Input-Output Tables for Wales, 2019: Project Report & Outline Methodology

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August 2022

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This project has benefitted from support from the ESRC Impact Acceleration Account at Cardiff University

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I. Background

This document outlines the estimation procedures for the 2019 Input-Output (IO) Tables for Wales, produced by the Welsh Economy Research Unit at Cardiff Business School.

We describe the desk-based compilation of a 64 sector industry-by-industry symmetrical input-output table for Wales with tourism elements reported discretely, and with a greenhouse gas environmental extension.

IO Tables have historically been published for Wales by The Welsh Economy Research Unit (WERU), with the most recent iteration for 2007[1]. Unlike the case in Scotland (and more recently Northern Ireland), the Welsh Government does not currently publish IO Tables. Additionally, the data required to compile a IO table for Wales from outside Government/ONS are lacking in a number of ways, so the 2019 table remains indicative and illustrative.

The following describes the methodological steps and key data sources used in estimation. The document is intended for readers with some knowledge of national accounting and IO concepts. Those wishing to familiarize themselves are directed to Miller & Blair (2009)[2].

This project has benefitted from assistance from Knowledge and Analytical Services at Welsh Government, the Office of the Chief Economic Adviser (OCEA) in the Scottish Government and the Fraser of Allander Institute, for which we are extremely grateful.

Sections II through X of this report describe our compilation methodology and indicate our key sources[3], whilst Section XI presents a summary Input Output Table for Wales in 2019.

II. Output and Components of Value Added ('bottom-left')

Initial estimates of gross value added were initially taken directly from ONS regional balanced GVA by industry and ITL. GVA was separated into components based on:

(1) examination of data from ONS regional gross value added balanced per head and income components (for 30 industries),
(2) allocation of compensation of employees from 30 to 64 IO sectors based on the ONS Annual Survey of Earnings and Hours (ASHE, for Wales or UK as available), and estimates of workforce jobs by sector combined from Business Register and Employment Survey (BRES), Annual Population Survey (APS) and other sources

[1] https://www.cardiff.ac.uk/__data/assets/pdf_file/0010/698869/input-output-tables-2007-final-30-6.pdf
[2] Miller, R.E. and Blair, P.D. (2009) Input-Output Analysis: Foundations and Extensions. 2nd Edition, Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9780511626982
[3] Rather than providing weblinks, we direct users to the ONS homepage where the most recent iterations of our source surveys will be available.

(3) further adjustment of compensation of employees, tax elements and other value added based on commercial jobseeker sites, annual company accounts (via Bureau van Dijk FAME[4]), Annual Business Survey (bespoke analysis) and prior, survey-based data collected for WERU industry projects. This was undertaken manually on a sector-by-sector basis.

Our estimates of output are based substantially on GVA. Output is not reported for regions by industry (or indeed at all) in the UK. Our estimates here relied on;

(1) Ratios of GVA-to-Output compiled from UK and Scottish Input-Output Tables (for 2017),
(2) Ratios of GVA-to-Output reported in the 2007 Input Output Tables for Wales[5]
(3) Ratios of GVA-to-Output reported in a desk-based IO Table for Wales (for 2016; unpublished) produced by the Fraser of Allander Institute (at Strathclyde University), using a Location-Quotient approach
(4) Estimates of output by 2-digit SIC reported in a bespoke Annual Business Survey analysis commissioned from ONS.

Following these steps (and iterative adjustment across rows and between sectors) a basic-price estimate of value adding elements – compensation of employees, taxes less subsidies, other value added/mixed income – was achieved for 64 sectors, along with an (initial) estimate of output.

III. Estimating Disposable Income ('bottom left')

IO Tables do not typically include estimates of non-financial elements (such as employment) or disposable income. These are both, however elements of policy interest (e.g. for multiplier analysis). These are included in our tables. This estimation requires however the disaggregation and reallocation of monies already reported in GVA above. The process was broadly as follows:

(1) Estimates of FTE employment by 64 sectors for 2019 taken from BRES[6],
(2) Estimates of self-employment by sector developed from APS, ONS Workforce Jobs estimates by broad sector, and bespoke analysis from Welsh Government colleagues,
(3) Estimates of gross aggregate compensation of employees and self-employment/mixed income for Wales based on the above analysis combined with ASHE and other data[7],
(4) Subtraction of employers' and employees' NI and pension contributions from employee compensation as required based on average sector wages, online take-home-salary calculators (for 2019/20, ASHE),

[4] Especially useful where one company is dominant in the sector, although often this is a multinational enterprise, complicating estimation significantly
[5] Although these Tables are very old, they are the last set based on a primary survey; some inference can be drawn for sectors where production functions are fairly stable, although the role of profit volatility must not be forgotten
[6] www.nomisweb.co.uk
[7] Typically we must assume a self-employed person works full time in that sector at the relevant gross CoE rate. This is clearly far from ideal given the changing nature of self-employment.

(5) Subtraction of national insurance (NI) from (other value added/mixed income row) self-employment earnings based on relevant NI rates and estimated income per self-employed person,
(6) Construction of new NI & Pensions row containing the above income deductions.

IV. Purchases of Intermediate Inputs ('top left')

The intermediate production function for each of 64 industries in Wales here denotes purchases of 64 intermediate inputs that enable production (and are the heart of IO Leontief analysis). We estimate these intermediate purchases via:

(1) Purchases of inputs reported in the Annual Business Inquiry (ABI) 2-digit bespoke analysis for Wales[8],
(2) Information provided across a range of WERU industry surveys in Wales,
(3) Inference drawn from company reports/accounts, media etc. for significant firms and purchases,
(4) Intermediate purchases detailed in UK and Scottish IO Tables[9], aggregated to 64 sectors.
(5) Distribution margins on products reallocated from the 23 relevant IO rows (based on UK/Scottish estimated margins) to achieve basic prices.

These sources enable an estimate of the intermediate production function, albeit with further adjustment where estimates are unrealistic, or where Wales-located plants have distinct and well understood operational modes and sector-specific information is a better source (for example for steel and energy).

V. Imports – Rest of the UK & Rest of the World ('bottom left')

Useful economic analysis requires the purchases of inputs in the top-left of the table to be disaggregated from all purchases to those from inside and outside the reference economy. Here, then we describe how, for each cell in the 64 x 64 intermediate purchase matrix, purchases are disaggregated into within-Wales, imported from the rest of the UK (RUK),and imported from the rest of the world (ROW).

There is almost no Wales-specific information available on regional purchases by sector. Our approach is to estimate (basic price) import propensities for each commodity purchased by each of the 64 IO

[8] Actually for a closely related 2018-base year project, but with this unlikely to result in large errors.
[9] Access to unpublished estimates for this and other Scottish IO data kindly granted by Scottish Government

industry sectors, and to thereby come to a total for intermediate Wales purchases by remainder. Sources for the estimation included;

(1) Propensities to import from ROW reported in the 2017 UK IO Analytical Tables, aggregated to Wales' 64 sectors,
(2) Propensities to import from RUK and ROW reported in the 2017 Scottish IO Tables, aggregated to Wales' 64 sectors,
(3) Imports (to Wales) by broad Standard International Trade Classification (SITC) reported in HMRC Regional Trade Statistics for 2019,
(4) The new Trade Survey for Wales undertaken by Welsh Government,
(5) IO 2007 and subsequent survey data collected for WERU industry projects.

Import propensities in (1) and (2) are reported for detailed industry sector and imported commodity, and thus are the starting point for estimation. Extensive adjustment – on a sector-by-sector basis is then undertaken[10], using data from (3) - (4). These estimates are also compared to prior estimates of output & production functions from (5) – in many cases, either supply does not exist in Wales (e.g. fossil fuel inputs), or the research team is aware of value-chain behaviours that drive imports even where local supply exists (such as car companies trading intermediate components within the firm but across borders).

This analysis results in estimates of import propensities for each of 64 commodities[11] across 64 industries, from rest of the UK and ROW. These import percentages are applied to each commodity purchase by each industry (estimated in IV), and by summing across all commodities we achieve estimates of import totals from RUK and ROW for each industry.

VI. Final Regional Demand ('top right')

Earlier sections described the supply of goods across 64 sectors in Wales. These goods and services are purchased, in balance, by either regional actors – households, non-profits (NPISH), government, and for capital formation being the dominant elements – or for export (including consumption within Wales by non-resident tourists. Within region consumption is estimated as follows.

(1) **Households** – UK household spend reported in UK IO Tables (2017) and adjusted to Wales by individual commodity based on ONS Family Spending and constrained to 2019 total expenditure. VAT & other relevant duties discounted, and distribution margins reallocated, to

[10] As a smaller and less broadly-based economy than either UK or Scotland, Wales will import proportionately more
[11] Effectively commodities and industries are identical in this symmetrical table construction.

report in basic prices. Import propensities[12] applied by-sector to remove purchases of non-Welsh commodities/services, with these aggregated into households' direct import row.

(2) **NPISH** – By ratio from Scotland IO Tables[13].

(3) **Government** expenditure – Initial reconciliation/ratio of UK 2017 totals to 2019 Wales aggregate Welsh Government & Welsh Office departmental spending, ONS experimental public regional public expenditure estimates. Adjusted across 64 sectors with reference to Welsh Government Budget Outturn by Major Expenditure Category (MEG) and detailed expenditure category 2019/20. Further adjustment where required to match regional supply[14]. Price, import & margin adjustments.

(4) **Gross Fixed Capital Formation (GFCF)** – UK IO ratio of GFCF to GVA applied across 64 industries in Wales. Further adjusted (downward) by use of Welsh Business R&D expenditure as a proxy[15].

(5) **Changes in Inventories & Valuables** – Estimated by ratio on sector supply from UK Input-Output Tables. Of limited policy interest, and used for final Table balancing (see below)

VII. Export Demand ('top right')

Any economic supply not consumed in the region or set aside for capital formation (or as stocks) is consumed by non-Welsh entities, i.e. exported. Here we have a number of mechanisms to estimate RUK and ROW exports of goods and services (subject to the usual adjustments for prices etc.)

(1) Already noted (in V. above) HMRC and Welsh Government trade surveys,

(2) Propensities to export to ROW reported in UK IO structures, and propensities to export reported in the Scottish IO Tables,

(3) Our intelligence compiled during WERU sector surveys,

(4) Sector specific grey-literature reports and media coverage which may note export levels (regional or international),

(5) Levels of regional relative specialism (employment) taken from BRES -– i.e. location quotients.

We are able to part-draw our ROW export vector, starting with the IO sectors that are directly reported by HMRC for Wales, with additional data available from the Wales Trade Survey. Other sectors benefit from detailed third party sector-specific reports and coverage that can enable estimation of both RUK

[12] Inferred from UK analytical tables, Scottish Final Demand import propensities and further adjustment to reflect Welsh regional supply. This is especially important where regional supply of services is very low, e.g. broadcast/streaming services.

[13] NPISH is not, typically of interest in IO analysis.

[14] e.g. for cultural services, education, health where a higher proportion is non-market and consumed by government than the UK average.

[15] Note recent ONS developments on regional GFCF, not available at the time of estimation; https://www.ons.gov.uk/economy/regionalaccounts/grossdisposablehouseholdincome/articles/experimentalregionalgrossfixedcapitalformationgfcfestimatesbyassettype1997to2020/2022-05-10

and ROW exports (steel, oil refining, chemicals, some cultural services etc.). Additionally, Scottish and UK data can be applied to Welsh sectors in ratio and aggregated to broader HMRC categories. Location quotients of full-time employees (relative to Scotland) are also used to adjust likely export propensity (a lower LQ suggests a lower likelihood of export). Further adjustment is required in juxtaposition with the overall level of regional supply[16].

VIII. Tourism Demand ('top right')

Unusually for a regional Input-Output Table, for Wales we report tourism demand separately for 64 Welsh sectors (plus moderate imports). We divide tourists into resident tourists; day visitors; (both subsets of regional household demand); rest of UK[17] visitors; and international visitors (subsets of respective exports).

Here we turn largely from ONS to visitor-specific surveys undertaken on behalf of Visit Britain and the devolved tourism agencies

(1) **Day Visitors** – Demand by major commodity and overall expenditure estimated with reference to GB Day Visitor Surveys (GBDVS) for 2019 and 2015[18] results for Wales. Key commodities reported include transport (inc. fuel separately), entrance fees, eating & drinking (serviced and takeaway) and shopping. Adjustments required for taxes, prices, reflation, margins etc.
(2) **Wales Resident and Rest GB (Overnight) Tourists** – Demand by major commodity from Great Britain Tourist Survey; commodities as for GBDVS plus accommodation & travel/tour agency services. Usual adjustments. Note that only aggregate expenditure is available for Wales-resident tourists separately, so by-commodity percentages do not vary.
(3) **International Visitors** – Major commodity spend (transport, accommodation & food, shopping, entrance fees/culture) estimated from UK Tourism Satellite Account 2017, constrained to regional expenditure total taken from ONS International Passenger Survey for 2019. Usual adjustments.

Following the estimation of these four tourism demand vectors, the spend for each sector/commodity is deducted from the relevant household or export demand.

IX. Reconciliation and Balancing

The process described in II – VIII above lead to an estimate of total demand for 64 products/industries, and an estimate of the regional and imported supply of those products. As IO describes systems in equilibrium, demand and supply must equate – but our separate estimation

[16] Clearly exports cannot be greater than the regional supply of any product.
[17] Actually, this is rest of GB as visitor surveys do not cover Northern Ireland
[18] The survey approach and questionnaire were changed in 2016, and does not now report % spent by each commodity on a trip

processes for rows and columns will lead to an unbalanced table. Thus we must adjust rows and columns such that the supply of each industry matches demand. This is a necessarily complex and iterative process, involving significant value judgement.

For each sector, the difference and demand and supply is examined, and a strategy for reconciliation is developed and applied that seeks to have the 'statistically best quality[19]' estimate dominate. Operations can include;

- Moving parts of final demand from one IO sector to another where surveys report only broad sectors that contain them both;
- Adjusting the ratio of industry value added to output (and hence reducing/increasing intermediate purchases) where there is deficit/surplus supply,
- Increasing or decreasing propensities to import by industries,
- Adjusting RUK exports (where data are typically quite uncertain)
- And, for small, and remainder differences, tweaking the levels of end-of-year stocks and valuables[20].

This is an involved process as, within this IO presentation, all rows and columns must balance, so one cell or row estimate cannot be changed in isolation. However, after multiple iterations, a fully balanced, 4,672-cell system is achieved[21].

X. The Greenhouse Gas Account

Additional to the non-financial information covering workforce labour by 64 sectors, our carbon module reports greenhouse gas arisings (GHG, in CO2-equivalents) for each sector. We estimate GHGs that are emitted territorially in Wales (production point), and in the rest of the UK and rest of the world as a result of Wales' economic activity.

As our data include estimates for carbon embodied in imports, we can approximate a global 'carbon footprint' for existing or proposed industries and other economic activities in Wales. The framework can also notionally cover emissions arising consequential on households' expenditure, although household-specific carbon footprint approaches are a better source for policy here[22].

Estimating a carbon footprint, especially with regard to emissions embodied in imports is fraught with difficulties, both conceptual and data-related. Our estimates are far from ideal. In particular we note that a full GHG footprint requires the estimation of GHGs arising in the supply chain in economies from which we import – effectively, not to just count the *direct* carbon emissions of, for example, the Indian textile export sector, but also the *indirect* emissions in the textile supply chain – for example in the

[19] For example, ONS published data weighs heavier than sector self-surveys and media reports
[20] These columns have no impact on estimates of regional value added, or any multiplier analysis.
[21] Note that most IO tables are balanced after initial estimation using automated statistical methodologies (RAS & derivatives) that take limited or no account of the quality of individual estimates.
[22] e.g., directly assessing kWh used or fuel burned is better than running pound-signs through a complex system.

Indian energy sector, or from the cotton-growing land (in India or elsewhere). This analysis properly requires a fully integrated multi-regional and environmentally extended set of IO Tables (EE-MRIO) in the same currency and structure as the Wales Tables[23]. Lacking the resource to develop such an integrated framework, we here use the workaround' of applying CO2e multipliers for Wales to the direct emissions intensity for imports. This method will still (likely) under-estimate the GHG footprint of Wales' rest of world imports due to both the relative size of the Wales-versus-ROW economies, and the higher carbon intensity of production in our main trading partners[24]. A similar approach is applied to RUK imports, but here, with the UK electricity grid for example around 40% less carbon intense than in (south) Wales, we cannot say whether our estimate of RUK indirect embodied emissions is an under- or over-estimate.

Remembering the above caveats, we report GHG emissions in tonnes of CO2e per unit of Welsh economic output using the methods outlined in broad brush below[25].

(1) **Wales Territorial Emissions** – National Air Emissions Inventory data for 2019 estimated by SIC for Wales, provided by Welsh Government/Ricardo and then aggregated into IO 64 group outputs to estimate territorial GHG intensity for sectors[26]. Some minor adjustments made to estimates to better reflect policy context[27].

(2) **Emissions Embodied in RUK Imports** – Output for UK (2016) aggregated to 56 sectors reported in the World Input Output Environmental Tables[28] to estimate CO2 intensities. Manual adjustment made for non-CO2 GHG arisings for agriculture (A01), waste remediation (E37-E39) and air transport (H51) to approximate the 'basket' of GHG arisings and intensity[29] *directly* in these sectors. Estimates of indirect CO2e from Wales CO2e multipliers for 2019. Resultant embodied emissions per unit output for UK applied to ratio of rUK imports per unit Wales' output to estimate GHG emissions embodied in RUK imports in Wales production.

(3) **Emissions Embodied in ROW Imports** – CO2 Emissions by 56 sector for three largest UK trading partners (China, EU USA) from World Input Output Environmental Tables (2014)[30] divided by sector output three country World Input Output Database[31] to estimate CO2 intensities, with these weighted by value of trade with UK. Manual adjustment made for non-CO2 GHG arisings for agriculture (A01) & air transport (H51) based on UK CO2-CO2e ratios to approximate the 'basket' of GHG arisings and intensity *directly* in these sectors. Estimates of indirect CO2e taken from Wales CO2e multipliers for 2019. Resultant embodied emissions per

[23] See https://link.springer.com/article/10.1007/s11356-022-19290-z for a recent Turkiye example.
[24] https://ourworldindata.org/grapher/co2-intensity
[25] Note all data exclude GHG emissions or sequestration due to land change/processes (LULUCF)
[26] These are direct GHG intensities; the stimulation of the input output table in a demand shock analysis provides the estimate of the indirect/supply chain CO2 via the Leontief transformation.
[27] e.g. aircraft emissions in the NAEI data are allocated by home territory of airline, leaving Wales with effectively zero. Here we allocate based on air passenger sector LQs.
[28] https://op.europa.eu/en/publication-detail/-/publication/df9c194b-81ba-11e9-9f05-01aa75ed71a1/language-en/format-RDF
[29] We accept there are non-CO2 GHG arisings in other industries that are missing here.
[30] https://op.europa.eu/en/publication-detail/-/publication/df9c194b-81ba-11e9-9f05-01aa75ed71a1/language-en/format-RDF
[31] https://www.rug.nl/ggdc/valuechain/wiod/?lang=en

unit output for CHN-DEU-USA then applied to ratio of ROW imports per unit Wales' output to estimate GHG emissions embodied in ROW imports in Wales production.

XI. The Welsh Economy in 2019

The table following presents our picture of the Welsh economy in 2019. We estimate a total regional output at £134bn, gross value added (constrained largely to ONS totals) at £67.7bn, and total workforce employment at almost 1.4m FTEs.

We estimate total exports at £43.5bn, around a third of final demand for regional products.

Gross value added per employee ranged from £23,000 in Primary industries up to £135,000 in (highly capital intense) Utilities.

Our best estimate of *global* greenhouse gas arisings as a result of this economic activity[32] is 43.1 megatons of CO2 equivalents.

Further information on Table development and the IO project in general, together with comments, suggests and identification of errors should be sought from/directed to the author.

[32] Excluding household arisings from heating & private transport

The Welsh Economy in 2019

£M Sales → Purchases ↓	Primary	Manuf.	Utilities	Constr-uction	Retail, Dist & Transp	Private Services	Public Sector & Social Serv.	Creative, Sport & Other Serv.	Total Intermediate		Households & NPISH	Government	GFCF	Inv & Valuables		Exports		Total Demand
Primary	41	384	7	52	158	43	0	2	**687**		131	3	26	-71		1,588		**2,364**
Manufacturing	194	4,009	287	344	959	736	813	108	**7,451**		3,778	232	390	-111		25,150		**36,890**
Utilities	32	832	1,182	12	274	507	458	97	**3,394**		1,769	446	31	162		1,302		**7,104**
Construction	93	53	224	2,972	27	1,335	310	22	**5,036**		333	0	1,999	67		2,319		**9,754**
Retail, Distribution & Transport	222	4,172	180	184	1,916	656	680	90	**8,100**		5,157	281	168	-52		2,779		**16,433**
Private Services	182	847	210	192	856	2,507	1,968	243	**7,006**		14,646	72	854	49		9,037		**31,662**
Public Sector & Social Services	2	71	5	0	8	109	924	2	**1,120**		2,615	21,670	121	12		821		**26,360**
Creative, Sport & Other Services	0	16	7	0	3	57	135	69	**287**		2,159	483	18	1		280		**3,229**
Imports	880	14,249	2,077	1,304	3,585	4,842	3,263	402	**30,602**		20,942	1,740	3,728	0		273		**57,284**
Compensation of Employees & Self Employed	905	7,278	894	3,126	6,337	8,805	14,275	1,221	**42,841**		0	0	0	0		0		**42,841**
Gross Operating Surplus (excluding mixed income)	51	4,692	1,762	1,309	1,683	11,195	2,557	846	**24,095**		0	0	0	0		0		**24,095**
Taxes less subsidies on production	-278	72	120	42	446	350	41	42	**834**		0	0	0	0		0		**834**
Taxes on products	40	215	148	217	179	519	936	86	**2,339**		0	0	0	0		0		**2,339**
Total Output	**2,364**	**36,890**	**7,104**	**9,754**	**16,432**	**31,661**	**26,360**	**3,229**	**133,794**		**51,527**	**24,927**	**7,335**	**58**		**43,549**		**261,298**
Gross Value Added (£m)	*678*	*12,041*	*2,776*	*4,477*	*8,466*	*20,350*	*16,873*	*2,109*	***67,770***									
Workforce Employment (FTE)	*29,400*	*147,100*	*20,500*	*81,400*	*249,600*	*374,300*	*425,800*	*63,100*	***1,391,100***									
Greenhouse gas arisings, direct + embodied (CO2e kilotons)	6,706	18,108	12,587	743	2,991	703	1,063	248	***43,149***									