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AN HEI-DISAGGREGATED INPUT-OUTPUT TABLE FOR WALES

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An HEI-Disaggregated Input-Output Table for Wales*

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Abstract

This paper describes how the education sector of the Welsh Input-Output tables is disaggregated to identify a separate sector for each of Wales's twelve Higher Education Institutions (HEIs). The process draws on accounting and survey data to accurately determine the incomes and expenditures of each institution. In particular we emphasise determining the HEIs incomes source of origin to inform their treatment, as endogenous or exogenous, in subsequent analyses. The HEI-disaggregated Input-Output table provides a useful descriptive snapshot of the Welsh economy and the role of HEIs within it for a particular year, 2006. The table can be used to derive multipliers and conduct various impact studies of each institution or the sector as a whole. The table is furthermore useful to calibrate other multi-sectoral, HEI-disaggregated models of regional economies, including Social Accounting Matrix (SAM) and computable general equilibrium (CGE) models.

Keywords: Higher Education Institutions, Universities, Input-Output, Wales, Impact study, Multipliers, Devolution.

JEL classifications: D57, I23, H75, R15.

1. Introduction

In this paper we explain how we augment the previously released Input-Output tables, constructed by the Welsh Economy Research Unit at Cardiff Business School (WERU, 2007) to construct an HEI-disaggregated Input-Output table for Wales. Within this table each Higher Education Institution (HEI) in Wales is represented as a separate sector with its own row, detailing its income structure, and its own column for its expenditures. The paper replicates the approach of Hermannsson et al (2010d) (where we constructed an HEI-disaggregated Input-Output table for Scotland) for the case of Wales, which is why we have given it a (virtually) identical title. The only difference in the construction of the two tables is in different data and data sources and hence results, tables and graphs.

The HEI-disaggregated Input-Output table provides a useful descriptive snapshot of the Welsh economy, and the role of HEIs within it for a particular year, 2006. The table can also be used to calibrate a conventional input-output model that enables the derivation of, for example, output, value-added and employment multipliers for each higher education institution, as well as for the HEI sector as a whole. Furthermore, the table facilitates a wide range of additional Input-Output based "impact" studies, and may also be used in attribution analyses. The Input Output table is, in addition, an essential component of databases used to calibrate other multi-sectoral, HEI-disaggregated models of regional economies, including Social Accounting Matrix (SAM) and computable general equilibrium (CGE) models.

To our knowledge this, and Hermannsson *et al* (2010d), are the first examples of an Input-Output table that treats each HEI as a separate sector in a single unified framework. We do not apply universal assumptions to all HEIs, but rather seek to determine incomes and expenditures individually for each in a coherent and transparent manner[1]. This enables the first consistent comparison of the expenditure effects of individual HEIs in Wales. To a significant degree we can determine the income and expenditure structure of each HEI from accounting data relating to each institution, by drawing on databases provided by the Higher Education

[1] The Input-Output table is a natural extension of the work undertaken by Iain McNicoll, Ursula Kelly and Donald McLellan. We gratefully acknowledge their comments and advice.

Statistics Agency (HESA). In addition we employ survey data and purchasing data from the Joint Consultative and Advisory Committee on Purchasing (JCAPC), the purchasing consortium of HEIs in Scotland and Northern-Ireland. Nevertheless, we have to make some general assumptions in respect of a number of elements of incomes and expenditures. While these impact on a relatively small part of the relevant totals, we endeavour to be as transparent as possible, so that other researchers may scrutinise, and perhaps choose to modify them, in future expenditure analyses of Welsh HEIs.

The paper is structured as follows. In Section 2 we explain how the HEI-disaggregated Input-Output table is constructed. In Section 3 we present an aggregated version of the table, and some summary descriptive statistics and multipliers for individual sectors and HEIs, the derivation of which is explained in an Appendix. Finally we present brief conclusions.

2. Construction of an HEI-disaggregated Input-Output table

Our chosen reference year is 2005/2006 since this is the latest year for which the necessary data were available. The procedure used to derive the HEI disaggregated IO-table can be divided into two steps. First we "rolled forward" the 2003 Welsh IO table to reflect changes in Gross Value Added (GVA) from 2003 to 2006. We then create an individual row and column for each institution.

2.1 Rolling forward the 2004 IO table

Since the academic year 2005/2006 has been chosen as the reference year of the study, the Welsh I-O Table for 2003 (WERU, 2007) had to be rolled forward to reflect the output level and prices in the year 2006. This is done using Gross Value Added (GVA) as a benchmark. Between 2003 and 2006 GVA increased by 14.59% from £37,262 million to £42,697 million. All of the figures in the 2003 table are uniformly adjusted upwards by a factor of 1.1459. Comparisons of surveyed IO tables have shown that changes in the technical structure of an economy occur slowly so that limited change can be expected over the short run (Miller & Blair, 2009). Accordingly, extrapolating the table to reflect price and volume changes over a three-year period is unlikely to result in significant errors. Furthermore, the analysis can be updated in due course to assess the impact of this assumption.

2.2 Disaggregation of the Education Sector

The next step is to separate out the HEIs' sector from the education sector as a whole, which corresponds to IO sector code 70 in the Welsh IO accounts. The additional data required are sourced from HESA (2007a), which gives information on output totals and expenditure on wages. In addition, data on income by source can be used to estimate exports for each institution. By combining income and expenditure totals from HESA with accounting and survey data on HEIs' expenditures we are able to construct a separate row and column for each institution. Finally, the individual HEI rows and columns are summed and then deducted from the education sector in the IO table to form an Education sector that excludes HEIs.

2.2.1 Creating separate columns for each HEI

A column in an IO table reveals the total expenditure of a sector and how it is divided between intermediate inputs, imports and valued added. The following is a description of the steps taken in creating a separate column for each HEI

Table 1 Summary of HEI columns

Column Component	Level of detail	Data source
Total expenditure	Individually determined for each HEI	HESA accounting data
Imports	Determined in a uniform manner for all HEIs	JCAPC data on aggregate purchases of Scottish and N-Irish HEIs
Compensation of employees	Individually determined for each HEI	HESA accounting data
Taxes on expenditure	Proxied by assuming ratios for the education sector as whole hold for HEIs	Welsh Input-Output tables
Other Value added	Proxied by assuming ratios for the education sector as whole hold for HEIs	Welsh Input-Output tables
Intermediate expenditures	Total intermediate expenditure determined as residual item. Distributed uniformly across all HEIs based on an expenditure survey	Expenditure survey obtained from previous work done by Kelly et al (1997).

The first issue is the estimation of imports for each institution. We have data on the amount of interregional and international imports from JCAPC, the purchasing consortium for Scottish and Northern Irish HEIs. These data reveal aggregate expenditures by Scottish and N-Irish HEIs broken down by category and geographic location of suppliers (Local region, rest of UK (RUK), overseas). Imports were 12.9% of total output in 2005/2006. Ninety eight per cent of total imports come from RUK and only 2% are international imports, so that the interregional links predominate. The data do not reveal purchases of individual HEIs so the proportions are applied uniformly to all of them. This import propensity differs from ones assumed in previous impact studies. For example (Kelly 2004) assume 25% while (Harris 1997) calculates imports to be 22% based on the narrow geographic definition of Portsmouth. In our judgement these findings from Scotland and N-Ireland are a reasonably proxy for Welsh HEIs. In any case, the import propensity of Welsh HEIs is very close to that reported for the imports of the Welsh Education sector as a whole in the Welsh Input-Output tables, at 11.17% of the value of total output.

From HESA publications we have data on employment costs (compensation of employees) and total output (income) by source. The remaining elements of each IO column we need to derive are: the intermediate purchases, net taxes and gross operating surplus. Net taxes and gross operating surplus were determined for each HEI as the same proportion of overall expenditure as in the education sector as a whole (IO 70) in the 2003 tables. These represent a small fraction of overall expenditure: 2.11% for net taxes, and 5.11% for gross operating surplus.

Having identified all of the other cost elements the residual is the amount of intermediate purchases from Welsh industries. The sectoral distribution of this expenditure was governed by the coefficients used by Kelly *et al* (2004). These coefficients of intermediate expenditures are based on a survey of UK HEIs described in Kelly *et al* (1997). Production technology in IO tables has been found to change only very gradually (Miller & Blair, 2009). It is likely therefore that new survey-based information would have a modest impact, since: it would only alter the composition of intermediate inputs; expenditure on intermediate inputs is less than a quarter of the total output of HEIs (22% on average). In any case there was no funding for new survey work on HEIs in our application, but this could easily be revisited in future.

2.2.2 Creating separate rows for each HEI

A row in an IO table reveals the total income of a sector and the various components of income, including intermediate sales to other production sectors and sales to final demand sectors such as households, government and exports. Table 2 summarises the methods and sources we used to identify individual HEI's revenues.

Table 2 Summary of HEI rows

Row Component	Level of detail	Data source
Income from exports	Individually determined for each HEI	Accounting data from HESA
Income from Welsh Assembly Government	Individually determined for each HEI	Accounting data from HESA
Income from other final demand categories and intermediate demand	Income apart from exports and Welsh Assembly Government funding is uniformly distributed along the row based on proportions of the overall education sector	Welsh Input Output table

Drawing on HESA data allows us to construct IO rows that reflect the particular structure of each HEI's income. HEI incomes from Exports and the Welsh Assembly Government amount to 32% and 56% respectively of HEIs' income on average. These two categories alone represent 88% of the HEI sector's total income and are determined separately for each HEI based on HESA accounting data. This is a key feature of the HEI-disaggregated IO table, which enables an accurate account of the heterogeneity of HEIs' income structures. The residual obtained by deducting the sum of export and government income from total income is then distributed along the row (other final demand categories and intermediate demand) in the same proportions as in the overall education sector (IO 70) of the Welsh Input-Output tables.

HESA classifies HEIs' income into broad categories and a number of subcategories. We allocate these incomes to four distinct categories depending on whether they come from the Welsh Assembly Government and whether they originate within or outwith the Welsh economy. From the definitions of these sub-categories, 81% of HEIs income can be attributed directly either to local demand (Welsh Assembly Government or other demand) or export demand (RUK, ROW). The remaining 19% of HEIs income categories constitute income originating from some combination of either local, RUK or ROW sources, for which the exact proportions are unknown. In these cases income is attributed indirectly based on the weights revealed by income sources with a known and unambiguous origin. The details of how each of these accounting categories is treated are provided below.

Table 3 Attribution of HESA income sources in IO table to origin – Welsh Assembly Government (WAG), rest of the UK (RUK), rest of the World (ROW) and other demand

Income category	Attribution	Total
Funding Council grants		
Recurrent grants (Teaching)	Welsh Assembly Government (WAG)	28%
Recurrent grants (Research)		7%
Recurrent grants (other)		4%
Release of deferred capital grants		1%
FE provision		0%
Tuition fees & education grants & contracts		
Standard rates	Attributed to WAG and RUK demand based on student numbers	10%
Non-standard rates		3%
Part-time HE fees		2%
Non-EU domicile	ROW	5%
Non-credit bearing course fees	Other (local demand)	1%
Other fees & support grants		0%
Research grants & contracts		
OSI Research Councils	RUK	4%
UK based charities	Indirectly attributed	2%
UK central government/local authorities, health & hospital authorities		4%
UK industry, commerce & public corporations		1%
Other sources	Other	1%
Other overseas sources	ROW	0%
EU sources		1%
Other income - other services rendered		
UK central government/local authorities, health and hospital authorities, EU government bodies	Indirectly attributed	7%
Other		3%
Other income - other		
Grants from local authorities	WAG	0%
Release of deferred capital grants	Indirectly attributed	0%
Income from health & hospital authorities (excluding teaching contracts for teaching provision)		2%
Income from intellectual property rights		0%
Residences & catering operations (including conferences)	Student numbers	7%
Other operating income	ROW	4%
Endowment & investment income	Other	2%
		100%

In the remainder of this section we discuss the treatment of income sources and the assumptions required to allow us to attribute all of HEIs' income to IO demand categories. We begin by considering those income categories that have a clear origin, and then discuss our treatment of those that are more ambiguous.

Funding Council grants

The whole of the category 'Funding Council Grants' reports funding provided by the Higher Education Funding Council Wales (HEFCW). This is ultimately drawn from the Welsh block grant and hence attributed to the Welsh Assembly Government.

Tuition fees & education grants & contracts

In the HESA dataset tuition fees are pooled for Welsh, RUK and REU students. Student numbers by origin are used to disaggregate these into Welsh, RUK and REU tuition fees. The Higher Education Funding Council Wales pays for Welsh students. We treat the tuition fees of REU students as Welsh Assembly Government demand under the assumption they are all Erasmus exchange students, whom the Higher Education Funding Council Wales pays for as well. RUK tuition income is treated as RUK exports. Tuition fees of students from outwith the EU are treated as ROW exports. *Non-credit bearing course fees* and *Other fees & support grants* represents courses that the HEIs charge for and are therefore attributed to *Other demand*. HESA (2007a) does not explicitly define the category *Other fees & support grants*. This is assumed to be income from *Other* local demand.

Research grants & contracts

Research income from the OSI research councils[2] is treated as RUK exports as these are funded by the central government of the UK. *Other overseas sources* and *EU sources* are classed as ROW exports. *Other*

[2] The category "OSI Research Councils" refers to funding from the various UK research councils: http://www.rcuk.ac.uk/

sources are, for simplicity, assumed to come from other demand[3] Other sub-categories under this heading are indirectly attributed (see discussion below).

Other income – other services rendered

These income streams are for various services rendered, including consultancy to external bodies both public and private, UK and foreign. These are attributed indirectly (see further discussion below)

Other income – other

The category *Other income – other* is treated in three different ways depending on the sub-category. *Grants from local authorities* are attributed to the Welsh Assembly Government. This is a simplifying assumption as only a part of Welsh local Government's incomes are derived from the Welsh Assembly Government and the Welsh block grant. *Residence & catering operations* mainly comprises student residences and on-campus catering services consumed by students. Therefore we use student numbers by origin to attribute this income to local demand and exports. Some of these services are consumed by conference attendees. We assume that the ability of the university to attract conference guests is proxied by the student population. *Other operating income* is treated as ROW exports since, according to HESA definitions, this mostly comprises European funding sources. *Income from intellectual property rights* is for simplicity assumed to stem from other local demands[4]. The remaining sub-categories are attributed indirectly.

Indirectly attributed incomes

Seven HESA accounting categories, 19% of the total of HEIs' income, have an ambiguous spatial origin. Although we cannot directly determine the origin of the various incomes that have to be attributed indirectly, the definitions of the HESA accounting categories give some indication of their nature. We try to capture this by devising an

[3] This contributes 1.14% of HEIs income.
[4] The category only comprises 0.16% of Welsh HEIs income.

attribution mechanism that is consistent with the nature of the income category. The application of these is summarised in Table 3 and described for each case below.

Research grants & contracts

Income from 'UK based charities' is from charities in either Wales or other UK regions. We expect the HEIs to draw mostly on local charities, so we attribute this income category to O*ther local demands*. However, we allow for some export income from RUK in the same proportion as the RUK export intensity of research income.

Income from *UK central government/local authorities, health & hospital authorities* will by definition either originate from central government funding at the UK level, in which case it will be counted as RUK-exports, or from funding sources that can ultimately be traced back to the Welsh block grant and hence will be attributed to the Welsh Government. To determine the relative weight of each we use non-student incomes as revealed by directly allocated income as a basis for distribution to final demand.

UK industry, commerce & public corporations is assumed to originate from other regions of the UK, in which case it is counted as exports, or Welsh non-government sources (intermediate demand) in which case it is attributed to other local demands. To determine the proportion that is attributed to RUK-exports we use the RUK export intensity of research incomes with known spatial origin (26% on average). We assume that the HEIs predominantly interact with local producers and hence allocate the remainder of this income to other local demands.

Other income – other services rendered

UK central government/local authorities, health and hospital authorities, EU government bodies can in principle originate from both local and external, and public and other bodies (e.g. the Welsh Government, Welsh production sectors, UK-consumers, EU-funding, etc,). We use non-student income as revealed by directly attributed income sources as a basis for distribution among final demand categories. This income category includes income from non-departmental public bodies and because of its services-rendered nature it is reasonable to assume some of this is intermediate demand from Welsh production sectors (other local demands), rather than attributing it solely to Welsh Assembly Government demand and exports.

Income classed as 'Other' is assumed to originate either from intermediate demand or exports. Again, we assume this income is primarily raised locally except for RUK income, based on the RUK export intensity as revealed by directly attributed income sources.

Table 4 Indirect attribution of incomes

	% of total income	Attributed to: Welsh Gov	RUK	ROW	Other
Research grants & contracts					
UK based charities	2%		●		●
UK central government/local authorities, health & hospital authorities	4%	●	●		
UK industry, commerce & public corporations	1%		●		●
Other income - other services rendered					
UK central government/local authorities, health and hospital authorities, EU government bodies	7%	●	●	●	●
Other	3%		●		●
Other income - other					
Release of deferred capital grants	0%		●		●
Income from health & hospital authorities (excluding teaching contracts for teaching provision)	2%	●	●		
	19%				

Other income – other

Release of deferred capital grants comprises capital grants from sources other than the higher education funding councils. We assume this can involve local non-government sources as well as sources in RUK and ROW (perhaps EU). We assume the pattern of this income source follows that of the HEIs research income in general and use the previously revealed origins of research income as a basis for distributing these grants between other demands and RUK and ROW exports.

Income from health & hospital authorities (excluding teaching contracts for teaching provision) can in principle derive from health and hospital authorities either within Wales(in which case they are ultimately derived from the Welsh block grant) or the other regions of the UK (in which case it will be treated as RUK exports). To determine the relative weight of each we use non-student incomes as revealed by directly allocated income as a basis for distribution to final demand.

Table 5 Income of Welsh HEIs by origin, £m %

	Devolved Government		RUK Exports		ROW exports		Other		Total	
UW, Aberystwyth	40,856	53%	16,942	22%	12,373	16%	7,013	9%	77,185	100%
UW, Bangor	52,257	54%	20,885	22%	15,671	16%	7,524	8%	96,337	100%
Cardiff	163,831	48%	79,918	23%	36,604	11%	64,083	19%	344,437	100%
UWI Cardiff	38,505	64%	8,690	15%	5,548	9%	7,002	12%	59,744	100%
UW CentralFunct.	1,209	14%	1,042	12%	1,763	21%	4,421	52%	8,436	100%
Glamorgan	65,395	69%	9,568	10%	12,648	13%	6,504	7%	94,115	100%
UW, Lampeter	7,748	60%	2,566	20%	1,560	12%	1,003	8%	12,877	100%
UW, Newport	27,870	78%	3,413	10%	2,693	8%	1,918	5%	35,894	100%
NEWIHE	21,041	77%	3,343	12%	1,583	6%	1,341	5%	27,307	100%
RWCMD	6,279	79%	823	10%	400	5%	491	6%	7,994	100%
SIHE	19,279	77%	2,282	9%	1,467	6%	2,004	8%	25,031	100%
UW, Swansea	60,965	52%	26,505	23%	21,095	18%	7,903	7%	116,467	100%
Trinity UC	7,891	67%	2,225	19%	1,403	12%	199	2%	11,718	100%
	513,126	**56%**	**178,203**	**19%**	**114,807**	**13%**	**111,406**	**12%**	**917,542**	**100%**

The calculated exports and Welsh Assembly Government incomes directly enter the rows as final demand categories. To complete the row we use coefficients of the Education sector from the existing IO table to distribute other income between other categories of final demand and intermediate income from other sectors for each institution. This concludes the procedure of estimating the IO rows for each institution. Having derived columns and rows for each HEI we next incorporate them into the existing (rolled forward) Input-Output table. The estimated rows and columns are subtracted from the existing "Education" sector. The resultant IO table has 94 sectors of which 13 represent the higher education institutions themselves.

2.3 Sectoral employment

Sectoral full-time-equivalent (FTE) employment figures are based on those published with the 2003 Welsh IO tables. Since the base year is 2006 these had to be updated. For this we use head count data from the Annual Business Inquiry, which reports full time and part time employment by region. Following convention, part time employment was divided by 3 to approximate full time equivalence. Comparing headcount figures for 2004 and 2006 revealed an employment growth of 12.5%, which was used to update the FTE employment level. Employment in the HEIs is reported in Table 25 of HESA (2007), which reveals FTE employment of all staff of each HEI for the academic year 2005/2006.

2.4 Student numbers

Student numbers are used to disaggregate UK tuition fees by their origin from within Wales or from other UK regions (RUK). Furthermore, in subsequent applications of the IO-tables, for calculating the economic impact of HEIs, student numbers are used to inform the estimation of students' consumption impact. The published student numbers in HESA (2007b) do not provide sufficient detail on the spatial origin of the students. Therefore we commissioned a custom query from HESA into their student records database, which provided us with FTE student numbers disaggregated by origin from each of the UK regions (England, N-Ireland, Scotland and Wales), the EU, the rest of Europe and the rest of the World. For the purpose of constructing the IO-table the student population of each institution is aggregated into three groups, Welsh students (WAL), students from the rest of the UK (RUK) and students from the rest of the World (ROW). A summary of these is provided below.

Table 6 Student numbers by origin at Welsh HEIs (FTEs, %)

	WAL		RUK		ROW		Total	
UW, Aberystwyth	2,288	29%	4,614	59%	966	12%	**7,868**	**100%**
UW, Bangor	3,460	45%	3,369	44%	817	11%	**7,646**	**100%**
Cardiff	8,896	39%	9,812	44%	3,820	17%	**22,528**	**100%**
UWI Cardiff	4,394	57%	2,500	32%	854	11%	**7,747**	**100%**
Glamorgan	9,172	67%	2,423	18%	2,116	15%	**13,711**	**100%**
UW, Lampeter	630	26%	1,176	49%	582	24%	**2,388**	**100%**
UW, Newport	3,701	71%	1,115	21%	377	7%	**5,193**	**100%**
NEWIHE	2,352	58%	1,084	27%	593	15%	**4,030**	**100%**
RWCMD	241	41%	315	54%	31	5%	**587**	**100%**
SIHE	3,025	70%	1,011	23%	317	7%	**4,352**	**100%**
UW, Swansea	5,694	53%	3,768	35%	1,379	13%	**10,840**	**100%**
Trinity UC	1,400	85%	180	11%	62	4%	**1,643**	**100%**
Total	**45,253**	**51%**	**31,367**	**35%**	**11,913**	**13%**	**88,533**	**100%**

3. The Welsh HEIs sector and the Welsh economy

In this section we draw on the HEI-disaggregated Input-Output table and some of the data sources used in its construction to describe the characteristics of the HEIs sector within the context of the Welsh economy. Although the table was constructed at a 94 sector level of aggregation it is presented in a condensed 12-sector format below to simplify the presentation. We explain how we compute the multipliers reported in this section of the paper in an Appendix.

Based on the HEI disaggregated IO-table we can obtain the broad characteristics of Welsh HEIs. Their relatively small type I multipliers reflect the fact that HEIs do not source much intermediate inputs locally, or indeed elsewhere as their import propensity is also low (12.9%). Of the 12 sectors shown in the table below HEIs exhibit the highest Type II multiplier indicating that local wages form a bigger share of expenditure than in other sectors.

Table 7: Output multipliers of IO sectors

Sector	Type I	Type II
Primary and utilities	1.72	1.57
Manufacturing	1.39	1.71
Construction	1.53	1.83
Distribution and retail	1.35	1.72
Hotels, catering, pubs, etc.	1.16	1.72
Transport, post and communications	1.48	1.78
Banking and financial services	1.59	1.79
House letting and real estate services	1.34	1.25
Business services	1.37	1.75
Public sector	1.30	1.98
HEIs	1.33	2.01
Other services	1.35	1.80

Table 8: 2006 HEI-disaggregated Input-Output for Wales, industry by industry, 12-sector, £m

	Primary and utilities	Manufacturing	Construction	Distribution and retail	Hotels, catering, pubs, etc.	Transport, post and communications	Banking and financial services	House letting and real estate services	Business services	Public sector	HEIs	Other services	Total intermediate demand	Local	Government	Capital	External	Total final demand	Total output
Primary and utilities	690	944	48	72	69	30	19	11	18	145	9	12	**2,066**	591	0	131	2,544	**3,266**	**5,332**
Manufacturing	242	3,027	312	287	246	187	119	24	93	676	65	37	**5,316**	1,736	0	1,041	18,780	**21,556**	**26,872**
Construction	38	109	608	36	11	33	36	225	13	242	31	7	**1,390**	185	0	1,750	538	**2,474**	**3,863**
Distribution and retail	98	932	77	129	43	112	36	23	33	188	5	15	**1,691**	4,447	0	58	1,391	**5,896**	**7,587**
Hotels, catering, pubs, etc.	9	46	2	86	13	18	20	3	18	61	2	1	**278**	889	5	59	1,610	**2,562**	**2,840**
Transport, post and communications	57	539	32	441	71	481	325	27	113	328	9	26	**2,450**	796	0	149	1,822	**2,767**	**5,218**
Banking and financial services	128	761	46	202	60	87	261	48	78	310	6	23	**2,011**	333	0	21	1,541	**1,895**	**3,906**
House letting and real estate services	16	103	79	103	14	59	11	10	13	40	24	9	**479**	4,079	0	268	140	**4,488**	**4,967**
Business services	85	409	109	304	66	198	285	90	432	685	21	79	**2,764**	51	0	408	1,597	**2,056**	**4,820**
Public sector	38	140	10	30	36	56	53	19	82	3,166	19	23	**3,671**	3,074	13,698	-74	639	**17,337**	**21,008**
HEIs	0	2	0	1	1	1	2	0	3	9	8	0	**28**	82	513	1	293	**889**	**918**
Other services	6	48	3	15	13	14	11	3	13	154	1	125	**406**	697	224	-123	476	**1,274**	**1,680**
Total domestic consumption	**1,408**	**7,059**	**1,327**	**1,706**	**642**	**1,277**	**1,177**	**483**	**908**	**6,003**	**202**	**357**	**22,549**	16,962	14,440	3,689	31,372	**66,462**	**89,011**
Imports	1,889	10,476	971	1,777	525	1,334	1,067	334	1,081	4,219	119	282	**24,073**	12,981	0	3,207	1,607	**17,795**	**41,868**
Net product & production taxes	250	672	134	427	159	242	185	30	129	429	19	68	**2,743**	2,324	0	296	1,617	**4,236**	**6,979**
Compensation of employees	648	6,468	823	2,315	852	1,680	911	341	1,813	8,600	530	646	**25,627**						
Gross operating surplus	1,138	2,197	608	1,363	662	685	566	3,779	888	1,758	47	327	**14,019**						
Total Primary inputs	3,925	19,813	2,536	5,882	2,198	3,941	2,729	4,484	3,912	15,005	715	1,323	**66,462**	15,305	0	3,503	3,223	**22,031**	**88,493**
Output at basic prices	**5,332**	**26,872**	**3,863**	**7,587**	**2,840**	**5,218**	**3,906**	**4,967**	**4,820**	**21,008**	**918**	**1,680**	**89,011**	**32,266**	**14,440**	**7,192**	**34,595**	**88,493**	**177,504**
FTE employment (thousands)	*45,939*	*199,087*	*74,126*	*183,173*	*72,705*	*67,338*	*27,759*	*16,313*	*110,175*	*336,938*	*15,149*	*26,113*	*1,174,814*						
FTE employment-output coefficients	8.6	7.4	19.2	24.1	25.6	12.9	7.1	3.3	22.9	16.0	16.5	15.5	13.2						

4. Conclusions

This paper explains how we augment the Welsh IO tables published by WERU to create an HEI-disaggregated IO table for Wales in 2006. We also present an aggregated version of the table and summarise some illustrative "multiplier" results. The purpose of this paper is to furnish interested providers and users of HEI regional impact studies with a publicly available, transparent account of how we create the database, and identify areas where such data might be improved in future, through further survey work for example.

Of course the main value of any database lies in the analyses that it allows us to undertake. Firstly, in Hermannsson *et al* (2010a) we explore the "policy scepticism" that has recently challenged the value of regional HEI impact studies. On the basis of our database we are able to reject the extreme form of policy scepticism, which asserts that HEI expenditure effects are negligible, for the HEI sector as a whole. However, we also establish the importance of accounting for the regional public sector budget constraint in regional economic impact analyses, at least within devolved regions. Secondly, we extend analysis to the expenditure impacts of individual HEIs and their students in Hermannsson *et al* (2010b), in which the heterogeneity of HEI expenditure impacts in Wales is highlighted.

Thirdly, we are further extending the approach to explore the expenditure impacts of HEIs in the third devolved region of the UK, Northern Ireland. Fourthly, even though there is no regional budget constraint for England, it is nevertheless instructive to explore the opportunity cost of the public funding of HEIs there, using the approach developed in Hermannsson *et al* (2010a,b).

Fifthly, the regional databases can be developed into HEI-disaggregated interregional IO tables, which allow an analysis of the impact of HEIs' expenditures on non-host regions. Sixthly, drawing on additional income and expenditure data we construct HEI-disaggregated social accounting matrices (SAMs), which we employ, together with other supplementary data and analysis, to parameterise HEI-disaggregated CGE models of regional economies. Such models allow us to explore the system-wide, regional supply-side impacts of HEIs that operate though for example, the productivity of their graduates and their knowledge exchange activities. In Hermannsson *et al* (2010c), for example, we employ an HEI-disaggregated CGE model of Wales to assess the contribution of graduates to the Welsh economy.

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Appendix. Input-Output tables, models and multipliers

A.1 Input-Output tables

Input-Output tables provide a snapshot of production in an economy for a given year. They reveal the activities of industries that both produce goods (outputs) and consume good from other industries (inputs). The Input-Output tables are put to a wide range of uses[5] but are most frequently employed in various multiplier or "impact" analyses. Input-output models are calibrated using IO tables. Multipliers are derived so that output is equal to the multiplier times the exogenous components of demand, i.e. an explicit distinction is made between exogenous and endogenous economic activity as we illustrate in section A.2. Here we briefly describe the layout of Input Output tables and how they are split into exogenous and endogenous components to derive multiplier values. We also show how multipliers are defined and how they are interpreted[6].

Table A1 Input-Output Transactions table. Source: Miller & Blair (2009), p. 3

		PRODUCERS AS CONSUMERS								FINAL DEMAND			
		Agric.	Mining	Const.	Manuf.	Trade	Transp.	Services	Other	Personal Consumption Expenditures	Gross Private Domestic Investment	Govt. Purchases of Goods & Services	Net Exports of Goods & Services
PRODUCERS	Agriculture												
	Mining												
	Construction												
	Manufacturing												
	Trade												
	Transportation												
	Services												
	Other Industry												
VALUE ADDED	Employees	Employee compensation								GROSS DOMESTIC PRODUCT			
	Business Owners and Capital	Profit-type income and capital consumption allowances											
	Government	Indirect business taxes											

Input-Output tables provide a description of the flows of inputs and outputs to and from production sectors in a particular year. A column in an Input-Output table reveals the consumption (expenditures) of production sectors. The inter-industry transactions table (shaded area) shows how each industry (reading down its column) purchases inputs from within the same industry and from other industries. The bottom part of the column shows the industry's expenditures on value added such as employees, capital and government taxes. Reading the rows in the table

[5] For details of Input-Output applications and methodology see Miller & Blair (2009).
[6] The following illustration draws heavily on Miller & Blair (2009) and Seafish (2007).

reveals the value of outputs sold by a particular industry to itself and to other industries within the region and to final demand. The Input Output table is consistent with national accounts. Adding up the final demand columns gives us GDP by the expenditure method (C+I+G+(E-M)) and summing the value added rows gives GDP by the factor income method[7].

A.2 Assumptions of Input-Output modelling

The underlying idea behind multipliers is that some independent (exogenous) disturbance occurring in one part of the economy can have subsequent "knock on" impacts in other parts of the economy and therefore on the economy as a whole.

Demand-driven multipliers[8] identify the impact of a sector as a purchaser of inputs. When a sector expands, it requires more inputs of intermediate goods and services and increases its employment and wage payments. This generates positive knock-on effects in sectors supplying the increased demand for intermediate and consumption goods. The expansion in these sectors will produce further increases in intermediate and consumption demands, the process continuing down successive rounds of the multiplier process, with the additional impact in each successive round becoming smaller and smaller. I-O analysis has a technique for capturing all these effects, as long as a number of assumptions hold.

A key characteristic of the procedure for determining the demand-driven multiplier values is to identify those elements of demand taken to be exogenous and those taken to be endogenous. The exogenous elements are those that are determined independently of the level of activity within the economy. The endogenous

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[7] Note however that in Table 5 the Welsh Input-Output table is presented in a slightly different format where imports enter as part of primary inputs and in final demand we have gross exports as opposed to net-exports as in Table 7.
[8] Two broad generic types of multiplier are identified in the I-O literature. These are known variously as; backward, demand-driven, Leontief, or upstream multipliers; and forward, supply-driven, Ghoshian, or downstream multipliers. In this paper we only utilise demand driven multipliers, but for wider discussions of different multiplier effects see Miller and Blair (2009).

demands are those determined by the level of activity in the economy. In conventional I-O demand-driven analysis, final demand, such as exports, government expenditure, investment and stock building are exogenous. Intermediate demand, including imports, is endogenous. Conventionally, we can classify consumption expenditure as either exogenous or endogenous. This is because it is not linked to production output through fixed production coefficients, but through behavioural relationships that assert that domestic consumption will rise in line with wage income.

When consumption expenditure is taken to be exogenous, the multiplier simply identifies the change in activity generated in the economy by changes in intermediate demand for goods and services. This multiplier is a Type I multiplier. It consists of the direct effects of the initial change in exogenous demand plus the indirect effects of the additional expenditure on intermediate goods and services. Where consumption demand is endogenous, and made to vary proportionately with wage income, the effects of induced consumption expenditure on activity is also included in the multiplier effect. This is a Type II multiplier. It covers the direct and indirect impacts that are quantified in the Type I multiplier but adds the induced effect of additional consumption.

In using I-O analysis to calculate demand multipliers, the following assumptions are made:

- Constant-returns to scale
- Fixed coefficient production technology
- Constant coefficients in consumption (where Type II multipliers are calculated)
- No supply constraints

Constant-returns to scale, fixed coefficient production technology: In calculating the Leontief multipliers, we assume that all inputs into production in a particular sector change in strict proportion to the change in the output of that sector. Therefore, if output increases by 10%, all inputs similarly increase by 10%. This implies constant returns to scale in production. It also implies that there is no substitution between inputs as output changes. This assumption is usually interpreted as implying that production is characterised by a fixed-coefficients technology. However, an alternative is that substitution is possible but input prices do not change, so that the cost minimising choice of technique does not vary as output varies (McGregor *et al*, 1996).

Constant coefficients in consumption: Where induced consumption is incorporated into the multiplier values, in conventional models the consumption of all commodities changes in line with changes in wage income.

No supply constraints: This is the key assumption underlying the use of I-O demand multipliers. There must be available labour and productive capacity to meet any increase in demand in any sector. Similarly, there must be no key fixed natural resources that are fully utilised. Supply must therefore react passively to demand so that there is no crowding out of some demands by others and no changes in production techniques to economise on scarce resources or commodities. A corollary of this position is that exogenous demand falls, I-O analysis assumes that there is no supply mechanism to redeploy the released resources.

Essentially a Type II demand-driven I-O multiplier is a sophisticated Keynesian multiplier. It operates in a conceptually similar way, but provides greater sectoral disaggregation and models imports and intermediate demands in a more accurate manner. It shares with the Keynesian multiplier the requirement that the supply-side of the economy plays a completely passive role. This might be appropriate in the short-run for an economy with unemployment problems or for a regional economy in the long-run where inter-regional migration and additional investment can relax labour market and capacity constraints. Clearly, the application to the UK national economy should be treated with some care, as the notion that the UK economy has no supply constraints in either the short or long run is less easy to maintain (McGregor *et al*, 1999).

A.3 Multipliers

In order to define the multipliers precisely, and to derive them, it is convenient to use a little matrix algebra. In matrix notation, a simplified standard I-O transaction matrix for an economy with n production sectors, and a vector of value added values and a final demand vector has the following form:

$$\begin{bmatrix} X & f & q \\ Y^T & \mathbf{0} & \mathbf{0} \\ q^T & \mathbf{0} & \mathbf{0} \end{bmatrix}$$

Where X is the n × n matrix of intermediate sales and purchases, $x_{i,j}$ is the sales of sector i to sector j, f is the n × 1 final demand vector, q is the n × 1 gross output vector, and y^T is the 1 × n vector of value added inputs.

All of these are conventionally expressed in value terms, and the following accounting identities hold.

$$Xi + f = q \qquad (4.1)$$

$$i^T X + y^T = q^T \qquad (4.2)$$

Where i is an n × 1 vector of ones. If the elements x_{ij} of equation (4.1) are replaced by $a_{ij}q_j$, where q_j is the output of industry j and the technical coefficient a_{ij} is defined as $a_{ij} = \frac{x_{ij}}{q_j}$, the accounting identity (4.1) can be replaced by:

$$Aq + f = q \qquad (4.3)$$

where A is an n × n matrix whose elements are the technical coefficients a_{ij}. If Aq is subtracted from both sides of equation (4.3), this produces:

$$f = q - Aq = (I - A)q \qquad (4.4)$$

where I is the n × n identity matrix.

Post-multiplying both sides of equation (4.4) by the inverse of the (I-A) matrix gives:

$$(I - A)^{-1} f = q \qquad (4.5)$$

The matrix $(I\text{-}A)^{-1}$ is the Leontief inverse matrix. This is used to calculate the vector of gross outputs, q, from the vector of final demands, f. Each element of the Leontief inverse, α_{ij}, measures the direct, indirect (and where appropriate induced) impact on sector i of a unit increase in the final demand for sector j. The sum of the elements of the jth column of the Leontief inverse is the output multiplier value for sector j.

The multiplier value for any industry is, in principle, determined by all the interactions between firms and, where appropriate, consumers within the economy. However, it is possible to make some generalisations concerning the relative size of multiplier values, usually based upon the cost characteristics of the industry receiving the initial injection.

For any industry, the multiplier values will differ between different measures of activity. That is to say, the output multiplier value will, in general, differ from the employment, income and value-added multiplier values. Further, not only are the absolute values different, but even the rankings of industries by their multiplier values can differ using different activity measures. The reasons for such differences are outlined below, but in general they revolve around the cost structure of the industry receiving the initial injection.

For any one activity measure, an industry's Type II multiplier will always be at least as large as the Type I multiplier. This is because more of the possible knock-on effects are captured by the Type II than by the Type I multiplier. Specifically, the Type I multiplier includes the indirect effects generated by the intermediate purchases made by the sector receiving the initial demand stimulus. However, the Type II multiplier also incorporates induced consumption effects generated by the change in wage income accompanying a change in a sector's activity.

The Type I output multiplier for a particular sector is strongly dependent on the proportion of its gross output that is spent on domestically-produced intermediate inputs. Where this proportion is high, we expect the Type I output multiplier to be large. High proportionate intermediate purchases by a sector will be linked to low purchases of intermediate imports and a low ratio of value-added to gross output.

For Type I calculations, the additional employment, income and value added produced by £1 million additional final demand to one sector is influenced by two effects. One is the direct effect: the employment, income or value-added intensity of the initial sector itself. The second will be the indirect impact, which should be correlated with the output multiplier value. However how will the corresponding multiplier values be calculated? The employment multiplier can be taken as an example, but the same logic holds for income and value added.

The ratio of direct employment to gross output of £1 million in the initial industry is here identified as e_i. The additional employment generated, primarily in other industries, as a result of the Type I multiplier process is similarly identified as Δe^I_i. This value is positively related to the value of the Type I output multiplier. The total employment-output multiplier, $M^I_{Q,E}$ is given by

$$M^{I}_{Q,E} = e_i + \Delta e^{I}_{i} \qquad (4.6)$$

The Type I employment-output multiplier is high therefore where both the output multiplier, determining Δe^I_i) and the direct employment-output ratio, e_i are high.

However, the conventional Type I employment multiplier, $M^I_{E,E}$ is defined as the total change in employment divided by the initial change in exogenous employment. If the initial increase in exogenous demand were £1 million, the corresponding increase in employment would be e_i. Therefore the employment multiplier is given as:

$$M_{E,E}^{I} = \frac{e_i + \Delta e_i^I}{e_i} = 1 + \frac{\Delta e_i^I}{e_i} \quad (4.7)$$

Equation (4.7) identifies a seeming paradox. Because the direct employment-output ratio, e_i, appears in the denominator of the second term on the right hand side of equation (4.7), *ceteris paribus*, the larger its value, the lower the value of $M^I_{E,E}$, That is to say, labour intensive industries tend to have a high value for the total employment generated by an additional expenditure injection. However, they have a relatively low employment multiplier.

Another factor that reinforces the low Type I employment multiplier for labour intensive industries is that the value of Δe^I_i is, in general, negatively related to the ratio of value-added to total output. However, the ratio of value-added to total output also tends to be positively related to the labour intensity e_i which again suggests a low value for $M^I_{E,E}$.

Exactly the same form of argument applies to the Type I income and value-added multipliers. A sector which has a high share of wage income or value added in total output will generally have high values for the additional income and value added generated by a given change in expenditure. However, their corresponding multiplier values tend to be low.

There are, in general, differences in the Type I employment, income and value added multiplier values for the same sector. In short, a high ratio of other value added to output depresses the value-added multiplier against the income and employment multipliers. A relatively high wage depresses the wage income multiplier against the employment multiplier.

Type II multipliers are slightly different. These multipliers incorporate the impact of not only the indirect additional intermediate demands but also the induced additional consumption expenditure. Here the value of a sector's output multiplier depends positively upon the ratio of the wages plus domestically supplied intermediate demand to gross output. Industries with low Type II output multipliers will have high imports and other value added (rents and profits payments) in proportion to their gross outputs.

For the standard Type II employment, wage income and value-added multipliers a similar relationship applies as expressed in equation (4.7) for Type I multipliers. However, one consideration is important. In this case the value of the output multiplier should be positively, not negatively, related to the ratio of the sector's employment, income and value added intensity. However, it is still the case that a sector with a low employment-output ratio but a high wage has, ceteris paribus, a high Type II employment multiplier. On the other hand, a labour intensive sector with a relatively low wage is likely to have a low Type II employment ratio. What really matters in determining the Type II employment multipliers is the absolute size of the average wage payment and domestically-supplied intermediate expenditures per worker.