South-West region of Ireland, for example, probably uses the same inputs in the same proportions as milk production in the South-East. However, electricity that is produced in the Mid-East by hydroelectric means (Turlough Hill Power Station) would require a different mix of inputs to electricity produced from coal in the Mid-West (Moneypoint power station). For this reason, the level of sectoral disaggregation is also an important factor in the construction of I-O models since highly disaggregated sectors are more likely to reflect regional differences in sectoral composition. The second feature relates to the size of the economic area. According to Miller & Blair (2009), the smaller the economy of a region, the higher the interdependence with other regions in terms of sales “exported” outside the region and inputs “imported” into the region.

Numerous Regional Input-Output tables have been compiled in Ireland for a single region in isolation; for example Ní Dhubhain *et al.* (1994) and Fannin & Johnson (2004), while MacFeely (2011) compiled the first set of fully integrated Supply and Use and domestic Input-Output Tables for the entire country. However, MacFeely’s tables were produced at a low level of spatial disaggregation - NUTS 2 level i.e. the Border, Midland and West (BMW) and Southern & Eastern (S&E) regions.



This limited the amount of information possible from any regional economic analysis. We believe any further regional input-output model developed in an Irish context should have a lower level of spatial disaggregation (at NUTS 3 or county level) and should take into consideration the interconnectedness between regions. One option in this regard is the Multi-Regional Input-Output - or MRIO – model.

Multi-Regional Input-Output (MRIO) models not only capture the economic relationships within each region, and sum them to the national accounts, but they also show the interregional linkages. This allows analysts to estimate the consequences of changes that occur in one region, on the economies of all other regions, including any feedback effects on the region where the original change occurred. To illustrate, let's return to the hypothetical example used above of a firm in the "food & beverages and tobacco products" sector, exporting an additional €1 million worth of produce. If we now know the firm is located in say the South-West region of Ireland, then an increase in the export of products

in the South-West region would lead to increased economic activity in the South-West region and other regions as the food and beverages sector purchased inputs. The increases in these other regions may lead to a subsequent increase in tourism and other expenditures in the South-West region. The strength of this effect (direct and indirect) would depend on the economic linkages between the food & beverage sector and other sectors and the interregional relationships between the South-West region and the other regions.

Multiregional IO Model (MRIO)

The Chenery-Moses Multi Regional Input-Output model (Chenery & Clark, 1953; Moses, 1955) extends the standard I-O arrangement to a larger system where each sector in each region has a separate row and column. The key elements of the basic MRIO are the multiregional matrix (**A**) of technical coefficients and the matrix of coefficients of proportion (**C**). The objective is to capture the various economic transactions between and among the several regions in a multi-regional economy.

An eight-region MRIO would be expressed as follows:

$$(I - CA)x = Cf,$$

and the solution for x is shown as follows (similar to the standard I-O solution for x):

$$x = (I - CA)^{-1}Cf,$$

where:

$$A = \begin{bmatrix} A^B & 0 & \dots & 0 \\ 0 & A^M & \dots & 0 \\ \vdots & \vdots & & \\ 0 & 0 & \dots & A^{SW} \end{bmatrix}, I = \begin{bmatrix} I & 0 & 0 \\ 0 & I & 0 \\ \vdots & & \\ 0 & 0 & I \end{bmatrix}, C = \begin{bmatrix} \hat{c}^{B,B} & \hat{c}^{B,M} & \dots & \hat{c}^{B,SW} \\ \hat{c}^{M,B} & \hat{c}^{M,M} & \dots & \hat{c}^{M,SW} \\ \vdots & \vdots & & \\ \hat{c}^{SW,B} & \hat{c}^{SW,M} & \dots & \hat{c}^{SW,SW} \end{bmatrix},$$

$$x = \begin{bmatrix} x^B \\ x^M \\ \vdots \\ x^{SW} \end{bmatrix}, \text{ and } f = \begin{bmatrix} f^B \\ f^M \\ \vdots \\ f^{SW} \end{bmatrix}$$

Then the MRIO can be expressed as,

x is a vector of gross output for each of the 8 regions (B, M, W, D, ME, MW, SE, SW)^{viii}

A is a regional technical coefficient matrix of sub-matrices

$$A^B = \begin{bmatrix} a_{11}^B & \dots & a_{1n}^B \\ \vdots & & \\ a_{n1}^B & \dots & a_{nn}^B \end{bmatrix}$$

I is the Identity matrix ("1" in the diagonal, "0" in all other fields)

$(I - A)^{-1}$ is an inverse of a square matrix (also known as the Leontief inverse)

C is a coefficient of shipments within and between regions

$$\hat{c}^{B,B} = \begin{bmatrix} c_1^{B,B} & 0 & \dots & 0 \\ \vdots & c_2^{B,B} & & \\ 0 & 0 & \dots & c_n^{B,B} \end{bmatrix}$$

f is a vector of final demand in each region

The Multiregional I-O model uses a regional technical coefficients matrix A^r ^{ix} in place of the input coefficient matrix A in the standard national I-O model. For each region, a regional technical coefficient, can be calculated if information on the amount of inputs from sector i used by sector j in region r is available. The data requirements of regional technical coefficients are less onerous than other regional models and are more readily available (at least in theory). When data is not available, the problem becomes how to transform the national coefficient matrix A into appropriate regional coefficient matrix A^r .

Regional Input-Output Models: Methods

The three main groups of approaches to generating regional Input-Output models – survey based, non-survey based, and a hybrid approach – are considered in this section along with the potential application to Ireland. Obtaining the data required to construct a regional Input-Output model would require the collection of comprehensive and detailed survey data across all sectors and regions. Survey-based regional I-O models are expensive and time-consuming and are less common than its non-survey based and hybrid alternatives (Miller & Blair, 2009).

Non-survey based regional I-O models are constructed using an estimation procedure to generate interregional sales and purchased. Most non-survey estimation procedures assume the average technologies employed by regional firms is the same as the average technologies used at the national level. They assume, therefore, that regional firms use the same level of inputs but since regional firms will purchase some of their inputs within the regions and the remaining inputs from sources outside the region. Regionalisation of I-O models involves estimating the proportion of inputs purchases from regional firms in each sector. Location Quotients (LQs) are amongst the most common estimation procedure used. LQs methods are used to reduce coefficients from the National Input-Output tables to smaller regional coefficients. Round (1978) suggested that any regional purchase coefficient is a function of three variables: (1) the relative size of the supplying sector i , (2) the relative size of the buying sector j , and (3) the relative size of the region, r . These three variables, or some of the variables, form the basis of the Location Quotient calculations.

The Simple Location Quotients (SLQs) and the Cross-Industry Location Quotient (CILQ) are the most commonly used LQs and can be defined as follows.

$$\text{Simple Location Quotients } (SLQ_i^r) = \frac{x_i^r/x^r}{x_i^n/x^n} = \frac{x_i^r}{x_i^n} * \frac{x^n}{x^r}$$

$$\text{Cross Industry Quotients } (CIQ_{ij}^r) = \frac{x_i^r/x_i^n}{x_j^r/x_j^n} \quad \text{or} \quad \frac{LQ_i^r}{LQ_j^r}$$

where

- x_i^r denotes regional output (or employment) in supplying sector i;
- x_j^r denotes regional output (or employment) in buying sector j;
- x_i^n denotes national output (or employment) in supplying sector i;
- x_j^n denotes national output (or employment) in buying sector j;
- x^r and x^n are the respective regional and national output (or employment total).

The SLQs estimate the ratio of the proportion of region r's total output contributed by sector i to the proportion of national output contributed by sector i. SLQs reflect the reality that small sectors are not able to supply all the demands of local buyers, but SLQs do not consider the relative size of the buying sector. A relatively larger sector will tend to pass over regional suppliers to purchase some of the inputs from sellers in other regions. For example, taking the office furniture sector supplying the relatively large Information & Communication Technology (ICT) sector in the Dublin region, we would expect the ICT sector to import much of its office furniture from outside of the Dublin region and outside of the country even to satisfy their needs. This reality is addressed with cross-industry location quotients that take the size of the buying sector into consideration. However, CLQs do not account for the size of the region (x^r/x^n). Round (1978) proposed the use of the below approach which applies a logarithmic transformation to the selling region LQ.

$$\text{Semilogarithmic Quotient } (Semi LQ_{ij}^r) = LQ_i^r / \log_2(1 + LQ_j^r)$$

However, SLQ applications have not proven to be an advancement over the simpler SLQ or CIQ (Miller & Blair, 2009). Flegg & Webber (1997) questioned the reasoning for applying the logarithmic transformation to SLQ_j^r instead of SLQ_i^r and suggested an alternative approach. The Flegg Location Quotient (FLQ) modifies the CIQ_{ij}^r by incorporating an additional measure for the relative size of the region, and adjusting national coefficients based on the relative size of the region (reduce national coefficients less for larger regions assuming they import less). The FLQ is defined as follows;

$$\text{Flegg Location Quotient } (FLQ_{ij}^r) = (\lambda^*) CIQ_{ij}^r \quad \text{if } i \neq j$$

$$\text{Flegg Location Quotient } (FLQ_{ij}^r) = (\lambda^*) SIQ_{ij}^r \quad \text{if } i = j$$

where:

$$\lambda^* = \{\log_2[1 + (x^r/x^n)]\}^\delta, 0 \leq \delta \leq 1$$



However, δ must be specified in advance and it is not clear what value should be used - Miller & Blair (2009) summarised the literature on this topic and found that the most commonly used value for δ is 0.3. Following some critics of the approach, Flegg adapted the estimation procedure to reflect regional specialisation (Flegg & Webber, 2000).

Augmented Flegg Location Quotient ($AFLQ_{ij}^r$) = $FLQ_{ij} * [\log_2(1 + LQ_j)]$ if $SLQ_j > 1$

The Augmented Flegg LQ (AFLQ) allows national coefficients to be increased if the SLQ is greater than 1. The basic idea is that specialisation in a region may lead to increased intra-regional trade as other firms that supply the specialised sector are attracted into the region. None of the other LQs allow the national coefficient to be increased even if the region is highly specialised. The existence of regional clusters in Ireland (such as "Silicon Docks" in the Dublin region) is likely to warrant consideration of the LQ approach, which allows for specialisation, in the construction of regional I-O tables. An additional benefit of the AFLQ approach is that cells can be adjusted individually, instead of uniformly, across each row (as with many other non-survey techniques). For a more detailed discussion of other non-survey techniques, including Regional Purchase Coefficients (RPCs), Supply-Demand Pool approach and gravity model formulations, see Miller & Blair (2009).

Hybrid models are the most common approach used to construct regional I-O tables (MacFeely, 2011). The Generating Regional Input-Output Tables (GRIT) procedure is the best-known type of the Hybrid approach (West, 1981 & 1990). The GRIT procedure applies Location Quotients (LQs) or some other allocation method to the national Input-Output table to derive regional input-output coefficients. The GRIT procedure allows for the possibility of inserting superior survey-based data into the table to produce more accurate results. Hybrid models combine a "top down" approach with the survey based "bottom up" approach. Hybrid models can help overcome some of the shortcomings of both the survey-based method (expensive and time-consuming) and the non-survey method (mechanical and inaccurate).

Conclusion

This article outlines the methodology implied and assumptions utilised in the construction of Ireland's Input-Output framework. Ireland's I-O framework is based on the revised European System of Accounts methodology, and the United Nations' Handbook of Input-Output Tables. Ireland's Supply and Use tables are transformed into a Symmetric Input-Output table using the Product Technology Assumption. The basic structure of an I-O model, and the potential uses of the model to capture the complex interactions between sectors and regions, are also considered in this article. The authors believe any regional Input-Output model developed in an Irish context should have a sufficient level of spatial disaggregation (at county or NUTS 3 level) and should take into consideration the interconnectedness between regions (a MRIO Model).

The article also considers the various approaches to developing an MRIO Model, and assesses them with respect to the structure of production in Ireland's regions. The Augmented FLQ is the preferred approach to develop the "top-down" model given the formula's ability to accommodate regional specialisation by allowing national coefficients to be increased. However, the fundamental problem in the development of any regional I-O model is the availability of survey data to estimate intra- and inter-regional trade. Either official data or specifically collected survey data could be used. Survey data or a "bottom-up" approach would also add a layer of reliability to the model. A hybrid model would allow researchers to do specialised, one-off surveys of particular sectors to refine and/or elaborate on particular sectors of regional/national significance. Needless to say, the involvement of the Central Statistics Office (CSO) would be crucial if official statistics were to be used.



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A shared-service type arrangement between the Central Statistics Office, the Department of Environment, Community and Local Government, the reconfigured Department of Regional Development, Rural Affairs, Arts & the Gaeltacht (following the national election in February 2016), the Regional Assemblies, the Local Authorities, interested semi-state institutions and academics could be used in the development and implementation of Ireland's Multi-Regional I-O model. An I-O statistics Expert Users Group could be formed to bring together the statisticians and users of the I-O tables. Such a group would play a core role in the promotion of such a tool in the development of evidence-based policy as well as in the sharing of expertise and experiences. The group would also be a forum in which to discuss the technical aspects of existing and developing methodologies and identify any potential issues with data or analysis being undertaken (including the MRIO).

An alternative to the shared-service arrangement would be "outsourcing" the running and implementation of the model to a privately owned company – similar to the IMpact analysis for PLANning (IMPLAN) example in the United States with interested parties paying a fee to access the data and software technology (see <http://implan.com> for more information on IMPLAN). Essentially, whichever approach is taken, making the most comprehensive model available to all interested parties should be the primary objective from the outset.

The ability to conduct comprehensive economic impact analyses at local and regional level in Ireland would assist in providing evidence-based policy. Unquestionably, Ireland's Regional Operational Programmes, the recent Local Economic and Community Plans (LECP) process, and the forthcoming National Planning Framework (the National Spatial Strategy Mark II) and Regional Spatial and Economic Strategies – as well as other local/regional/national policies - would greatly benefit from the availability of a Multi-Regional I-O model. So who's up for the challenge?

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Endnotes

- i Issues around data availability, comparability and compatibility for the island of Ireland have been highlighted in detail by the All Island Research Observatory (AIRO) in Maynooth University (see for example Gleeson *et al*, 2008).
- ii NACE is the acronym for “Nomenclature statistique des activités économiques dans la Communauté européenne” and translates to the statistical classification of economic activities in the European Community.
- iii All notation used will follow the notation convention included in Miller & Blair (2009)
- iv The Census of Industrial Production comprises two separate but closely related annual inquiries, namely: (i) the Census of Industrial Enterprises which covers those enterprises which are wholly or primarily engaged in industrial production and have three or more persons engaged; and (ii) the Census of Industrial Local Units which covers all industrial local units with three or more persons engaged.
- v The Building and Construction Inquiry is an annual statutory survey which collects structural information from key year end accounting variables for the Construction Industry (including the allied trades). This includes building and construction work at all sites within the State and any subsidiary (e.g. joinery) activity.
- vi The Annual Services Inquiry is an annual survey of enterprises in the retail, wholesale, transport, ICT, real estate, renting, business and selected personal services sectors. The results of the Inquiry serve as a basis for compilation of National Accounts and various economic indicators that are used to facilitate political decision making at national and European level.
- vii Supply and use tables can be rectangular/asymmetrical (in theory may have a non-equal number of products & industries), however, a symmetric input-output matrix is required to obtain the Leontief inverse (only a square matrix may be inverted).
- viii 8 NUTS 3 level regions in Ireland with the following notation: Border (B), Midland (M), West (W), Dublin

(D), Mid-East (ME), Mid-West (MW), South-East (SE), South-West (SW).

- ix A^r refers to the sub-matrices for each of the eight NUTS 3 regions in Ireland (Border, Midland, West, Dublin, Mid-East, Mid-West, South-East, South-West), so $r = (B, \dots, SW)$, n refers to the national equivalent and ij refers to the supplying and buying sectors.

References

- Central Statistics Office, (2014), *Supply and Use and Input-Output Tables for Ireland*, Ireland.
- Chenery, H., Clark, P., and Pinna, V., (1953), *The Structure and Growth of the Italian Economy*, Rome: United States Mutual Security Agency
- European System of Accounts (2008), *Eurostat Manual of Supply, Use and Input-Output Tables. Eurostat Methodologies and Working Papers*, ISSN 1977-0375, Luxembourg: European Commission
- Fannin, M., and Johnson, T., (2004), *A Social Accounting Matrix Project for the Border, Midland and Western (BMW) Region of Ireland*, BMW Regional Assembly & Letterkenny Institute of Technology
- Flegg A., and Webber, C., (1997), On the Appropriate Use of Location Quotients in Generating Regional Input-Output Tables, *Regional Studies*, 31, 8, 795-805
- Flegg A., and Webber C., (2000), “Regional size, regional specialisation and the FLQ formula”, *Regional Studies* 34, 563–69
- Flegg, A., and Tohmo, T., (2016), *Estimating regional input coefficients and multipliers: The use of the FLQ is not a gamble. Regional Studies*, 50, 2, 310-325
- Gleeson, J., Kitchin, R., Driscoll, J., Foley, R., Fotheringham, S. and Lloyd, C. (2008): *The Atlas of the Island of Ireland - Mapping Social and Economic Change*, Armagh: All-Island Research Observatory and The International Centre for Regional and Local Development, NUI Maynooth.



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Grealis, E. & O'Donoghue, C. (2015). *The Bio-Economy Input-Output Model: Development and Uses, Preliminary Report*, Galway: NUI Galway.

Leontief, W., (1936), Quantitative Input and Output Relations in the Economic System of the United States, *Review of Economics and Statistics*, 18, 105-125

MacFeely, S., (2011), *Compilation and analysis of integrated regional input-output tables for NUTS 2 regions in Ireland*, PhD Thesis, University College Cork, Ireland

Miller, R., and Blair, P., (2009), *Input-Output Analysis Foundations and Extensions*, second edition, New York: Cambridge University Press.

Moses, L., (1955), The stability of interregional trading patterns and input-output analysis, *The American Economic Review*, 45, 803-832

Ni Dhubhain, A., and Gardiner J.J., (Eds.) (1994), *The Socio-Economic Impact of Afforestation on Rural Development – Final Report*, Contract No. 8001-CT90-0008, University College Dublin, The Queen's University of Belfast and University of Aberdeen

O'Doherty, J & Tol, R (2007), *An Environmental Input-Output Model for Ireland. ESRI Working Paper Series – No. 178*, January 2007, Dublin: The Economic and Social Research Institute.

Ralston, S., Hastings, S., and Brucker, S., (1986), Improving regional I-O models: Evidence against uniform regional purchase coefficients across rows, *Annals of Regional Science*, 20, 1, 65-80.

Round, J., (1978), An Interregional Input-Output Approach to the Evaluation of Non-Survey Methods, *Regional Science*, 18, 179–194

Siegel, P., and Johnson, T., (1993), Measuring the Economic Impacts of Reducing Environmentally Damaging Production Activities, *Review of Regional Studies*, 23, 3, 237-254

Stone, R., (1961), *Input–Output and National Accounts*, Paris: Organization for European Economic Cooperation

United Nations (UN) (1999), *Handbook of Input-Output Table. Compilation and Analysis*, Series F,74. New York: United Nations.

West, G., (1981), An efficient approach to the estimation of regional input output multipliers, *Environment and Planning A*, 13, 857 – 867

West, G., (1990), Regional Trade Estimation: A Hybrid Approach, *International Regional Science Review*, 13, 1 & 2, 103 – 118